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Karen V. Czachorowski

# Digital Transformation in the Offshore Oil and Gas Exploration and Production supply chain operations

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A PhD dissertation in
**Nautical operations**

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# Dedication

To Izabel, Amauri, and Alexandra.

# Preface

This dissertation, entitled "Digital Transformation in the Offshore Oil and Gas Exploration and Production supply chain operations", is a doctoral thesis composed to partially attain the requirements needed for the completion of the joint Doctor of Philosophy (PhD) degree in nautical operations.

This thesis is the result of action research conducted in the Industrial PhD modality over the course of three years, half of which was during the COVID-19 pandemic. This applied research was partially funded by Aker BP, a Norwegian private E&P operator, and by the Research Council of Norway (RCN) through the Industrial PhD programme (grant number 291198).

Being an industrial PhD, most of the work was conducted at the industrial partner in its headquarters in Oslo and Stavanger (Norway), while the other parts of the work were conducted at the Department of Maritime Operations (IMA) at the University of South-Eastern Norway (USN), and in general, at home due to the restrictions imposed by the pandemic. The work was conducted under the academic supervision of Professor Ziaul Haque Munim (USN), Professor Cecilia Haskins (NTNU) and Professor Lokukaluge Prasad Perera (UiT).

The body of knowledge of this research lies mostly within supply chain management and system theory, while systems engineering, and soft systems engineering have greatly influenced this research. Soft systems engineering provided the foundation to design and execute this research. Its methods and approaches provide a transdisciplinary and integrative way of looking into complex systems to focus on how to design, integrate and manage them, using multidimensional principles and concepts from several scientific fields.

A PhD degree is generally recognised as a great challenge in normal conditions, so conducting half of the work during a pandemic added an interesting element to the mix, to say the least. At the same time, it gave me extra motivation to complete this work, which turned out to be a transformative personal experience.

Oslo, Norway
September 2021

# Acknowledgements

By now, most of us have heard something like *"completing a PhD is like running a marathon"*, referring to the long and lonely journey that it is to run those 42,195m. Yet, to me, my PhD journey does not refer to the perseverance that this saying denotes, but to the support system that surrounded me and helped prepare for the journey, navigate through it, and finally, helped me cross the finish line.

Through this journey I had the pleasure to come across amazing people, places, organizations, and gained a lot of experience and knowledge. I am grateful for each and every one of these people and experiences and would like to acknowledge those that made a difference in my journey and provided me with a great deal of support through this process.

Firstly, I would like to thank my team of supervisors, Professors Ziaul Haque Munim, Cecilia Haskins and Lokukaluge Prasad Perera. Thank you for your expertise, guidance, patience, and insightful feedback, which pushed me further and were fundamental to the completion of this work.

I would like to extend my deepest appreciation to Cecilia, whose mentorship, wise counsel, patience, and kindness helped me not only to get through this academic journey, but also through the personal journey that is pursuing a PhD.

I would also like to extend my formal appreciation to the organizations that have made it possible for me to conduct my research. To Aker BP, the Research Council of Norway (RCN) and the University of South-Eastern Norway (USN): thank you for the partnership, funding, and overall support you provided throughout this process.

To my dear colleagues at USN and the other universities in the PhD joint programme, thank you for providing feedback, helpful guidance, and an ear when things were not so bright ahead. A special thank you to Professor Mo Mansouri, who introduced me to the world of systems thinking and challenged me to always think differently.

Even though I had all this amazing assistance, I could not have finished this work without the support of my parents. To Amauri and Izabel: thank you for being there for me through whatever comes. I can hear you cheering despite the 10,931km between us.

Finally, to my life partner Ale, who is always there to help in the hard moments and cheer in the happy ones. Thank you for being there *with* me, it made all the difference.

A todos, deixo o meu muito obrigada!

# Abstract

The offshore oil and gas exploration and production (E&P) industry currently faces significant challenges that jeopardise its profitability and future. Sustainable operations are needed to comply with increased regulations and to help address climate change, while at the same time, global demand for energy and other consumable products is increasing at a rate that alternative sources of energy cannot meet alone.

Nonetheless, competing sources of energy pose an economic challenge to the industry, which needs to reinvent itself to remain competitive and become more sustainable. Meanwhile, higher competition for exploration areas and increased complexity in their exploitation translate into higher capital and operational costs and lower oil prices, which usually result in lower profits.

Sources such as DNV, UNDP, Boston Consulting and McKinsey strongly suggest that the Norwegian E&P industry requires a digital transformation of its operations, and the industry has been adopting technology and digital solutions to tackle these challenges. To this end, the recommended and adopted technology has mostly focused on the drilling operations and offshore activities within the industry. Paradoxically, the support offered to drilling operations by supply chain and logistics operations have been minimal, with limited software and tool upgrades focused on replacing the "pen and paper" practises of everyday operations without taking advantage of potential benefits for streamlining or integrating the functions.

This research addresses these challenges by investigating the transformation already started in the offshore E&P supply chain operations support underway in an established Norwegian operator and aims to contribute to the success of this transformation through (1) an analysis of how the operational functions can be made more efficient, (2) a presentation of potential alternatives based on research into state-of the art options, and (3) a strategic roadmap as a guide for their implementation. The discussion in this research, the proposed alternatives and the roadmap focus on the supply chain and logistics support to the drilling operations that are part of E&P due to the sheer size of the industry and the value of addressing an area most in need of attention.

The research was designed as a longitudinal action research study conducted in three cycles over three years, resulting in three articles that present the research outcomes and contributions. The body of knowledge of this research lies mostly within supply chain management and system theory, while systems engineering and systems thinking have greatly influenced this research. Systems engineering and systems thinking provided the foundation to design and execute this research. Their methods and approaches provide a transdisciplinary and integrative way of looking into complex systems to focus on how to design, integrate and manage them, using multidimensional principles and concepts from several scientific fields.

The results from this research are presented in relation to the supply chain operations' "AS-IS" and desired "TO-BE" states. To reach the research objective, a thorough investigation of the operator's operational structure, its goals, and the potential alternatives to reach these goals was conducted. This investigation showed that the current "AS-IS" supply chain operations are fragmented into silos within and across the organisation, lack software and data interoperability, and have a high dependency on manual inputs to collect the information that is required to execute the operational tasks. Three root causes were identified: (1) a traditional organisational culture that dictates how operations are conducted, (2) a traditional lack of urgency in improving supply chain operations due to high profit margins, and (3) failure to invest in technology that focuses on supply chain operations. The desired "TO-BE" vision presented by the stakeholders involved in this research shows an end-state for supply chain that addresses different organisation levels, with focus spread into cultural, organisational, operational, and technological elements.

The results indicate that technology and organisational change are at the centre of the desired transformation for supply chain operations. With technology at the centre of supply chain activities, the focus shifts to automation, software, and data interoperability, and the use of data as triggers to operations to decrease the dependency on manual intervention. The results show that such an infrastructure could be expected to lead to more autonomy, that is, less reliance on human decisions that could be a bottleneck to the efficiency of operations and suggests potential changes to many other aspects of current operations. The results also indicate that this transformation and vision can only be reached through organisational and cultural changes that embrace new approaches to how operations are to be conducted.

The main contributions from this research are threefold: (1) for the industry, (2) for academia, and (3) for policymaking. Contributions to the industry include the description and visualisation of current and desired states through rich-picture techniques that provide the convergence of goals and ideas from multiple stakeholders into one common image that can serve both the operator and as a benchmark for other operators in the industry. Still, with the industry in focus, this research contributes to the body of knowledge by suggesting methods and techniques that the Operator and others in the industry can adopt to innovate their business models as a precursor to help them in this transition from current ways of working to newer, more digital, ones. Finally, this research presents a strategic roadmap that shows the steps to be taken to conduct this transformation based on the identified “AS-IS”, “TO-BE” and proposed alternatives, thus helping to achieve a successful digital transformation journey.

The academic contributions from this research come in the form of helping to enrich the existing literature and practice through the dissemination of empirical, scientifically peer-reviewed reports from an industry that is mostly new to the existing offshore E&P and the upstream supply chain academic literature. The present research also presents soft systems engineering applications in a domain that expand and contribute to its body of knowledge and literature. Technology roadmapping for the oil and gas industry is relatively undocumented, and this research offers a practical adoption of the methodology through a scientific process and with peer-reviewed disseminated results for a traditional and engineering-oriented industry.

Finally, this research contributes to policymaking by providing real-world observations from the offshore E&P industry that may contribute to the creation, verification, and/or validation of policies aimed at the industry. Although the results of this research are not intended to be generalised to the whole industry, the information revealed in this research is in line with the generalised industry tendencies exposed by the accredited research institutions that were used as sources of data collection in this research. The

information revealed through this research gives explicit direction based on the Operator’s current status on important issues, such as sustainability, and the direction that operations are heading in relation to technology creation and adoption, digital solutions, and technological innovation. Such information guides decisions towards policies aimed at sustainability and human/work relationships within the E&P industry.

*Keywords: Offshore Exploration and Production, offshore oil and gas, offshore supply chain and logistics, systems engineering, systems thinking, digital transformation.*

# List of papers in this Thesis

### Article 1

Czachorowski, K.V., Haskins, C., Mansouri, M. (2021). Minding the gap between the front and back offices: A systemic analysis of the offshore oil and gas upstream supply chain for framing digital transformation (Systems Engineering, in review).

### Article 2

Czachorowski, Karen V. (2021). Cleaning Up Our Act: Systems Engineering to Promote Business Model Innovation for the Offshore Exploration and Production Supply Chain Operations. Sustainability 13, no. 4: 2113. https://doi.org/10.3390/su13042113

### Article 3

Czachorowski, K.V., Haskins, C. (2021). Applying systems engineering to roadmapping for digital transformation in the offshore exploration and production supply chain operations. Systems Engineering, 1 - 16. https://doi.org/10.1002/sys.21611

# List of other publications by the candidate

L. P. Perera and K. Czachorowski. (2019). Decentralized System Intelligence in Data Driven Networks for Shipping Industrial Applications: Digital Models to Blockchain Technologies. OCEANS 2019 - Marseille, 2019, pp. 1-6, doi: 10.1109/OCEANSE.2019.8867045.

Czachorowski K., Solesvik M., Kondratenko Y. (2019) The Application of Blockchain Technology in the Maritime Industry. In: Kharchenko V., Kondratenko Y., Kacprzyk J. (eds) Green IT Engineering: Social, Business and Industrial Applications. Studies in Systems, Decision and Control, vol 171. Springer, Cham. doi: 10.1007/978-3-030-00253-4_24

Gausdal, A., Czachorowski, K., & Solesvik, M. (2018). Applying Blockchain Technology: Evidence from Norwegian Companies. Sustainability, 10(6), 1985. doi: 10.3390/su10061985

# Table of contents

# List of figures

# List of tables

# PART I

# 1 Chapter

This chapter introduces this thesis, presenting the objectives of this research, the research questions, and the context in which it is conducted. The chapter concludes by detailing the structure of this thesis to show what will be presented and discussed.

## 1.1 Introduction

The offshore oil and gas industry consists of activities conducted in the open sea for the appraisal, exploration and exploitation of fossil fuel resources that are utilised globally as sources of fuel, energy, and other components used in the production of everyday consumption items (Dokkum, 2003; Inkpen & Moffett, 2011). Three main groups constitute this industry: upstream, midstream, and downstream. The first comprises the exploration and production (E&P) operations that are performed to discover and extract oil and gas resources from offshore reservoirs and to operate the platforms set up for these activities. Midstream comprises activities (such as transportation, processing, and storage) refine these resources and produce other products from them. Finally, the downstream is concerned with the wholesaling and distribution of products from the previous groups to consumers and others (Czachorowski, 2021; Inkpen & Moffett, 2011; Jacoby, 2012; The World Bank Group, 2010). Offshore E&P is the focus of the present research.

The offshore E&P industry is highly competitive, with many operators competing to find new areas to appraise and new licences to operate. Such competition has driven operators to seek further in the open sea, moving from exploration in shallow waters to deeper waters and remote areas, where remoteness and weather pose additional challenges to operations – such as increased human and environmental risks – and challenges to efficient operations execution (Grant, 2003; Inkpen & Moffett, 2011; Jacoby, 2012; Olesen, 2016). Global competition and agreements also affect the reserves of oil globally, which has a direct effect on the prices of oil (Alhosani, Zabri, Aljaberi, & Almansoori, 2019; Forbes & McCain, 2015; Grant, 2003; Hassani, Silva, & Al Kaabi, 2017). Low price spikes have become more frequent in the past 15 years, and the COVID-19 global pandemic that hit the industry in 2020 again showed the effects of very

low prices on profitability (DNV GL, 2021). As lower oil prices usually mean lower profits, the need to reduce costs wherever possible has been an important driver of innovation and transformation in the industry (DNV GL, 2021; Forbes & McCain, 2015; International Energy Agency – IEA, 2020). Sustainability has also been an important driver in this regard. Managing possible risks to the environment is a high priority for regulatory bodies, which is usually translated into increasingly strict regulations (DNV GL, 2020; International Energy Agency – IEA, 2021; KonKraft, 2020). Finally, the economic threat from alternative sources of energy and fuel (solar, wind, etc.) also challenges the industry to reinvent itself to remain competitive (DNV GL, 2020, 2021; KonKraft, 2020).
One of the main sources of offshore oil and gas resources globally is the Norwegian continental shelf (NCS), situated alongside Norway, limited by the Barents Sea and the Artic to the north and the North Sea to the south (Norwegian Petroleum Directorate – NPD & Ministry of Petroleum and Energy – OEDDEP, 2021). NCS operators and other stakeholders are among the most technically advanced, innovative, and highly engineering-oriented companies in the industry. Nevertheless, the activities involved in offshore E&P are executed by many stakeholders with intricate relationships, comprising a complex and highly interdependent system. Traditionally, these activities have been manually managed in silos with the assistance of monolithic legacy software with low levels of data and system interoperability and following traditional business models that have remained mostly unchanged (Forbes-Cable & Liu, 2019; KonKraft, 2018; World Economic Forum & Accenture, 2017). However, cutting-edge technology is available for adoption in supply chain management systems in the oil and gas industry (Everaard, 2019; Forbes-Cable & Liu, 2019; Joshi, Haghnegahdar, Anika, & Singh, 2017). Such a transformative upgrade relies on understanding the operational inefficiencies and preparing an accurate picture of how these operations should be performed (Everaard, 2019; Fitz et al, 2018; Forbes-Cable & Liu, 2019).

Over the past decade, discussions of digital transformation (DT) in the oil and gas industry, particularly in the NCS, have focused on the development and implementation of digital tools and software (KonKraft, 2018; Santamarta, Singh, & Forbes, 2017). The future of this highly regulated industry is jeopardised by several factors (as explained previously) that also compromise its efficiency, profitability, and sustainability. Nevertheless, maintaining competitiveness, reducing cost and emissions and expanding operations are seen as the most important reasons for this emphasis, as well as the main benefits of digitalisation, digital collaboration, and data access in general (Beck, Bellone, Hall, Kar, & Olufon, 2021; De la Boutetière, Montagner, & Reich, 2018). As with activities and operations execution, the industry has prioritised the development of technology, tools, software, and techniques that make it possible to access more oil, further from the shore, and in tougher conditions. At the same time, the support provided by supply chain and logistics operations to these activities has not been the focus of transformation (KonKraft, 2018, 2020). Even when highlighted by global consultancy agents and academia, the supply chain is perceived through a single view of one of its parts, usually logistics. Nevertheless, the improvement of one or a few parts of the supply chain in separation from its whole – and the stakeholders involved in operations – is likely to fail when addressing transformation. Hence, successful digital transformation relies on seeing and adopting a holistic view and approach to operations conduction. The present research seeks to address this gap by looking at the offshore E&P activities and its supply chain support, both holistically and systematically, to identify the best alternatives to bridge these two domains and to help promote changes to business models and formulate plans to address the above-described challenges and help assure success in digital transformation.

The present research addresses these challenges by investigating the digital transformation started in the offshore E&P supply chain operations support underway in an established Norwegian operator. The research also aims to contribute to the success of this transformation through (1) analysing how the operational functions can be made more efficient, (2) presenting potential alternatives based on real-world observations, and (3) providing a strategic roadmap as a guide for their implementation. The discussion in this research, the proposed alternatives and the roadmap focus on the supply chain and logistics support to the drilling operations and the drilling activities involved in well development and construction, which narrows the research focus due to the sheer size of the industry. Although this research investigates a single Norwegian operator and its results mainly benefit this operator, the entire industry can benefit from the results from this research, as the operator works very similarly to others in the NCS (KonKraft, 2018, 2020; Ryggvik, 2010). More importantly, the industry is a highly interdependent system; therefore, the success in transformation for one operator depends on the success of the majority of – if not all – stakeholders involved in the industry. Therefore, such stakeholders are key drivers and can potentially impose barriers to improvement and transformation.

## 1.2 Research Objectives and Questions

This research is a longitudinal participatory action research (AR) study structured in three cycles over three years, from June 2018 to August 2021. The study was conducted in an offshore oil and gas Norwegian operator on the NCS focused on the E&P domain. The main objective of this research is to investigate the digital transformation of the offshore E&P supply chain operations support, with an emphasis on drilling activities related to well construction. The second research objective is to contribute to the success of this transformation by presenting potential alternatives based on workshops and a strategic roadmap as a guide for implementation. To reach this objective, a thorough investigation of the operator's operational structure, its goals, and the potential alternatives to reach these goals were investigated, guided by three research questions:

**RQ1:** What is the current offshore E&P supply chain structure and what are its challenges to supply chain operations handling?

**RQ2:** What is the desired end-state for supply chain operations support, with an emphasis on the offshore E&P drilling activities?

**RQ3:** What alternatives can be adopted, and what new technology offers the potential for promoting operational efficiency, sustainability, and the progressive digital transformation of the offshore E&P supply chain?

The outcomes from this research are presented in three articles, accessible in Part II of this thesis. Table 1 shows a high-level overview of the outcomes and relationships among the research questions, AR cycles, and the applied methodological tools and research contribution by article. In the sequence, Section 1.3 presents an overall summary of each article.

*Table 1. Overview of Research Questions, Cycles, Methods, and Summarised Research Contribution*

| Article | RQ’s | AR Cycle | Method | Tasks per Cycle | Industrial contribution | Academic contribution |
|---|---|---|---|---|---|---|
| 1 | 1, 2 | 1, 2 | Soft systems and systems thinking | Task 1: Workshops to discover what was being done in the company related to SCM in general and its support to drilling operations<br>Task 2: Interviews with selected stakeholders to collect detailed information<br>Task 3: Analysis of literature and company processes<br>Task 4: Converted gathered information into visual explanations of the AS-IS and TO-BE | ‘AS-IS’ and ‘TO-BE’ state of the drilling supply chain | Enrich literature on SSM to include explicit application to E&P engineering |
| 2 | 2, 3 | 2, 3 | Morphological analysis | Task 1: Workshops to validate the information gathered in the previous cycle<br>Task 2: Analysis of literature | Propose alternatives to foster the ‘AS-IS’ and business model innovation | Enrich literature on application of Morphological analysis to assist innovation of E&P supply chain business models |
| 3 | 3 | 3 | Technology roadmapping | Task 1: Workshops<br>to discover what was being done in the company in relation to the adoption of digital tools in SCM, focused on the support provided to drilling operations<br>Task 2: Converted a proprietary "big picture" application ecosystem into a strategic technology roadmap | Strategic technology roadmap | Enrich literature on roadmapping adoption in the offshore E&P |

## 1.3 Summary of Articles

This section presents a summary of the three articles that resulted from this research.

- Article 1: This article adopts a systemic approach to examine the offshore E&P supply chain operations and identify areas for improvement through a soft systems lens applied in AR to capture and analyse the Operator's existing operations. The objective of the article is to determine the current 'AS-IS' supply chain operations support and the desired 'TO-BE' state for these operations. The outcomes of this research are that the identification of information exchange is a major barrier to reaching the desired 'TO-BE' state and that technology and organisational gaps are the primary hindrances for a digital transformation. The study concludes that the effort needed to recognise the full value of the 'TO-BE' model represents a digital transformation in supply chain operations to strengthen its relationship to the supported areas, especially drilling operations. This study suggests preliminary areas that must be addressed so that this transformation can occur. In summary, there is a need for a higher level of data exchange and increased data quality, as well as a focus on organisation and culture, to leverage the success of new tools and ways of working and reduce resistance to change and digital solutions.
- Article 2: Instead of proposing a business model archetype, this article suggests a flexible and granular way to foster business model innovation (BMI) in offshore E&P supply chain operations through the proposition of individual elements for adoption in the BMI process. A further goal is to create opportunities for the E&P operator, and possibly the industry, to help it contribute reaching the United Nations (UN) Sustainable Development Goals (SDGs); specifically, goals 7, 9, 12, 13 and 14. More details of the possible contributions identified are presented and discussed in Section 4.2 and Article 2. The elements suggested in the article are proposed to function as 'bricks' that can be adopted and rearranged as necessary to foster BMI and support the innovations in the offshore E&P supply chain that are needed to address the SDGs. Systems engineering (SE) is applied to this study through the employment of morphological analysis (MA) technique to define the suggested

elements for BMI. The resulting elements from the MA analysis constitute the article's contribution. Morphological boxes are adopted in the article to present the proposed elements, divided in three dimensions: technology, organisation, and the human element. These dimensions are elicited by sustainable business model (SBM) existing literature. This approach was selected because it provides granularity and flexibility that may facilitate BMI for organisations of different sizes.

- Article 3: This article presents a strategic technology roadmap to support the continuous and successful digital transformation of the supply chain activities focused on drilling operations. First, an investigation was performed to identify the main factors that lead to success in digital transformations, then SE methods were applied through the adoption of the T-Plan roadmapping process to create and present the strategic roadmap. The conclusion from the investigation performed to identify the factors that lead to success in digital transformations show that it depends on (1) the adoption of the most appropriate technology and digital tools to support reaching organisational goals and visions, (2) transforming operating and business models to facilitate the successful transition to these new technologies and tools, and (3) creating an idealised implementation strategy and successfully communicating this strategy with stakeholders. Therefore, the roadmap is intended as a strategic communication tool that stakeholders could use to assist the integration of technology and business planning and help assess the impact of new technologies and market development towards a successful digital transformation. The roadmap is presented as a novel adoption of technology roadmapping methodology in the researched industry that may serve as an example to other operators in their DTs and enrich relevant academic literature.

## 1.4 Industrial Settings: Aker BP

This research project is an applied research that was partially funded by Aker BP, a Norwegian private E&P operator, and by the Research Council of Norway (RCN) through the Industrial PhD programme (grant number 291198).

Aker BP was created in 2016 through the merger of the Norwegian E&P operations of British Petroleum (BP) and Norway's first national oil company, called Det Norske Oljeselskap, which has operated in the NCS since 1971. Today, Aker BP is a 'pure-play' E&P operator that executes exploration, development, and production activities in the NCS, mainly in the Norwegian Sea, the Barents Sea, and in the more established areas of the North Sea. The company ownership is divided mainly into three groups, with its ownership divided as follows: 40 per cent owned by Aker ASA, 30 per cent by BP, and 30 per cent by others (multiple stakeholders). The company is listed on the Oslo Stock Exchange under the AKBP ticker, with headquarters in Fornebu outside Oslo and offices in Stavanger, Trondheim, Sandnessjøen, and Harstad (Aker BP, 2021c).

Aker BP operates five assets (offshore platforms) and is a major partner in a sixth one, operating a total of 135 licences in the NCS. It produced an average of 223,100 barrels of oil equivalents (BOE) per day in 2020, with earnings of USD 2,128 million (EBITDA) in the same year (Aker BP, 2021c). In the first half of 2021, the company reported a production volume of 210,400 BOE per day, with a production cost of USD 8.8 per BOE produced, and 4.2 kg of $CO_2$ emission per BOE (Aker BP, 2021b). Figure 1 shows the company's key figures for 2020 and 2019.

| Key figures | | 2020 | 2019 |
|---|---|---|---|
| Production | mboepd | 210.7 | 155.9 |
| Sales | mboepd | 210.2 | 157.6 |
| Realized liquids price | USD/bbl | 40.0 | 64.8 |
| Realized gas price | USD/scm | 0.14 | 0.18 |
| Total income | USDm | 2 979 | 3 347 |
| EBITDA | USDm | 2 128 | 2 286 |
| Net profit | USDm | 45 | 141 |
| Free cash flow[1] | USDm | 356 | -293 |
| Net interest-bearing debt | USDm | 3 647 | 3 180 |
| Leverage rato | | 1.51 | 1.24 |

*Figure 1. Aker BP's key figures* (Aker BP, 2021a)

Aker BP is currently one of the largest independent “pure-play” oil companies in Europe when measured in oil production and has been positioning itself as a leader in the industry’s transformation to become safer, more efficient, and more environmentally friendly, with the ambition of producing in Norway the cleanest oil and gas in the world. The company’s ambition is to become the leading E&P company in the NCS through stakeholder collaboration via alliances, use of new technology and continuous improvement.

## 1.5 Thesis Structure

This thesis is divided into two parts. Part I presents the theoretical foundations of this research; its research design, strategy, and methods; and the research’s results and conclusion. Part II contains the articles that resulted from this research. In Part I, Chapter 1 presents the introduction to this research, the research objectives and questions, the summary of articles resulting from this research, and the industrial setting in which it was conducted. Chapter 2 presents the background supporting this research and its body of knowledge and the strategy and methods adopted in this research. The chapter starts with a review of the research background, continued by the research approach adopted, overall methods, and an overview of qualitative research methods. It then continues with the methodological tools adopted per article appended in this thesis and an in-depth explanation of the adopted methodology in this research. Chapter 2 concludes with a discussion of validity, reliability, and the ethical aspects of this research. Chapter 3 presents the research results, an overall discussion per article, and is followed by Chapter 4, with the research concluding remarks, summary of research contributions, and suggestions for future work. Finally, additional material is made available in the thesis appendix.

# 2 Chapter – Research Background, Strategy and Methods

This chapter presents the research background, a review of the body of knowledge to which this research contributes and the strategy and methods applied. It starts with an overview of supply chain management focused on offshore E&P operations and the support given to well construction and drilling activities. The chapter continues with the presentation of the research design, strategy, approach, and the methods adopted in this research to find the answers to the research questions and achieve the research objectives stated in Chapter 1. First, an overview of the philosophical and research paradigms that support the research and the rationale for method selection is presented in the research approach sub-section. This is followed by an overview of digital transformation and of systems theory and soft systems engineering and a summary of applied methodological tools per article. Subsequently, how the adopted methods supported the research is presented and discussed. The chapter finishes with a discussion of the research's reliability, validity, and ethical considerations.

## 2.1 Research Background and Strategies

### 2.1.1 Supply Chain Management Focused on Exploration and Production

The supply chain is a web that involves all the organisations, activities, technology, resources, processes, and individuals related to a product, from its creation to its sale. A general supply chain starts at the most upstream supplier (for example, raw material), followed by product manufacturing, and moves downstream through transportation and distribution channels until it reaches an end customer (LeMay, Helms, Kimball, & McMahon, 2017; Mentzer et al., 2001). In general, supply chains are constituted of four main elements – procurement, operations, distribution, and integration – and grouped into six generic supply chain models that have two main goals: efficiency and responsiveness. Each model looks for a combination of these goals, but approaches them differently (Fayezi & Zomorrodi, 2016; LeMay et al., 2017; Supply Chain Council, 2012). Different industries inflect variations in their supply chain and adopt models to execute and optimise the goals of the supply chain and manage it.

Supply chain management (SCM) is a discipline that manages the supply chain flow across multiple organisations and functions to ensure that the goals of that supply chain are accomplished. This management includes all the information related to the supply chain, planning, execution of operations, integration, research and development, and total system/value analysis (Cooper, Lambert, & Pagh, 1997; Lambert & Cooper, 2000; Mentzer et al., 2001). The term 'supply chain' emerged in the 1980s to describe the series of activities performed to procure and manage supplies, mainly focused on purchasing and cost reduction initiatives (Lambert & Cooper, 2000; LeMay et al., 2017). In the 1990s, SCM emerged as a discipline that incorporated the management of logistics activities executed within the overall supply chain and expanded as a concept to include supplier–buyer relationships, supply chain integration and cross-SCM (Cooper et al., 1997; Mentzer et al., 2001).

SCM is generally divided into three categories – strategic, tactical and operational – that classify the supply chain activities to help achieve their intended business goals (LeMay et al., 2017; G. Stevens, 1990; Supply Chain Council, 2012). Strategic SCM comprises the whole scope of a supply chain network, addressing long-term strategy and elements in the supply chain, such as partnerships, alliances, technology, suppliers, and facilities. The tactical level comprises how the strategy will be delivered, with a shorter duration and a more granular specification towards production, logistics, software, contracts, etc. Finally, the operational level entails the execution of supply chain operations, such as production, shipping, and invoicing (Fayezi & Zomorrodi, 2016; LeMay et al., 2017; Supply Chain Council, 2012).

According to Jacoby (2009), four generic supply chain strategies are adopted in SCM: rationalisation, synchronisation, customisation, and innovation. Rationalisation aims to contain operating costs (OPEX), while synchronisation aims to balance supply and demand. Customisation aims to improve relationships with customers, and innovation focuses on achieving fast product development and introduction to the market. Choosing the most appropriate depends on the industry and type of business (D. Jacoby, 2009). Still, accomplishing supply chain activities successfully relies on organising supply chains, which can be completed through the adoption of supply chain models. The type of industry, business goals, and value proposition are used as input to define which supply chain model is to be adopted and influence how each SCM level is to be executed. Industries with continuous operations focused on low cost and/or asset utilisation (such as chemicals, cement and steel manufacturing) might focus on 'efficient', 'fast', and 'continuous-flow' supply chain models to maximise asset exploitation with minimum cost, whereas industries that focus on products with a high level of uncertainty or customisable or tailored 'on demand' products (for example, high-end products, manufacturers that provide services to several industries) might adopt models that focus on the responsiveness capabilities of their supply chains to enable rapid adaptation to the new conditions and variations of their supply chains (Lu, 2014; Van Der Vorst, 2004).

From a high-level perspective, the offshore E&P supply chain resembles those of high-value process manufacturing industries with continuous operations, such as petrochemicals and pharmaceuticals (Jacoby, 2012). Nevertheless, in the offshore E&P context, supply chains are much more complex networks or systems with a broad scope that starts with the support to the fields' pre-appraisal and continues throughout the field's lifecycle until decommission. In between, supply chain activities support decisions regarding whether to build and/or expand platforms and support the activities involved in the drilling of new wells, operating, and maintaining wells, and managing the resources and stakeholders involved in these processes (Aas, Halskau, & Wallace, 2009; Jacoby, 2012). In this supply chain, the type of items that require purchasing, the type of activities that need to be executed, and the transportation of materials and equipment to the remote locations where these activities occur result in a high number of specificities and much higher complexity, making offshore E&P extremely special and intricate to manage (Albjerk, Danielsen, & Krey, 2015; Jacoby, 2012; Menhat, Jeevan, Zaideen, & Yusuf, 2019). In offshore E&P supply chains, technology, chemistry, and location have a great impact on every supply chain decision, ranging from which suppliers or partners to collaborate with when selecting specific and tailor-made items that take a long time to be produced (such as Christmas trees) to the delivery and complex installation of items in remote offshore and deep waters. The remoteness and accessibility of offshore platforms heavily influences the design of offshore E&P supply chains by impacting the procurement of material and supplies (for example, specific items that resist certain weather conditions) and thus the choice of suppliers and partners and how the logistics operations are to be planned and conducted (Albjerk et al., 2015; Inkpen & Moffett, 2011; Jacoby, 2012).

The supply chain activities are executed by a large network of stakeholders – including partners, suppliers, service providers, supply bases and terminals, warehouses, and specialised logistics providers – that deal with a great number of complex products and dangerous conditions, and must comply with different legislation and rules (Inkpen & Moffett, 2011; Jacoby, 2012). In the offshore E&P supply chain, logistics operations form an intricate network on their own. They rely on special purpose-built vessels that can either be owned by the operator or hired from specialised companies that provide these vessels, normally together with other activities (for example, manning, bunkering, and other services), but are normally managed by the operator that hired them (Aas et al., 2009; Albjerk et al., 2015; Borch & Batalden, 2015). Additionally, the operations to deliver and retrieve materials are often done in extreme conditions, such as winter storms and frozen waters, creating potentially hazardous situations that could result in accidents that have negative consequences for the workers involved and for the environment (Aas et al., 2009; Inkpen & Moffett, 2011; IPIECA & IOGP, 2020). With so many interactions and subdivisions, the success of operations relies on collaboration, yet this business model limits the possibility of these service and logistics providers adopting different strategies, business models, and innovation, often leaving them submissive to the operators who hired them. In the Norwegian offshore E&P industry, in particular, compliance with ever-growing regulation can also demand extra management, potentially causing delays and additional operating costs (DNV GL Energy, 2020; KonKraft, 2018, 2020). Figure 2 illustrates the high-level activities related to the offshore E&P industry: the highlighted area includes the blocks that are addressed in this research.

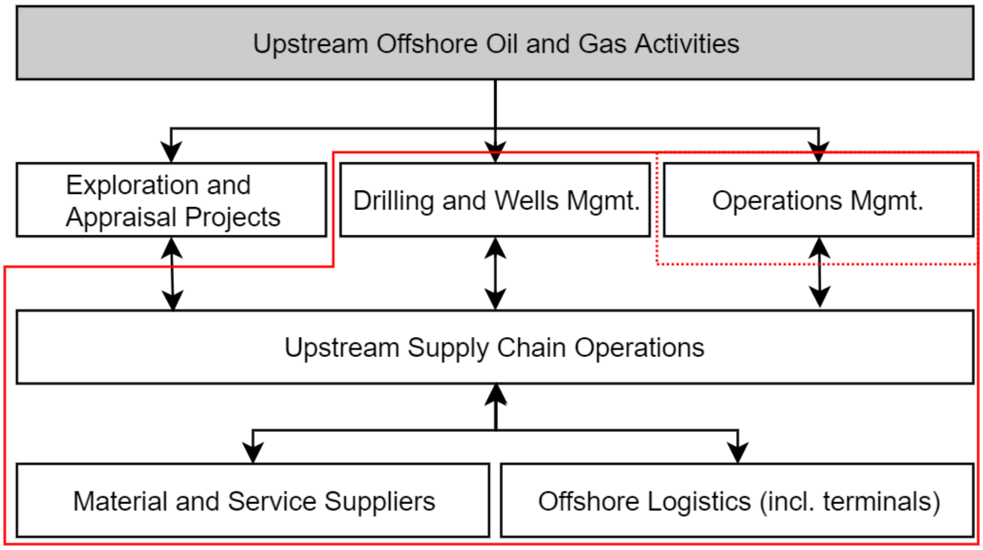


*Figure 2. Summarised Upstream Offshore (Exploration and Production) Activities (adapted from* Czachorowski, 2021*).*

A considerable contributor to offshore E&P supply chain complexity is the support that is dedicated to drilling activities. These activities occur over a long period, which can start with the exploration of reserves or the identification of possible areas to be drilled for the construction of wells. These activities rely on the support of many different specialised service providers; specific, complex, and expensive equipment that is usually rented at a high cost (for example, tools for bottom hole assembly, BHA); and a high level of coordination that needs to be executed flawlessly for the drilling execution to be successful (Inkpen & Moffett, 2011; The World Bank Group, 2010). Figure 3 summarises the E&P supply chain operations that support the offshore E&P drilling activities.

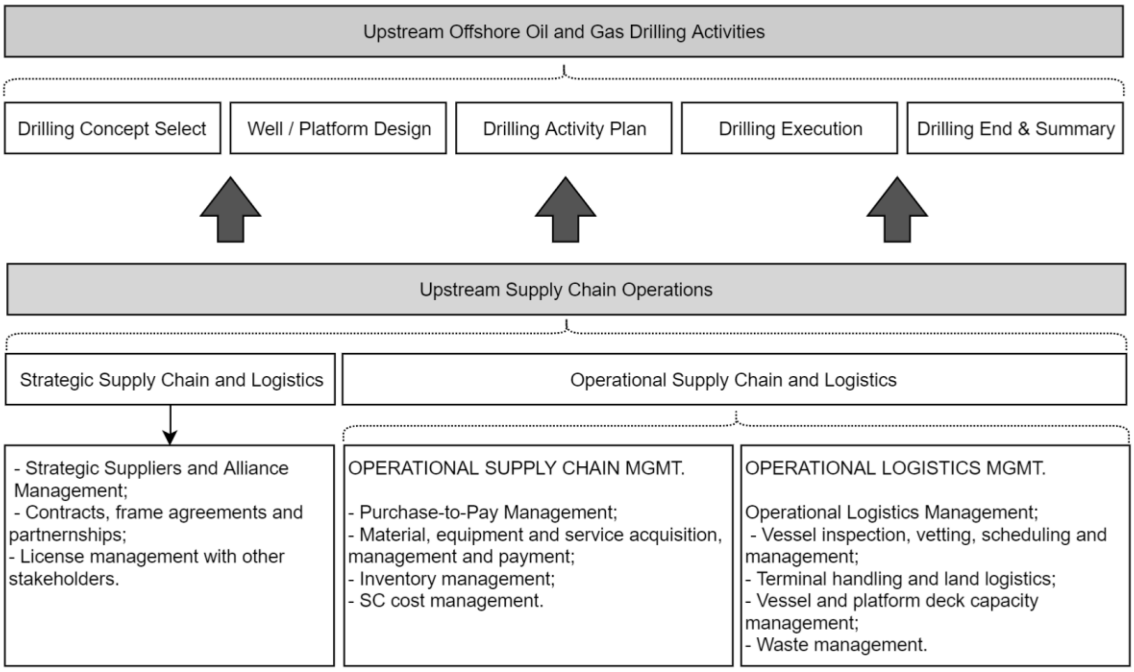


*Figure 3. Supply Chain Operations in the Context of Drilling Activities (Czachorowski, 2021)*

Jacoby (2012) stated that a combination of rationalisation and synchronisation is the most appropriate strategy for the design of oil and gas and offshore E&P supply chains, as these have a higher dependency on asset and cost management and reliability, rather than agility, customisation, and other supply chain principles. The offshore E&P has a strong dependency on the discovery of new reserves and areas to operate, and the appraisal of additional reserves in current assets in explorations, translating into higher capital expenditures (capex; Inkpen & Moffett, 2011; Jacoby, 2012). Although rationalisation focuses on the management of operating costs (opex) instead of asset management in order to achieve cost control and greater profitability than the competition, it emphasises procurement strategies and activities (such as sourcing or supplier selection) (Jacoby, 2009), which can contribute to increasing capex. Combining elements of synchronisation can help balance the strategy. Synchronisation focuses on achieving reliable and faultless supply chain execution that optimises output volume with fixed production capacity and inventory with less variation and reduced risk, emphasising activities such as inventory management, maintenance, demand planning, standardisation, and replenishment (Jacoby, 2009). Thus, synchronisation can increase the focus on asset productivity, helping to achieve a balance between CAPEX and OPEX due to the relative importance of OPEX against CAPEX in the industry.

However, the management of these complex supply chain activities, or parts of them, has increasingly become outsourced to other involved organisations and stakeholders, which are growing strongly reliant on cross-organisational supply chain and logistics (Cooper et al., 1997), where a network of organisations with different focus and goals rely on each other's success to achieve their own. More recently, these have included the introduction of new and other business and operation models (such as 'as-a-service', or aaS), and the introduction of modern digital technologies (Klingebiel & Wagenitz, 2013; H. Lu, Guo, Azimi, & Huang, 2019; Menhat et al., 2019; P. Stevens, 2016). Consequently, sharing information and collaboration has become increasingly important in accomplishing SCM effectively. Nevertheless, success in collaborations relies on information sharing among the participants in a supply chain, transparency, trust, and on overcoming power gaps, different financial situations, and different goals and disagreements related to the use of technology (Petersson, Baur, & Jensen, 2018; Ralston, Richey, & Grawe, 2017). Understanding how these variables affect the supply chain is fundamental to the selection of the best plan or option to be adopted in SCM, and its strategic planning and execution ought to be considered during the supply chain's design and management. Such a high level of complexity and inter-relation results in technology becoming a decisive factor for how supply chain operations are designed, executed, and managed (Albjerk et al., 2015; Inkpen & Moffett, 2011; D Jacoby, 2012).

#### *2.1.1.1 Supply Chain Management Operations Models*

The adoption of frameworks, tools, and models to help design, plan, and operate supply chains – such as the traditional supply chain operations reference (SCOR) developed by the Supply Chain Council (SCC) (Supply Chain Council, 2012), which is well recognised both in academic literature and industrial practises (Huan, Sheoran, & Wan, 2004) – may reduce their complexity and improve operations. Nevertheless, SCOR and other less-adopted models, such as the customer chain operations reference model and the design chain operations reference model (APICS, 2013, 2014; Supply Chain Council, 2012) have focused on traditional consumer and production supply chains, with minimal consideration of lean, flexible and agile strategies (Lima-Junior & Carpinetti, 2017). Additionally, many of the stages, business processes, and relationships presented in these models do not exist or are different in the contexts of offshore E&P and the oil and gas industry in general. This is because the industry is asset-centric, resulting in key business processes focused on asset procurement, construction and installation, deployment, operation, and maintenance, strongly differing from those in traditional supply chains (Jacoby, 2012).

Nevertheless, a recognised model that holistically addresses the offshore E&P industry is not yet available (Ahmad, de Brito, Rezaei, & Tavasszy, 2017; Alhosani et al., 2019). The SCC made an initial attempt at the end of 2007 with the creation of a forum to benchmark the oil and gas practises and create an oil and gas process model, as the forum realised that a common high-level industry-wide model was required to allow the industry to benchmark and implement best practices (Kilponen, 2010). Hafeez et al. (2017) reported having adopted a step-by-step process to implement SCOR in an oil and gas company in an emerging market, and although the implementation was considered effective, their report concluded that adapting the SCOR model was time-consuming, and that the adoption of the suggested best practises may be a more suitable choice. Within the context of sustainability, Ahmad et al. (2017) presented a framework to address this model gap in the oil and gas industry, while Raut, Narkhede and Gardas (2017) and Gardas, Raut and Narkhede (2019) identified conditions and factors for the successful management of the oil and gas supply chain.

Rebs, Brandenburg and Seuring (2019) found that most of the models they investigated consisted of a high-level perspective of analysis, while models for intra and interorganisational supply chains were less frequent, also making the case for the application of a systems-thinking perspective in a theoretical framework. Rebs et al. (2019) fostered the importance of multilevel frameworks that can handle the entire complexity of supply chains and inter-relationships between the levels of analysis (Fabbe-Costes, Roussat & Colin, 2011). The success of such frameworks lies in the inclusion of all stakeholders' perspectives and the adoption of an outline that allows examination of the impacts of multiple and collective interaction among all participants of the system with an organisational network perspective.

##### *2.1.1.2 Business Model and Business Model Innovation*

Business models in the offshore E&P industry are generally traditional, based on the 1990s models that focused on maximising shareholder value and bookable reserves and minimising costs (Stevens, 2016). The disruption of traditional models requires breaking the barriers imposed by conservatism and vested interests (Stevens, 2016), but a pressing need to revisit these business models has created a new reality for the industry, developed with volatile prices, marginal profits, and pressure from the call for stop the exploration for new oil and gas reserves in favour of renewable sources of energy (Ebneyamini & Bandarian, 2019; Financial Times, 2019; International Energy Agency – IEA, 2021). In addition, technological advances can disrupt traditional business models, either to promote competitive advantage or by necessity (Gardas, Raut, & Narkhede, 2019; Stevens, 2016; Wendel, 2017).

Multiple definitions of business models (BM) exist in the literature, while existing business models frameworks have been explored extensively (Zott et al., 2011), particularly addressing technology innovation (Ahmad et al., 2017; Baden-Fuller & Haefliger, 2013; Gassmann, Frankenberger, & Csik, 2013). According to Trott (2017), the business model is an instrument that describes how firms use their resources to generate and offer value in the setting that it is inserted, providing a structure for organisations to yield profit through the products and services it creates, and the value that they deliver to their customers. Therefore, a business model is an instrument for firms to operate and manage their business, and to verify their ongoing performance (Bocken, Short, Rana, & Evans, 2014; Bouncken, Kraus, & Roig-Tierno, 2019; Osterwalder & Pigneur, 2010).

A business model generally contains three main elements: (1) value proposition, (2) value creation and delivery, and (3) value capture (Bocken et al., 2014; Osterwalder & Pigneur, 2010). The value proposition relates to how the product and/or service offered by the organisation generates financial returns, and which consumer segment is focused on (Bocken et al., 2014; Chesbrough, 2010). Value creation and delivery relate to the resources (for example, technology, distribution methods, partners, general activities) that are utilised to deliver the value proposition (Bocken et al., 2014; Osterwalder & Pigneur, 2010). Value capture is related to how revenue is captured, which can also be in the form of cost reductions (Bocken et al., 2014; Bouncken et al., 2019; Osterwalder & Pigneur, 2010). Meanwhile, technology-focused business models have four functions: (1) to demonstrate the value proposition of a specific technology to its users, (2) to identify the market segment in which the technology has meaning, (3) to demonstrate the value chain involved in the technology(ies) and/or product(s), and (4) to evaluate the potential profit and cost structure (ROI, potential return on investment) of the offering(s) (Chesbrough, 2002). While Chesbrough (2002) affirmed that these elements provide opportunities for firms to capture value from innovation, Zott et al. (2011) claimed that business models may be subjected to innovation themselves as they have a role in fostering innovation in firms. Therefore, business models are not static tools or rigid frameworks but fluid, transient, and dynamic systems that can possibly adapt and change so that the success of the organisation remains (Bucherer, Eisert, & Gassmann, 2012; Morris, Schindehutte, & Allen, 2005; Rezazade Mehrizi & Lashkarbolouki, 2016).

The innovation of business models is a continuous process of change that is referred to as BMI (Bucherer et al., 2012). According to Trott (2017), organisations that innovate their business models perceive greater growth than those that focus on the innovation of products and operations alone. Still, BMI is a complex process that depends on evaluation of how the elements that comprise the organisation's current business model work towards its desired outcome and can benefit from a more holistic approach, rather than innovating single elements in the business model (Bucherer et al., 2012; Kraus et al., 2020). The success of BMI relies on the ability of leadership and management to break existing cultures of passiveness and conservatism in their organisations towards the implementation of new ingredients in their business models that are not new products and/or services alone (Gassmann et al., 2013; Markides, 2006). Tools that are available to support the BMI process include the St. Gallen business model navigator (Gassmann et al., 2013), the business model canvas by Osterwalder and

Pigneur (2010), and the triple-layered business model canvas (Joyce & Paquin, 2016), which focuses on designing SBMs.

### 2.1.2 Digital Transformation

Digital transformation (DT) is currently being discussed in many different arenas at different levels worldwide as a response to the challenges that organisations face, and a way for them to innovate business models and create value. There are multiple academic and non-academic DT definitions available, and for the purpose of this thesis, the one proposed by Vial (2019) is adopted because it stresses improvement as a desired outcome of DT without being organisation-centric, but rather provides a broader definition that accepts society, and different industries as entities that can implement a DT with the goal of improving themselves for a specific reason. Vial (2019) states that digital transformation is:

> *"a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies"* (Vial, 2019, p. 121).

Accordingly, DT relates to the strategic adoption of computer-based technologies and tools to reimagine business through the creation of new or the modification of existing processes, organisations, cultural environments, and customer experiences to fundamentally change the ways operations are conducted, how value is delivered to customers and partners, and to meet new and rapidly changing demands of markets, governments, and society (Berman, 2012; Bouncken et al., 2019; Gobble, 2018b).

Therefore, DT goes beyond the mere adoption of digital technologies and tools by delving into an entity's business models and ways value is created. DT requires an understanding of these technologies and tools to define how to generate business value opportunities out of initiatives that include the adoption of digital technologies and tools, in a continuous process in many initiatives operating in parallel (Brown, 2021). Ideally, the DT process begins with an understanding of the stakeholders involved and their needs to derive a clear expression of the problems that are intended to be solved. The information collected in the search for these answers is to serve as a starting point for designing the digital solution of the future in a circular and iterative process until a final model is achieved that fulfils business needs and objectives (Plekhanov & Netland, 2019). Westerman, Bonnet and McAfee (2014) recommended starting the DT process with an assessment of the organisation's current digital maturity to identify and decide which business elements will benefit the most from the investment in DT. They suggested that concentrating on transforming business models and operational processes may best generate benefits through investment in infrastructure, workforce empowerment, and performance administration.

Finally, a successful DT also relies on creating and following a successful strategy – a plan of action that correctly positions and guides an organisation; this is referred to as a DT strategy (De la Boutetière et al., 2018; Gobble, 2018a; Matt, Hess, & Benlian, 2015).

Matt et al. (2015) defines DT strategy as *'the blueprint that supports companies in governing the transformations that arise owing to the integration of digital technologies, as well as in their operations after a transformation'* (Matt et al., 2015, p. 340).

A robust and well-thought-out DT strategy must address technology, software, systems, and digital solutions, as well as innovations in these areas that can appear in a short timeframe (Matt et al., 2015). At the same time, the DT strategy must account for how these solutions and tools affect business models, processes, and culture to determine the best approach to the implementation of the strategy and its success (Schallmo et al., 2020; Westerman et al., 2014).

An example of a framework that supports a DT strategy is given in Figure 4. This framework depicts how the DT process allows organisations to change the manner in which value is created through the adoption of computer-based technologies, resulting in positive outcomes, although negative impacts can be possible. In this framework, the use of technology results in disruptions that generate strategic responses, while enabling changes in how value creation occurs at the same time. The changes to value creation are affected by the organisation's structure (such as culture and leadership) and structural changes and barriers that affect possible changes (such as internal resistance to change). Finally, the resulting changes in how value is created generate positive impacts, such as operational/organisational improvement and efficiency, while possible negative impacts can occur, such as conflicts of privacy and security "breaches".

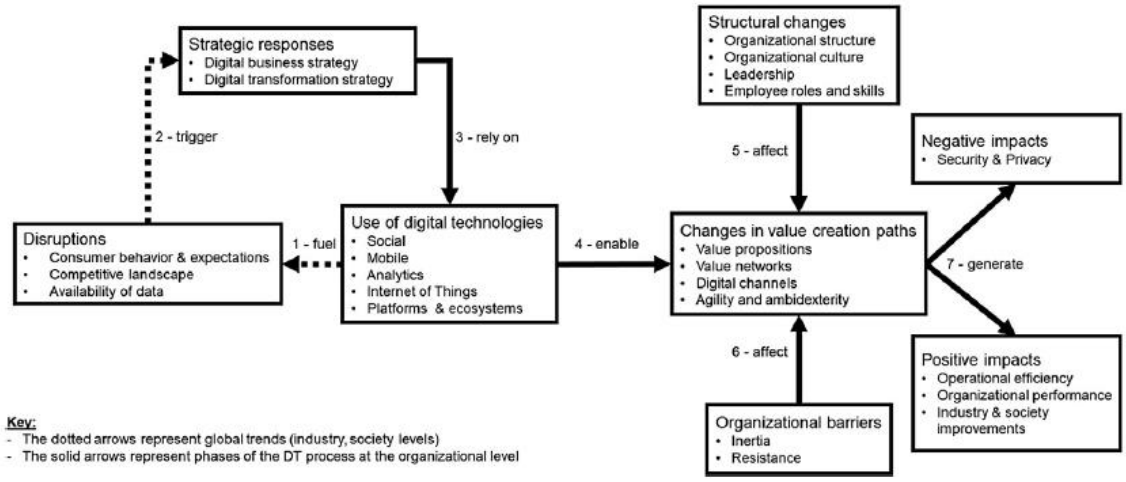


*Figure 4. DT Framework - Building blocks of the DT process (source:* Vial, 2019, p.122)*.*

Therefore, a successful DT relies on the ability of organisations to find the appropriate balance among business strategies, technology, organisational structure, and culture, and eventually sustain an advantage through the adaptation and maintenance of their operating and business models (Czachorowski & Haskins, 2021; Schallmo et al., 2020; Westerman et al., 2014). Consequently, DT strategy plays a role that can be effectively and successfully executed by the adoption of SE and soft SE (Matt et al., 2015).

The adoption of such DT framework can help organisations navigate DT internally but with focus on value creation from within organisations and their structure. However, it does not consider the possible effect that external partners that collaborate with the organisation might have in its DT, neither the effect that its DT might have in its partners.

## 2.2 Research Approach

The results and conclusions drawn in research are considered to be of scientific value when the research is executed using a method and techniques that are appropriate for answering the research questions and/or addressing the research objectives. The decisions about which methods and techniques are to be adopted are based on philosophical and research paradigms that support the researcher and the kind of research being conducted (case studies, AR, experiments, etc.). These factors – plus the research objectives, questions, available knowledge, and resources to conduct the research – determine the choice of data and data collection (Opoku, Ahmed, & Akotia, 2016; Saunders, Lewis, & Thornhill, 2009).

Research paradigms comprise a set of fundamental beliefs and assumptions that serve as a mental model or framework for how the researcher perceives and understands the world and to guide their behaviour and affect the practice of research (Jonker & Pennink, 2010; Saunders et al., 2009). Addressing the research paradigms that support research is important because it influences how to frame and conduct a study to understand the research phenomena, creating the theoretical assumptions and fundamental beliefs that guide the research and the choice of how it is to be conducted (Creswell, 2009; Saunders et al., 2009). The research paradigms are distinguished by two main philosophical dimensions: ontology and epistemology (Saunders et al., 2009). Ontology relates to the nature of knowledge and how reality is perceived, while epistemology concerns the beliefs that comprise what is considered acceptable and valid knowledge (Saunders et al., 2009). Two additional beliefs that affect the way research is conducted to investigate reality are axiology and methodology. Axiology relates to the role that values have in the researcher's beliefs in relation to ethics, while methodology comprises the model that guides the research process in the context of the research paradigm (Saunders et al., 2009).

Five main research paradigms are found in literature: positivism, critical realism, interpretivism (constructivism), postmodernism, and pragmatism (Saunders et al., 2009). The first two – positivism and critical realism – share common ontological and epistemological views, in which reality is external and objective, and advocate the use of numeric elements as the appropriate means of generating knowledge, constructed based on hypotheses tested statistically. However, the axiology beliefs of these two paradigms are divergent, where the positivist researcher must be value-free and maintain an independent and objective approach to data. The critical realism paradigm's axiological stance diverges by being value-laden, believing that knowledge results from social conditioning, as reality is framed within a certain context that has created phenomena within the observable world. Interpretivism, on the other hand, is ontologically subjective and socially constructed within the research boundaries, where reality might change. The epistemological views in this paradigm are built based on the construction of the subjective meaning of the investigated phenomenon. Axiologically, this research is value-bound, meaning that it will be subjective because the researcher cannot be set apart from the research and, consequently, their values will have a certain impact on the research. Postmodernism goes beyond interpretivism in its subjectiveness and in-depth investigation of phenomena but focuses on the role that language has and the power relations resulting from the use of language. Finally, pragmatism preaches that concepts are only applicable if they support action and merges both objectivism and subjectivism by considering theories, hypotheses, findings, and concepts based on their role in achieving practical outcomes in certain contexts. Accordingly, reality and knowledge exist as long as they allow solving of the specific problem they seek to solve (Saunders et al., 2009). This last paradigm reflects the beliefs of the researcher that conducted this research and reflected in this thesis.

The approach to theory development or modification is also important in research and strongly linked to the research and philosophical paradigms that are adopted, with three main approaches – deduction, induction, and abduction – typically being adopted. The deductive approach focuses on testing a theory to verify or falsify it, generally starting with a theoretical review of the existing academic literature as the basis for building the research strategy to test it. The inductive approach focuses on exploring a phenomenon and/or generating theory, which often comes as a conceptual framework and starts with data collection to try to understand that phenomenon and/or build theory. In the abductive approach, the researchers collect data to explore phenomena, identify themes and patterns and explain them, and create new theories or modify them by subsequently testing them through additional data collection (Saunders et al., 2009). Hence, the abductive approach works similarly to the inductive approach as it can also focus on exploring a phenomenon and allows building theory, although it also incorporates elements of the deductive approach by allowing verification of the theory being built and/or changing theory by subsequently collecting data to verify previous differences and identified patterns.

Therefore, given its pragmatic and problem-solving nature, this research adopts an abductive approach to theory and a qualitative approach to understanding the offshore E&P supply chain by investigating how its participants understand it to be able to answer the research questions presented in Chapter 1, with emphasis on practical solutions and outcomes. The combination of AR and a multimethod qualitative procedure constitute the strategy applied to this research. For researchers embedded in the subject of the research, AR (Kemmis, 2009; Susman, 1983) is the most appropriate methodology to generate contributions to both the industry and academia, and its combination with a multimethod qualitative approach was the most appropriate choice for achieving the research's objectives and the answers to the research questions stated in Chapter 1.

Qualitative research can provide rich descriptions to create general constructs, giving in-depth knowledge about one or more phenomena by analysing them through a naturalistic approach (Denzin & Lincoln, 2011). The purpose of qualitative research is to understand a phenomenon, behaviour, and institution by exploring the individuals involved and understanding their values, beliefs, and emotions (Miles, Huberman, & Saldaña, 2014). The qualitative methodology provides additional layers of complexity to data sets collected from several sources in several possible formats. This complexity allows the researcher to explore further the meaning that the studied phenomenon has in relation to the individuals' perspectives (Eisenhardt, 1989). By studying the phenomenon in a specific context, the researcher can create a thick description of the subject matter and explore the phenomenon in depth, creating theory and/or inferring results that are novel and rich (Geertz, 1973). According to Denzin and Lincoln (2011), qualitative research is comprised of a 'set of interpretive practices' that, when applied to the world, turn these practises into a series of representations that need to be interpreted according to their natural settings to provide understanding of the phenomena based on what type of meanings people assign to them. By applying such a perspective, the researcher is supported by 'local groundedness' (Miles et al., 2014), providing them with local data and context and meaning that they can study a phenomenon by immersing themselves in the world rather than simply examining collected data from questionnaires. Thus, the examination of the social phenomenon's meaning and intentions in the way it is experienced by the people involved increases its understanding, leading to theory development and inferring conclusions about the research findings (Denzin & Lincoln, 2011).

## 2.3 Research Methods

### 2.3.1 Systems Thinking methods and practices

General systems theory (GST) refers to the study of systems and was first introduced by Ludwig von Bertalanffy in the 1940s as an alternative way of studying complex systems. The aim of GST is to model the dynamics, conditions, and limitations of a system and explicate its principles (that is, its purpose, methods, and tools) to determine and explain its interactions and relationships among and beyond the systems' parts towards other systems. Generally, GST is concerned with the development of widely applicable principles and concepts, rather than being strictly restricted to a single area of knowledge by bringing together knowledge from physics, biology, and the social sciences. Therefore, GST is concerned with generating many and different ways of seeing the world and the situations in it and how they interact with one another and/or with the world. It is based on the principle that a system goes beyond the confluence of its parts and is best understood when its parts are studied in the context of their relationships with each other and the system as a whole, rather than being studied in isolation (Montuori, 2011; Von Bertalanffy, 1972, 1976). In GST, systems are a combination of components or subsystems, each limited by its physical, logical, and functional characteristics, that cooperate towards the same final objective or goal (Checkland & Poulter, 2010; Von Bertalanffy, 1976). These components and characteristics are not limited to 'hard parts' (such as software, physical components, pieces, and parts) but also include the 'soft parts' in a system, such as the human and social aspects associated with that system (Hitchins, 2008). This approach to viewing and studying systems confers a transdisciplinary character to GST that makes it sufficiently valuable and flexible to be adopted in many different fields of study, ranging from heavy engineering-oriented areas to others such as healthcare, education, and societal issues (Checkland & Poulter, 2010; Gharajedaghi, 2011; Montuori, 2011). Ultimately, GST is the foundation that supports many different approaches to studying systems and many tools are available for analysis and investigation, such as Forrester's systems dynamics (Forrester, 1990), Beer's viable system model (Beer, 1972, 1981), Checkland's soft systems methodology (SSM) (Checkland, 1985; Checkland & Poulter, 2010), and others (Mingers & White, 2010; Reynolds & Holwell, 2010).

The interdisciplinary, multidisciplinary, and transdisciplinary approach to the study of systems is referred to as SE, focusing on the design, integration, use, management, and retirement of complex systems throughout their lifecycles in a cohesive effort that enables their success (Adcock, Jackson, Singer, & Hybertson, 2021; INCOSE, 2021; Lawson et al., 2021; Sheard & Mostashari, 2010). INCOSE (2021) defined SE as the '*transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods*'. According to INCOSE (2021), the SE viewpoint is based on systems thinking principles that provide a single standpoint to understand reality. Systems practitioners now understand and accept systems as conceptual constructs that can be used for engaging with and improving real-world complex situations (Reynolds & Holwell, 2010). This approach to systems is known as systems thinking, an approach that has been widely adopted in SSM. Systems thinking is a concept that permits perceiving and understanding relationships, cause and effect, connections, interdependencies, and feedback that can help resolve complex problems and describe systemic behaviour (Checkland, 1985; Gharajedaghi, 2011; Meadows & Wright, 2008). Senge (2006, p.7) defined systems thinking as a *'conceptual framework, a body of knowledge and tools that have been developed over the past seventy years, to make the full patterns clearer, and to help us see how to change them effectively'*. From a systems-thinking perspective, a system is an *'adaptive whole'* that changes and adapts itself to survive its environment (Checkland, 2012). For this to be true, each of the systems' functional parts must be properly linked to the others, maintaining a flow of appropriate information and allowing the system's adaptation to maintain performance

(Checkland, 2012). Through the adoption of systems thinking, it is possible to begin understanding the multi-layered nature of the world through systemic reflection and by being able to think critically in complex situations (Boardman & Sauser, 2013; Checkland, 1985; Gharajedaghi, 2011; Hossain, Dayarathna, Nagahi, & Jaradat, 2020).

Nevertheless, not all approaches to systems allow consideration of the 'soft parts'. The formal systems approaches generally focus on targets, 'best practice' and performance indicators, and are set up to work to achieve these. As a result, the system is likely to focus on measurable outcomes and may ignore interrelationships and interconnections. The analysis of the system's behaviour and potential flaws is likely to point to a single perspective or individual to blame, rather than looking into the context and other factors that are to be considered in setting up and running the system, which could have led to potential flaws (Gharajedaghi, 2011; Reynolds & Holwell, 2010). Therefore, a soft perspective may be required to understand and contextualise the intricacies in systems that will make it possible to transform the system into an improved and enhanced version of itself. SSM was created by Checkland in the 1970s as a follow-up to his critique of formal systems methods; that is, the lack of possibility to focus on the social and 'soft' aspects of a system (Checkland, 1985, 1994; Checkland & Poulter, 2010). SSM techniques are suitable for investigating complex and challenging problems and to help discover the most appropriate action to be taken through an iterative analytical approach to scenarios that contain multiple participants and systems with little or no direct clear link between them.

The many techniques and approaches available in the soft engineering toolkit can be applied in a multitude of contexts and disciplines. In the oil and gas and E&P domains, studies have explored SE and systems thinking for gathering business requirements (Engen, Mansouri, & Muller, 2019), development of 'configure-to-order' supplier-led solutions (Falk, Ulsvik, Engen, & Syverud, 2019), early-phase system development and validation (Kjørstad, Mansouri, Muller, & Kjenner, 2019), DT of systems maintenance documentation (Falk et al., 2020), architecting systems in conceptual phase (Engen, Falk, & Muller, 2019), and several other applications within the oil and gas domain that show benefits and potential from the implementation of SE in the industry (Muller & Falk, 2018). Many other studies are available when the search is expanded to maritime and nautical domains, specifically in relation to supply chain and maritime transportation, such as maritime transportation governance and governance in marine transportation systems of systems (Mansouri, Gorod, Wakeman, & Sauser, 2009, 2010), the organisation of acquisition criteria and decisions in technologies related to the reduction of marine emission (Aspen, Haskins, & Fet, 2018), policy-making frameworks for systems of port infrastructure (Mansouri, Nilchiani, & Mostashari, 2010), maritime transportation systems resiliency (Omer, Mostashari, Nilchiani, & Mansouri, 2012), 'engineer-to-order' supply chain of ship building (Mello, Gosling, Naim, Strandhagen, & Brett, 2017), and many other examples of SE adoption (Rebs et al., 2019).

Thus, the foundation provided by GST, SE and soft SE, and systems thinking techniques is ideal for systematically examining the supply chain to simultaneously understand its parts and how it operates in its entirety. This has the potential to support the success of the DT pursued in the case company. This systems' approach assists in studying and understanding the processes and functions that exist in complex organisations by offering a methodological structure that allows an organisation to be analysed and broken down as a collection of numerous subsystems and systematically reconstructing it while considering the interrelations that exist in organisations (Gharajedaghi, 2011; Montuori, 2011; Willcocks, Sauer, & Lacity, 2016). The present research adopts this approach because it is ideal for showing that diverting from traditional mindsets and business models can provide opportunities for organisational transformation through the adoption of innovations, technologies, and digital solutions for aspects of the supply chain that need improvement, which traditional models, techniques, and mindsets may fail to perceive. Finally, the combination of these approaches is ideal for providing a plan of action that can lead to a successful DT through taking the network into consideration as the context for organizational transformation.

### 2.3.2 Summary of Applied Methodological Tools per Article

This section details the methodological tools that supported each article beyond the AR methodology explained in the previous section and the activities executed (literature review, for example) in each cycle.

#### *2.3.2.1 Article 1: Soft Systems Methods and Systems Thinking tools*

Article 1 adopted SSM employed in AR (Baskerville & Wood-Harper, 2016; Levin, 1994) to holistically and systematically examine the supply chain under consideration in the article and to identify and propose the ideal approaches to generating the expected outcomes expected in this research, rather than adopting the traditional models available, which are inadequate for the task. Tools available from systems science help explain and represent our observations, both temporarily and spatially (Falk et al., 2020). SSM contains visual techniques that allow the exploration of multiple viewpoints to help stakeholders collaboratively study complex situations and engage in mutual understanding of different perspectives and desired changes. The SSM techniques involve activities such as 'rich picture' creation that build a visualisation of people's mental models surrounding a certain complex problem, which in turn helps identify possible transformations and visualise the required actions needed to realise the wanted change and find a common ground between stakeholders so that the most desirable and feasible way forward is adopted (Checkland & Poulter, 2010; Mingers & White, 2010). A systems thinking tool called a systemigram (Boardman & Sauser, 2013; Checkland, 1985) was adopted in this article to visually present its results against the article objectives; specifically, the 'AS-IS' and 'TO-BE' system states, inherited from the AR cycle from which it was derived. A systemigram supports a description of complex systems' construction and functionality (Checkland, 1985; Mehler, McGee, & Edson, 2010; Squires et al., 2010) through understanding them as relationships. When applied to this study, they provided an understanding of how supply chain operations are interrelated to other parts of the organisation and beyond and allowed the creation of a powerful visualisation of these relationships in a holistic manner. The complete explanation of how these methods were adopted is available in the article in Part II of this thesis.

#### *2.3.2.2 Article 2: Morphological Analysis and Business Model Typology*

Article 2 performed an MA (Im & Cho, 2013; Kwon, Lee, & Hong, 2019; Martin, 1994; Zwicky, 1969) to identify, define, classify, and present elements to be adopted to promote BMI in the offshore E&P supply chain. MA was applied to systematically classify and evaluate the possible options that, when combined, can deliver certain functionality (Martin, 1994). In addition to the information made available in Cycles 1 and 2, this MA was executed by examining two main groups of collected information: (1) existing literature on offshore E&P, its supply chain, general business models, BMI, and SBMs (retrieved from databases as Web of Science, Scopus, and others); and (2) E&P-related information from oil and gas-related organisations (IPIECA, DNV, etc.), collected through reports and publications published by these organisations. The elements that were identified from this process were then classified based on the adoption of business model typology developed by Tukker (2004) to identify the elements that pertained to classic business model typology and the ones that pertained to new business model typology. Finally, a list of characteristics related to technology, organisation and the human element was used to present and classify the identified elements, adopted from Bocken et al. (2014), to address the sustainability dimension explored in this article. Additional details of how Tukker's typology was adopted, and the results of these classification exercises, are presented in in the article in Part II of this thesis.

#### *2.3.2.3 Article 3: T-Plan approach to Technology Roadmapping*

The T-Plan is a fast-start customisation of the technology roadmapping process (Phaal, Farrukh, & Probert, 2001). The T-Plan methodology was developed by Phaal, Farrukh, and Probert (Phaal et al., 2001) to support a solid and thriving roadmapping process that can be utilised quickly and economically. The T-Plan consists of a four-workshop process that starts with the planning of what is to be investigated and finishes with the roadmap roll-out. Each workshop deals with one domain in the roadmapping process: (1) identify the market domain, (2) focus on the involved product(s) or service(s), (3) focus on technology, and (4) construct the roadmapping visualisation that links technology and market to deliver the product or service (Phaal et al., 2001).

The T-Plan methodology was adopted in this article, as illustrated in Figure 5. As explained in Section 2.3.3.3.2, the domains identified were (1) market, (2) service, (3) technology and (4) roadmap, and the multiple workshops conducted following these domains. A summary of the results and discussion from the process is presented in Section 3.3, and the complete explanation of the process is available in Part II of this thesis.

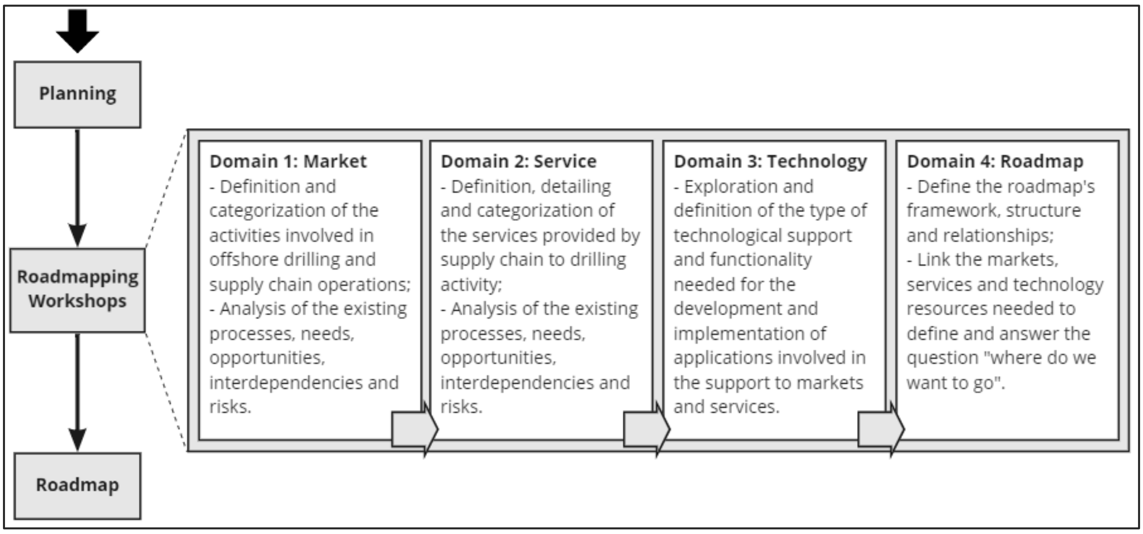


*Figure 5. The T-Plan Methodology* (Czachorowski & Haskins, 2021) *(adapted from Phaal et al., 2001).*

## 2.3.3 In-depth Research Methodology: Action Research and Research Cycles

The action research (AR) methodology integrates theory and practice with the goal of solving complex problems in organisational or social dimensions by embedding the researcher(s) to work together with the person(s) experiencing those problems (Baskerville & Wood-Harper, 2016; Kemmis, McTaggart, & Nixon, 2014; Shani & Coghlan, 2019). AR perceives the world as changing constantly, which influences both the research and the researcher. Thus, combining research, researchers, and the environment allows simultaneous research and participation, and through this combination, AR supports theory development, knowledge creation, and problem-solving to achieve research and practical objectives simultaneously (Baskerville & Wood-Harper, 2016; Kemmis et al., 2014; Susman, 1983). Lewin (1946) pioneered AR with the proposal – a continuing spiral of steps, or phases, to be taken to complete the AR – divided into cycles. Each phase serves as the basis for the next phase within the cycle, and each cycle has an objective and serves as the basis for the next cycle (Kemmis et al., 2014; Susman, 1983). Since Lewin (1946), many different AR approaches have been proposed with a different number of phases. The present research adopted the four-phase approach proposed by Kemmis et al. (2014), as it was considered to be a better fit for the research due to time and resource availability.

This research was divided into three cycles conducted over the course of three years. Each cycle was divided into four phases adapted from Kemmis et al. (2014) – plan, act, observe and reflect – which were conducted sequentially. Each phase had an objective and a set of activities that were executed to reach the cycle's objective. The first cycle began in the second quarter of 2018 and was completed in the fourth quarter of 2019. The second cycle began in the first quarter of 2020 and lasted until the fourth quarter of the same year. The third and last cycle began in the third quarter of 2020 and lasted until the first quarter of 2021. The second and third cycles overlapped in the second semester of 2020 due to delays in the completion of the second cycle because of the COVID-19 pandemic.

The AR cycles conducted in this research focused on these questions, with their results presented in the articles in part II of this thesis. Each article was supported by additional methodological tools to ensure valid results. Together, these articles make specific contributions that address the research questions and research objectives. The overall contribution of this research body of knowledge was to introduce a systemic approach to examine the offshore E&P supply chain holistically to identify problems, gaps, and opportunities for its improvement, as opposed to traditional supply chain models that are not a fit for offshore E&P supply chains (such as SCOR). Additionally, SE techniques and perspectives were adopted to define the criteria to be addressed and the steps to be taken to a successful DT initiative. The main sources of data in all cycles were internal and external stakeholders through many interactions in form of meetings and workshops (see workshop details in Sections 2.3.3.1.3, 2.3.3.2.2 and 2.3.3.3.2), interviews (see details in Section 2.3.3.1.2), and information retrieved through literature review and from online reports from accredited institutions (such as DNV) that research the E&P industry (see details in Section 2.3.3.1.1).

The interactions with internal and external stakeholders were divided into two main categories: workshops and general interactions. A workshop is defined as brief learning experience for a small group of people in a certain field that fosters experimentation and active learning, with emphasis on participation to reach a certain goal (such as problem solving, generating and/or increasing knowledge, building skills, learning, etc.) (Brooks-Harris & Stock, 1999; Paszkowski & Gołebiewski, 2020; Tejedor & Segalas, 2018). This research adopted the following parameters to classify an interaction as a workshop: a physical or digital encounter with a minimum duration of three hours with five or more internal and/or external stakeholders. The definition of three hours was adopted to be the equivalent of a half-day encounter, rounded down as the total daily workload in the operator is 7.5 hours. Although the workshops were initially thought to be full-day encounters, it became known in the early phases of the research that many of the stakeholders were operational in the organisation, and it was very difficult for them to find replacements for full-day encounters. Therefore, to facilitate and foster participation, the research adopted half-day as the standard. The number of minimum participants to define a workshop was defined from the calculation of 1 per cent (chosen arbitrarily) of the total audience that this research focused on. The audience was the sum of the drilling and wells (around 305 people), supply chain management and logistics (around 173 people) business units and the number of external stakeholders (around 33 people) selected for Cycle 1, a total of around 511 people. Since 1 per cent of 511 is 5.11, the parameter was rounded down to 5. Eighty-seven individual participants participated in one or more interaction or workshop in all cycles, and therefore the whole extent of the research. Some participants partook in different workshops and cycles, particularly the workshops, and although some participants could not be present in one or more workshops, all of the key stakeholders to each workshop were present when the workshop was conducted, as some workshops were rescheduled to ensure key stakeholder participation.

The second interaction category comprises all interactions that do not fit into the adopted classification of a workshop. These interactions happened in general with one or more stakeholder in any form (conversations, meetings, phone calls, etc.) with different purposes, such as: validation of information presented in another interaction or workshop; following-up on previously presented information that was not completely understood or was too complex or detailed to be addressed at the time it was presented; and the collection of additional information from stakeholders that could not participate in specific meetings and/or workshops.

The activities conducted in cycles 1 and 2 were applied to Czachorowski, Haskins, & Mansouri (2021), and the results from this cycle were applied for both Czachorowski et. al (2021) and Czachorowski (2021), while the activities and results from cycle 3 were applied to Czachorowski & Haskins (2021). The summary and relationship between the cycles, their objectives and activities, the resulting articles, and what was addressed in each article are illustrated in Figure 6. The cycles, their activities, and participants are detailed in the sequence.

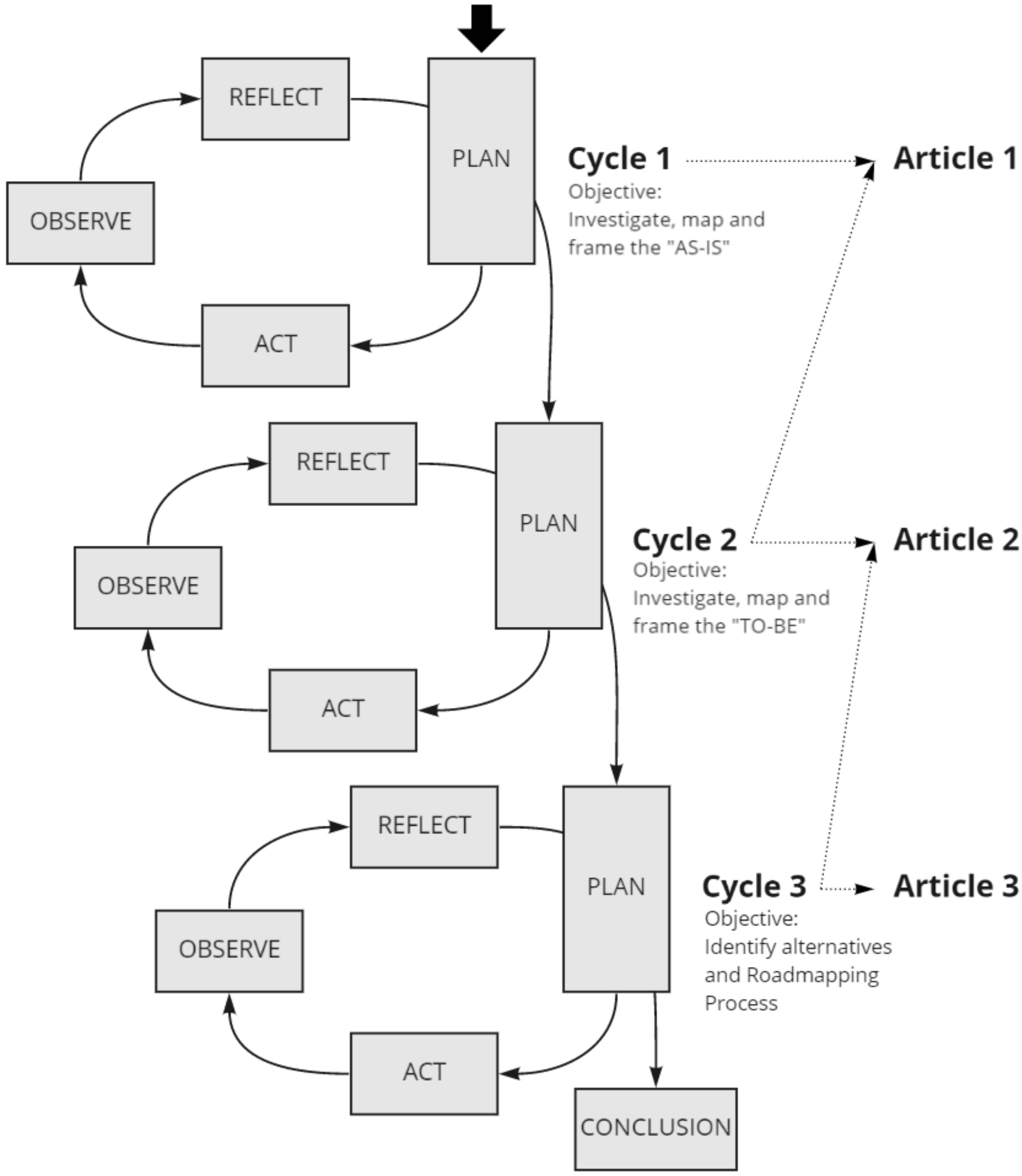


*Figure 6. Summary and Relationship between Action Research Cycles and Objectives and Resulting Articles (source: author)*

*2.3.3.1 Cycle 1*

The main objectives in Cycle 1 were to identify, map, and frame the current supply chain operations 'AS-IS' addressed in this research. Working towards this objective, each of the phases in the cycle had specific objectives and an activity set that was executed to achieve the phase objectives. The successful completion of each phase contributed to the successful completion of the cycle. The summary of Cycle 1 and its objectives and activities are illustrated in Figure 7.

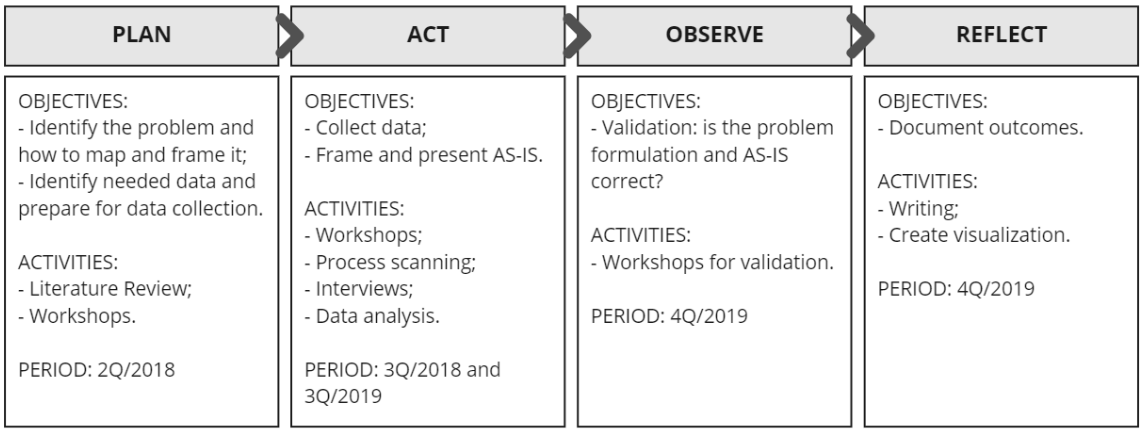


*Figure 7. Details of Cycle 1 phases*

The activity set in each phase consisted of different steps to collect and analyse data, conduct validation, and document the cycle outcomes. In Cycle 1, four activities were conducted to collect data: (a) literature review; (b) semi-structured interviews with the supply chain and logistics departments, their internal customers, and additional stakeholders; (c) workshops where participant observations were logged; and (d) a review of the organisation's operational processes, software/applications, and their overlap, collected through an analysis of the organisation's internal tools. The data collected in each activity were analysed at the end of the activity. These activities are summarised in Table 2 and detailed in the sequence. Finally, the documentation activities conducted in the 'reflect' phase were executed in two ways: writing the article related to the cycle (or parts of it) and creating a visualisation of results, which was done by adopting systems thinking tools. This is detailed further in Sections 2.3.2.1 and 3.1.

*Table 2. Cycle 1 – Detailed Data Collection and Validation Activities (Data Analysis and Documentation Excluded)* (applied to Czachorowski, Haskins, & Mansouri, 2021)

| Cycle Phase | Year | Quarter | Nr. of general Interactions | Number of Workshops | Interviews | Interviewee's Category (see Table 4) |
|---|---|---|---|---|---|---|
| Plan | 2018 | Q2 | 13 | 2 | - | - |
| Act | 2018 | Q3 | 24 | 2 | - | - |
| Act | 2018 | Q4 | 41 | 6 | 8 | Decision Makers, Internal Stakeholders and End Users |
| Act | 2019 | Q1 | 30 | 13 | 1 | External Stakeholders |
| Observe | 2019 | Q4 | 7 | 5 | - | - |
| TOTAL | | | 115 | 28 | 9 | - |

*2.3.3.1.1 Literature Review*

To examine the existing literature related to the Cycle 1 objectives and establish the academic foundation necessary to support this research, a literature review was conducted in the first phase of this cycle. This review was conducted by examining peer-reviewed academic articles extracted from academic databases, mainly Scopus and Web of Knowledge. The search for relevant articles was conducted via Boolean expressions using variations on the following keywords: 'oil and gas', 'digitisation', 'oil and gas supply chain', 'Norwegian oil', and 'gas operations'. The results from this literature review are discussed in the appended articles resulting from this cycle.

A second source of literature review comes from reviewing reports published online by accredited institutions that researched this industry (such as DNV, KonKraft, Capgemini, IPIECA, etc.). Table 3 presents the 10 selected reports with a summary of the learnings from what these sources say about the offshore E&P domain. The learnings from these sources were utilised for overall learning about the industry and benchmarking the results from this research against trusted sources.

*Table 3. Online Reports Utilised for Data Collection and Validation*

| No | Source | Report Name | Main information from source |
|---|---|---|---|
| 1 | DNV (DNV GL, 2020) | "Energy Transition Outlook 2020 – Power Supply and use" | - Electricity demand is expected to double from 2017 to 2050.<br>- Electrification will increase and change how energy is sourced and delivered, also decreasing carbon emissions, but also increases demand.<br>- Renewable electricity production and its transmission grid will need investment and upgrades before being available to meet energy demands.<br>- Digital solutions are key enablers of sustaining energy production. |
| 2 | DNV (DNV GL Energy, 2020) | "Energy Transition Outlook 2020 – A global and regional forecast to 2050" | - The share of renewable energy sources is expected to be approximately 60 per cent by 2050.<br>- Natural gas use is expected to peak by 2035 and crude oil use likely peaked in 2019.<br>- Conventional oil production is expected to decline by an average of 1.4 per cent a year until 2050 but will continue to play a critical role in energy production.<br>- Policies and policy-enforcing practises will impact how much and how fast oil demand decreases due to transition to other sources.<br>- Fossil fuels are still expected to supply about half of the global energetic demand by 2050. |

| No | Source | Report Name | Main information from source |
|---|---|---|---|
| 3 | DNV (DNV GL, 2021) | "Turmoil and Transformation" | - Companies that opt to continue to invest in oil and gas are likely to choose more flexible and quicker projects with lower marginal costs, such as tiebacks, enhanced oil recovery and short cycle production.<br>- Decarbonisation has become a central theme pursued in the industry that is focusing on a 'less carbon-intensive energy mix'.<br>- Power demand is growing, but many people and industries are still supplied with energy from coal. Many of these are seeking to decarbonise and are moving from coal to gas, which shifts the demand to another fossil source and the oil and gas industry.<br>- Many of the renewable sources of energy considered for the energetic transition are still in the prototype or development stages and have some time before being available on a large scale. |
| 4 | KonKraft (KonKraft, 2020) | "The Energy Industry of tomorrow on the Norwegian Continental Shelf: Climate Strategy towards 2030 and 2050" | - World oil and gas consumption is expected to decrease significantly by 2050, but gas in particular is expected to have additional demand during the transition from coal.<br>- Norway's gas supply will be important in replacing coal in Europe to meet decarbonisation goals.<br>- Natural gas as a source of power is expected to decline, but it is expected that gas-fired power stations will play an important role in balancing the variable supply from renewable power sources such as solar and wind.<br>- Petroleum as a feedstock is expected to maintain its demand to supply the world with wholly or partially made products from petroleum, such as composites and plastic products.<br>- Demand for single-use plastics is dropping in many parts of the world but increasing in others, in an overall increase for items made of plastic (car parts, computers, shoes, textiles, etc.). |

| No | Source | Report Name | Main information from source |
|---|---|---|---|
| 5 | KonKraft (KonKraft, 2018) | "Project Competitiveness – changing tide on the Norwegian continental shelf" | - The NCS has a traditional role in offshore innovation and collaboration, and this is required to continue to sustain the shelf's competitiveness.<br>- The industry must innovate to maintain competitiveness in a reduced demand scenario or in a scenario where few oil discoveries are made in the shelf.<br>- The industry must continue reducing its $CO_2$ intensity to further increase its competitiveness, which can be done through many alternatives (carbon-capture, electrification, digitalised collaboration, etc.).<br>- Increased digital collaboration in operations is expected through the adoption of common platforms, software, information exchange, common standards, and resource sharing (vessels and transportation terminals, inventory, spare parts, etc.). |
| 6 | Wood Mackenzie (Forbes-Cable & Liu, 2019) | "Digital disruption: upstream supply chain threats and opportunities" | - The oil prices downturn was a 'wake-up call' for the oil and gas sector to move from being a 'digitalisation laggard'.<br>- The industry is both technically advanced and an early adopter of digital solutions, but a wide-digitalisation initiative was not perceived as a necessity.<br>- Intensifying competition from alternative sources of energy is expected to force the industry to revise its long-term competitiveness capacity.<br>- Digitalisation in the industry is expected to transform its supply chain both vertically and horizontally and is expected to have a long-term in the upstream supply chain's business models and activities. |

| No | Source | Report Name | Main information from source |
|---|---|---|---|
| 7 | Boston Consulting Group (Santamarta et al., 2017) | "How digital will transform the upstream oil ecosystem" | - Despite being a long-term adopter of technology, the oil sector has been slower in adopting digital solutions until the oil price downturn.<br>- Digitalisation is expected to bring significant change to business models, traditional value chains and how business is conducted.<br>- It is important that companies understand what their position in their value chain is to define the best digital solutions (that is, technology stack) to be adopted.<br>- Fostering the use of sensors and sharing data among companies and suppliers is expected to have a transformative effect in business models. |
| 8 | McKinsey & Company (Beck et al., 2021) | "The big choices for oil and gas in navigating the energy transition" | - The oil and gas sector's traditional business models have been under stress for some time, as shown by the lag in annual total return to shareholder (TTS) for the average oil and gas company.<br>- Oil and gas companies must build a portfolio that is resilient to both higher carbon prices and lower commodity prices.<br>- A change in operating models is needed to increase competitiveness, and a diversification of portfolio might be needed. |
| 9 | UNDP (UNDP, IFC, IPIECA, & CCSI, 2017) | "Mapping the Oil and Gas Industry to the Sustainable Development Goals: An Atlas" | - The oil and gas sector has the potential to contribute to all 17 Sustainable Development Goals defined by the United Nations.<br>- An increased awareness of how the sector can contribute to SDGs, and multi-stakeholder dialogue and collaboration are needed to enhance the sector's collaboration to the SDGs.<br>- Collaboration with other stakeholders can enhance the ability of oil and gas companies to leverage the necessary and additional resources needed to contribute to the SDGs. |

| No | Source | Report Name | Main information from source |
|---|---|---|---|
| 10 | E&P Forum & UNEP (E&P Forum & UNEP, 1997) | "Environmental management in oil and gas exploration and production: An overview of issues and management approaches" | - Many of the potential impacts in the oil and gas industry, which vary depending on the stage of the industry's value chain, can be avoided, minimised, reduced, and mitigated with the proper set of actions and attention.<br>- Beyond environmental impacts, human, socio-economic and cultural impacts are likely to exist as consequence of exploration and production (E&P) and need special attention and initiatives for their mitigation.<br>- The industry has proactively introduced new engineering and operational techniques to prevent impacts from the industry, but it needs to remain in focus to avoid additional and increased consequences from exploratory activity. |

*2.3.3.1.2 Interviews*

In this cycle, nine semi-structured, face-to-face interviews were conducted with informants in different roles connected to the conduction of E&P drilling and supply chain operations. The interviews had two main objectives: (1) to explore the informants' understanding of the current state of supply chain and logistics operations, and (2) to explore the informants' recommendations for how supply chain operations and logistics operations should be conducted and confirm their understanding of what was missing to reach this desired state. Although the second objective is related to Cycle 2, it was included in this same interview process to optimise data collection due to time constraints. The interviews were conducted with the assistance of an interview guide that consisted of 16 open-ended questions (Appendix A), with small adaptations for the external stakeholder interview. The guide was adapted after the first interview, and during the executions of the interviews, some questions were aggregated to improve the interview flow and manage time.

The selection of the informants to be interviewed was based on four criteria: (a) decision makers – persons authorised to make any decision over the supply chain operations; (b) internal stakeholders – supply chain and logistics personnel working directly in the operations; (c) end users – internal departments supported by supply chain operations; and (d) external stakeholders – supply chain stakeholders outside the organisation. These four criteria were used later to classify the collected data. The informants were categorised based on the scope of their work: (1) general operations, (2) supply chain operations, and (3) logistics operations (Czachorowski et al., 2021). The informants' profiles are presented in Table 4, and additional information is not given, in order to maintain anonymity.

*Table 4. Informants Profile – Interviews* (applied to Czachorowski et al., 2021).

| Category | Type of Role | Informant ID |
|---|---|---|
| Internal Stakeholder | Supply Chain Operations | I.1 |
| Internal Stakeholder | General operations | I.6 |
| Internal Stakeholder | Logistics operations | I.8 |
| Decision Maker | General operations | I.2 |
| Decision Maker | Supply chain operations | I.4 |
| Decision Maker | Logistics operations | I.5 |
| Decision Maker | General operations | I.7 |
| End User | Supply chain operations | I.3 |
| External Stakeholder | Logistics operations | I.9 |

The interview recordings were saved as individual files in the operator's cloud server in the researcher's personal folder, which was accessible only with a personal login, password, and multi-factor authentication (MFA). The files were individually identified using only the informant ID number given according to Table 4. This procedure was adopted following directions given by USN's library (bibliotek.usn.no/guidelines-for-the-management-of-research-data) and the Norwegian Centre for Research Data (NSD; nsd.no/en) guidelines. The analysis of each interview started with the full transcription of each interview recording, first using software for this purpose named Trint (trint.com), before being revised manually. The transcriptions were stored in the same manner as the recordings and were then analysed using deductive coding (Frankfort-Nachmias, 2008) using NVivo software (qsrinternational.com).

The deductive coding process was conducted through the adoption of a predefined code set (Glaser, 2013): (1) organisation and culture, (2) operations handling, and (3) technology-related aspects. These codes were selected because the researcher perceived that the information collected from the researched literature, reports and from the conducted workshops prior to data analysis aligned with variations of these three patterns. Thus, the researcher opted to define these as the categories for the code set as such prior to data analysis. Each code contains the content that relates to the problems, expectations, and the informant's perception of the topic. This code set was also adopted to classify the information collected during the workshops in each of the cycle's phases (see Table 2).

*2.3.3.1.3 Workshops*

The workshops conducted in this cycle took the form of physical and digital encounters and were classified according to the definition of a workshop presented previously. The participants in the workshops were employees of the Operator and/or other stakeholders involved in the offshore E&P, and the main focus of the workshops in this cycle was on drilling and supply chain operations. Twenty-eight workshops were conducted in this cycle, with 76 individuals participating in at least one workshop and many participating in more than one. Some of these individuals were the same as the selected informants formally interviewed in this cycle, discussed previously. The workshops ranged from three to five hours, with some conducted face-to-face and others conducted digitally via Microsoft Teams software (microsoft.com/en-us/microsoftteams) due to office locations in different cities and travel limitations. The information provided in these workshops was coded using the same code set adopted for the analysis of the interviews. Unlike the formal interviews, however, the workshops were conducted without a formal structure and with a loose agenda to encourage active participation. To foster participation in the workshops, multiple pens, sticky notes, and whiteboards were available for all the physically conducted sections, which is standard in the operator's facilities. A similar approach was adopted in the digitally conducted workshops through the adoption of the Miro software (Miro.com), a cloud-based platform that allows multiple users to create whiteboards and collaborate in sketches and drawings in real-time. The operator provides a licence to all employees, and externals may be allowed access to the whiteboards if access is provided by the whiteboard owner. Examples of these collaborations are shown in Figures B1 and B2 (Appendix B).

*2.3.3.1.4 Operational Process Scanning*

A thorough exploration of the operator's processes and the software was adopted in their execution to understand how the supply chain operations are managed daily. This exploration was conducted through the analysis of two of the organisation's internal tools; specifically, the business management system (BMS) and a workflow definition software used to map processes and applications. All the main data elements that are connected to the organisation's processes, the applications which support the execution of the processes and the reference system for each process are found in these tools. The following sequence was adopted in the collection of information about the organisation supply chain processes: first, the processes not related to supply chain were excluded; then, the remaining processes were separated into the following categories: strategic operations (suppliers, contracts, and area), operational procurement, inventory management, strategic logistics (contracts, long-term planning), operational logistics, and marine operations. The processes related to aviation logistics and manning coordination were excluded because they fall outside the scope of the research. The information retrieved from this step was mostly used to validate the information collected from literature and report review and was provided by the informants during the workshops and interviews, supporting the data triangulation process adopted for research reliability and validity (see Section 2.4.1 for details).

*2.3.3.2 Cycle 2*

The main objectives of Cycle 2 were to identify the desired 'TO-BE' state for E&P supply chain operations. For example, in Cycle 1, each of the phases in the cycle had specific objectives and activity sets that were executed to achieve the phase objectives and the successful completion of each phase contributed to the successful completion of the cycle. The summary of Cycle 2 and its objectives and activities is illustrated in Figure 8.

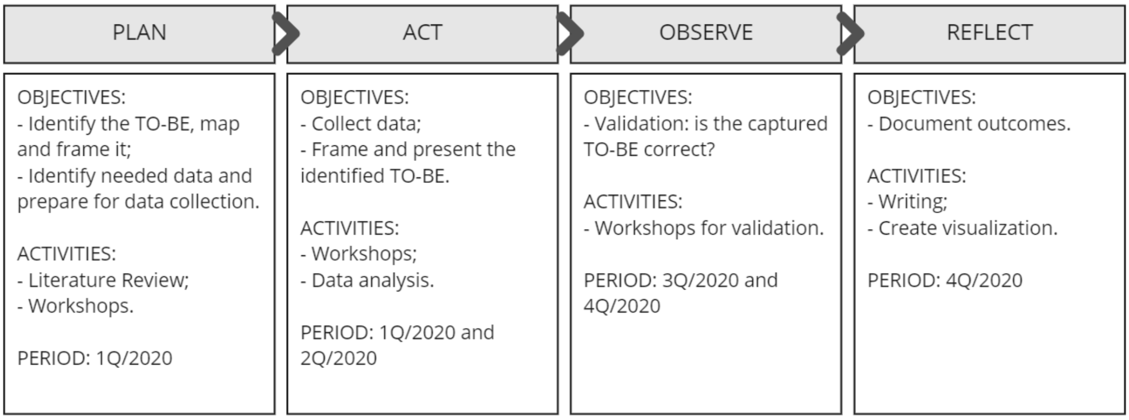


*Figure 8. Details of Cycle 2 Phases*

The main difference between this cycle and the previous one is the number of activities executed during the cycle. In Cycle 2, data were collected through two activities: (a) literature review and (b) workshops where participant observations were logged. As in Cycle 1, the data collected in each activity was analysed at the end of the activity. Additional data were logged in this cycle resulting from the analysis of the interviews conducted in Cycle 1. The cycle details are summarised in Table 5.

*Table 5. Cycle 2 – Detailed Data Collection and Validation Activities (Data Analysis and Documentation Excluded)* (applied to Czachorowski et al., 2021).

| Cycle Stage | Year | Quarter | Nr. of general Interactions | Nr. of Workshops |
|---|---|---|---|---|
| Plan | 2020 | Q1 | 3 | 0 |
| Act | 2020 | Q1 | 40 | 4 |
| Act | 2020 | Q2 | 37 | 3 |
| Observe | 2020 | Q3 | 20 | 1 |
| Observe | 2020 | Q4 | 25 | 3 |
| TOTAL | | | 125 | 11 |

*2.3.3.2.1 Literature Review*

The literature review conducted in this cycle was similar to the one described in Cycle 1.

*2.3.3.2.2 Workshops*

The workshops conducted in Cycle 2 followed the same structure as those conducted in Cycle 1, but most were conducted digitally via Microsoft Teams software due to the physical encounters and travelling restrictions imposed from the first quarter of 2020 by the case company and the Norwegian government to control the COVID-19 pandemic. For this reason, the workshops were slightly reduced in duration, generally lasting no longer than three hours. In this cycle, a total of 11 workshops were conducted, with 47 individuals participating in at least one workshop and many participating in more than one. Most of these individuals also participated in the workshops from Cycle 1, except for four individuals who participated in Cycle 2 but not in Cycle 1. The information provided in these workshops was coded using the same code set adopted in Cycle 1, and the workshops also followed a similar informal approach and loose agenda. Again, the participants were encouraged to actively collaborate in the workshops, which relied on the use of Miro software. Examples of these collaborations are shown in Figures C1 and C2 (Appendix C).

#### *2.3.3.3 Cycle 3*

The main objective of Cycle 3 was to identify and present relevant alternatives for reaching the desired 'TO-BE' and a strategy to the DT necessary to reach it through the confection of a strategic technology roadmap. This cycle had two main activities: (a) literature review and (b) workshops where participant observations were logged, as in Cycle 2. As in both previous cycles, the data collected in each activity were analysed at the end of the activity. The main difference in this cycle was that the workshops were aggregated in domains following the T-Plan process adopted to create the technology roadmap intended for this cycle. More details of this methodology, its application, and results can be found in Sections 2.3.2.3 and 3.3, and in Article 3 in part II of this thesis. The roadmapping process was executed in the 'act' phase, validated in the 'observe' phase, and its final confection was done in the 'reflect' phase. The details of Cycle 3 phases are illustrated in Figure 9, and the summary of the cycle and its activities are presented in Table 6.

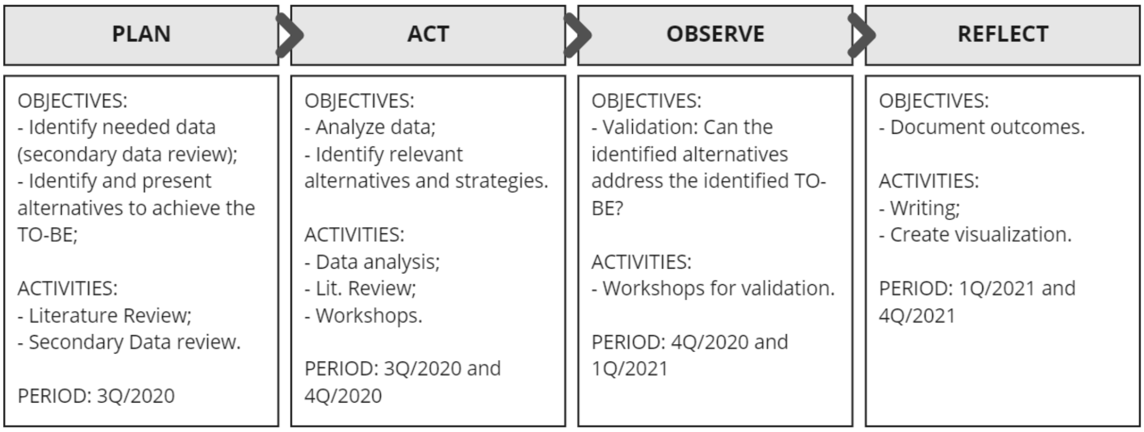


*Figure 9. Details of Cycle 3 Phases*

*Table 6. Cycle 3 – Detailed Data Collection and Validation Activities (Data Analysis and Documentation Excluded)* (applied to Czachorowski & Haskins, 2021).

| Cycle Stage | Year | Quarter | Nr. of general Interactions | Nr. of Workshops |
|---|---|---|---|---|
| Act | 2020 | Q3 | 10 | 1 |
| Act | 2020 | Q4 | 9 | 3 |
| Observe | 2020 | Q4 | 1 | 0 |
| Observe | 2021 | Q1 | 1 | 1 |
| TOTAL | | | 21 | 5 |

*2.3.3.3.1 Literature Review*

The literature review conducted in this cycle was similar to that described in Cycle 1, but an additional review was conducted in the first phase of this cycle by revisiting the data collected in the previous cycles to seek potentially relevant information that was previously collected.

*2.3.3.3.2 Workshops*

The workshops in this cycle were initially thought to be four full-day face-to-face workshops, following the T-Plan methodology adopted in the roadmapping process (Phaal et al., 2001). Nevertheless, due to the restrictions related to the COVID-19 pandemic already faced in Cycle 2, the workshops had to be conducted digitally via Microsoft Teams. Given that full-day digital workshops can be exhaustive and ineffective, the extensions of the workshops were reduced to 3–4 hours, with general interactions when follow-up on information was needed. Still, the number of workshops in this cycle was significantly lower than the previous cycles because much of the necessary information had already been collected in the previous cycles.

Five workshops were conducted in this cycle, with 20 individuals participating in at least one workshop – seven of whom were new to this cycle – and some participating in more than one. The main difference in the workshops in this cycle was that they followed a specific domain, which was used to group the logged information in the roadmapping process. These domains were (1) market, (2) service, (3) technology and (4) roadmap (see Table 7 and Figure 5). The information collected from each workshop was grouped and later summarised by domain in a Miro board using the Miro software. The number of interactions per cycle phase and domain are shown in Table 7, with the number of workshops expressed between parentheses. Examples of these collaborations are shown in Figure D1 (Appendix D). More information about the adoption of the T-Plan methodology can be found in Section 2.3.2.3 and in Part II of this thesis.

*Table 7. Interactions and Workshops (in parenthesis) in Cycle 3 Per Phase and Domain* (Czachorowski & Haskins, 2021).

| | MARKET | SERVICE | TECHNOLOGY | ROADMAP |
|---|---|---|---|---|
| ACT - Q3/20 | 5 (1) | 3 | 3 | 0 |
| ACT - Q4/20 | 0 | 3 (1) | 6 (1) | 3 (1) |
| OBSERVE - Q4/20 | 0 | 0 | 0 | 1 |
| OBSERVE - Q1/21 | 0 | 0 | 0 | 2 (1) |
| Sub-total | 5 (1) | 6 (1) | 9 (1) | 6 (2) |
| Total | | | | 26 (5) |

## 2.4 Research Reliability, Validity and Ethics

This section discusses research validity, reliability, and ethics and how these concepts were addressed in this research. First, validity and reliability are explored, discussed, and explained in relation to this research. Then, the ethical aspects of research are discussed briefly, followed by a discussion of how the ethical considerations were handled in this research.

### 2.4.1 Validity and Reliability

Establishing confidence in the results depends on reaching reliability and validity, which are notions that verify whether research is trustworthy (Denzin & Lincoln, 2011; Lincoln & Guba, 1985). Reliability relates to whether the results of a study are replicable (Bryman, 2012), and validity is the notion that assures quality in the research (Frankfort-Nachmias, 2008; Stenbacka, 2001). Validity can be either internal or external. Internal validity is concerned whether the developed theories from the observations noted during the research are equal or complementary to the collected data and observations themselves, while external validity verifies the level of generalisation that the results reach based on the social settings that the research is inserted (Bryman, 2012; Bryman & Bell, 2015). Validity also has implications for reliability. Reliability is the notion that the results reached in a research are repeatable (Bryman & Bell, 2015), and is also divided into internal and external. Internal reliability verifies the consensus (or lack thereof) among the researchers regarding the collected data and information, while external reliability verifies whether the research can be replicated with the same outcome (Bryman & Bell, 2015). However, qualitative research confronts a difficulty that is to *'freeze a social setting and the circumstances of an initial study to make it replicable'* (Bryman & Bell, 2015, p. 400). Therefore, it can be challenging to replicate qualitative studies because they are not based on a static phenomenon such as quantitative research but dig deeper into networks or 'organisms' that interact, change, and evolve before, during, and after the research, so one scenario is rarely the same as that tested again. Consequently, context is important and once the variables that existed at the time when the research was being conducted are put in perspective, it is possible to compare scenarios and it is very likely that the results to be achieved will be the same, or at least very similar. Finally, the systematic and transparent reporting of methodology also contributes to reliability. Nevertheless, Lincoln and Guba (1985, p. 316) stated that *'since there can be no validity without reliability, a demonstration of the former is sufficient to establish the latter'*, which means that by showing a study as valid, it can also be considered reliable. Patton (2002) supported this notion by stating that the result of a valid research is also considered reliable. Therefore, the reliability of this research is conferred by the demonstration of its validity.

In the present research, validity is reached by executing a triangulation process. According to Creswell and Miller (2000, p. 126), triangulation is *'a validity procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study'*. Many forms of data collection can be used in triangulation, and the process usually involves extensive literature research about the phenomena being researched and the parties involved in the research. The process can help eliminate bias from the data that was collected and help to increase the truthfulness of the research. Therefore, multiple sources contributed to data collection and guarantee research reliability through data triangulation (Frankfort-Nachmias, 2008). In the present research, data triangulation was achieved by collecting data from three main sources: (1) workshops and interviews, (2) online reports by accredited institutions, and (3) scanning of the operator's operational processes (details of each of these steps are provided in Section 2.3.3.1). Additional activities were conducted during the workshops to validate the results of each cycle during the cycle's 'observe' phase. During the workshops, participants were presented with the preliminary results from the cycle and confirmed the researcher's understanding of the 'AS-IS' and 'TO-BE' system states, respectively, derived from the research process. In each cycle, minor corrections were suggested by the participants and ratified by the researcher. The participants in both validation rounds were selected randomly among the participants from the previous data collection phases, depending primarily on their availability to participate in the workshops. The results in Chapter 3 are based on the accumulated information collected in each cycle and despite of the commonalities that can be found between the industry and the results from this research, the results are not intended to portray a generalisation of the practices or activities existing in the industry.

### 2.4.2 Research Ethics

Adopting high ethical standards is fundamental to the conduction of high-quality scientific investigation and the construction of trustworthy knowledge (Chalmers, 2013; Frankfort-Nachmias, 2008). The present research followed the research ethics guidelines provided by two of the Norwegian National Research Ethics Committees, the National Committee for Research Ethics in the Social Sciences and the Humanities (NESH), and the National Committee for Research Ethics in Science and Technology (NENT; both available at www.forskningsetikk.no/en/guidelines). In relation to handling data, additional guidelines provided by USN's library (bibliotek.usn.no/guidelines-for-the-management-of-research-data) and the Norwegian Centre for Research Data (NSD; nsd.no/en) were followed.

In conducting this research, all participations in this research were voluntary, and all participants were informed that the information they disclosed could be disseminated through the publication of the research results, although all data would be anonymised, and no information would be directly quoted or could be potentially linked back to them. Participants were also given the option to inform at any time prior to publication whether there was anything that they no longer wanted to disclose such that it would be excluded from the collected data. This was applied both in the workshops and the recorded interviews. All interviews were recorded following informed consent and the recording files were anonymised for storage and stored under different layers of protection (as explained in Section 2.3.3.1.2). No personal information (name, IP, ID numbers, etc.) was collected from the participants, and no proprietary data from the operator was disclosed in the research and/or the publication of its results. The publications resulting from this research followed the Vancouver Convention rules for co-authorship guidelines (http://www.icmje.org/icmje-recommendations.pdf). All accredited co-authors met these criteria, and acknowledgement was given to those who contributed to the research and publications but whose contribution did not meet the criteria for co-authorship. Finally, all publications disclose that the industrial partner partially funded the research together with the RCN.

# 3 Chapter – Results and Discussion

This chapter presents and discusses the results from this research. For each article, the general results are presented, followed by a discussion thereof. The article limitations are then presented, and suggestions for further research are indicated. Finally, a summary of the implications of each article is provided. The full results and discussions are provided in each article in Part II of this thesis.

## 3.1 Article 1: Results and discussion

The supply chain operations that provide the support to the offshore drilling activities and the inefficiencies in this system were examined in order to identify how they can be addressed. The examination was executed as explained in Sections 2.3.3.1 and 2.3.3.2.

The results from this examination are the identification of the offshore supply chain system as it is (referred to as 'AS-IS'), as it is desired to be (referred to as 'TO-BE') and their schematic presentation. The findings related to 'AS-IS' and 'TO-BE' are discussed in the sequence. Both 'AS-IS' and 'TO-BE' are illustrated by systemigrams that combine the participants in the corresponding system, the key stakeholders and their relationships, and the business context of the operations conducted within the system (Czachorowski et al., 2021). The systemigrams show the flow of task interactions, focusing on supply chain and logistics support operations, and are presented in Figure 10 and Figure 11.

The information leading to the article results were categorised using three codes, each designating the area that the findings relate to. These codes are (I) organisation and culture, (II) operations handling, and (III) technology related. Table 8 and Table 9 summarise the AS-IS and TO-BE-related findings, with each table summarising the major issues and inefficiencies identified and a few quotes from the interview informants related to each code. The informants are identified only with a numerical ID; more details can be found in Section 2.3.3.1.2.

### *'AS-IS' – The current offshore supply chain system structure*

The examination of the 'AS-IS' suggested that the current supply chain operations are inefficient and fragmented into silos within and across the organisation. The management of operations relies on monolithic software with little or no interoperability in the IT support platform, potentially due to the current overengineered processes and monolithic software in the operational setup. Hence, the communication between those managing supply chain and logistics operations and the activities to be executed offshore are poor, which results in critical supply chain information exchange relying on manual work to gather information, emails, and phone calls (Czachorowski et al., 2021).

Finally, exploration, production, and maintenance business units are not interconnected with supply chain operations, which makes their management increasingly complex. As a result, the reliance on supply chain operations in manual interventions incurs overhead costs that are an expensive burden on the organisation's profitability.

This ineffective condition creates challenges and constraints that hamper supply chain efficiency, and they need to be addressed in order to improve efficiency and effectiveness for the operator. The results suggest that the operator understands the magnitude of the limitations of its supply chain operations and has a desire to change it and for a vision to be achieved (Czachorowski et al., 2021). Technology is at the centre of this vision and the operator has pursued numerous initiatives. However, most of these initiatives have focused on drilling productivity and efficiency, and decision making has not essentially been based on a systemic approach, but rather on single interventions within certain areas of the organisation. In addition, some of the stakeholders involved in this change might not have the appropriate level of knowledge or the correct skills to define the necessary tasks to reach the desired results. Therefore, the initiatives have been hindered by the complexity of carrying out a complete organisational DT and possibly by the knowledge and skills gap of the organisational stakeholders (Czachorowski et al., 2021).

These implications show that, unless these gaps are closed, the organisation and industry are unlikely to remove their supply chain inefficiencies and achieve a return on investment from the initiatives that are already in place (Czachorowski et al., 2021). Figure 10 shows the systemigram that illustrates the 'AS-IS' system, while Table 8 summarises the 'AS-IS' related findings.

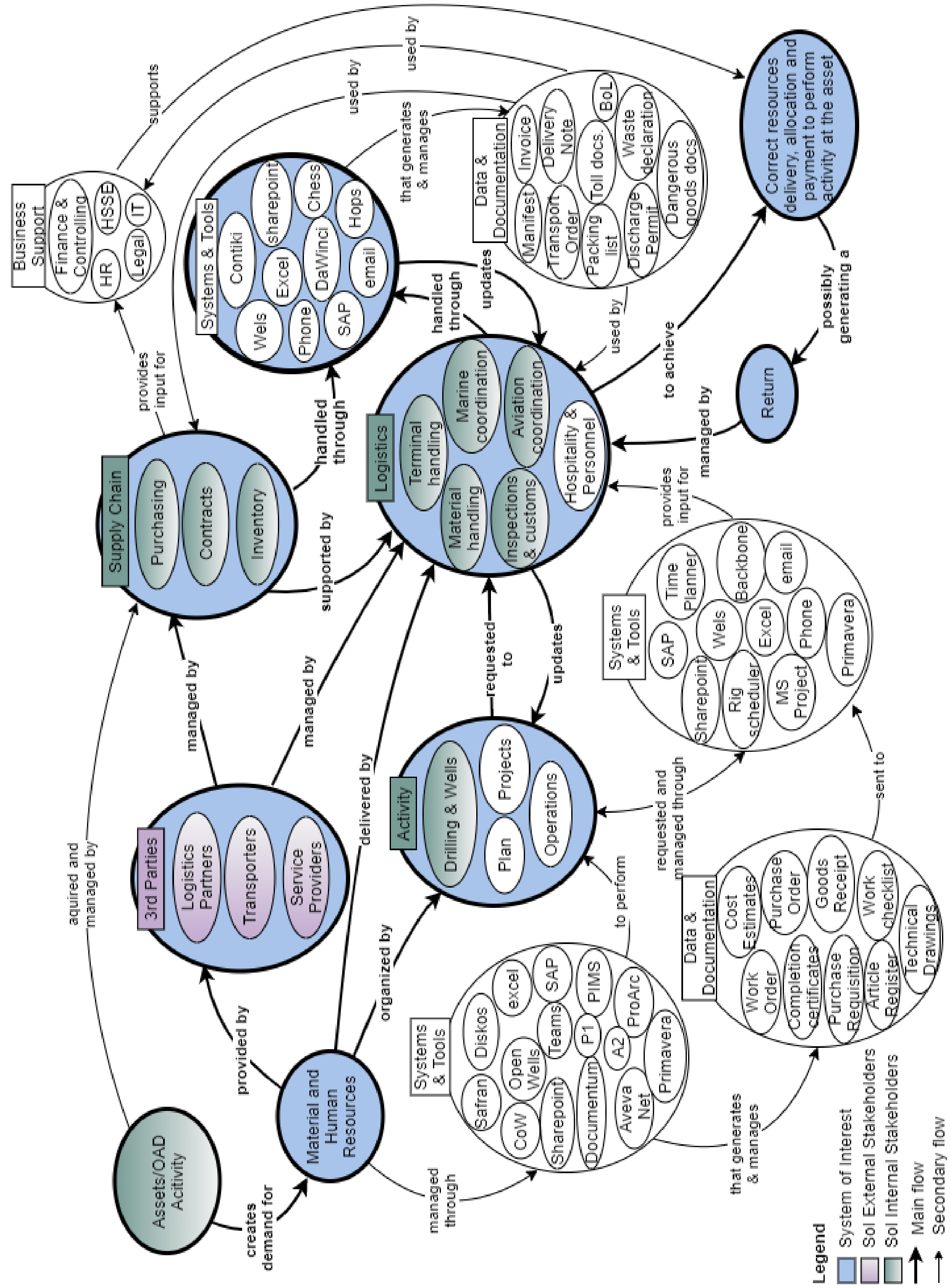


*Figure 10. Documented 'AS-IS' Systemigram* (Czachorowski et al., 2021).

*Table 8. Summary of 'AS-IS' Related Findings* (Czachorowski et al., 2021)

| Code | Major issues and inefficiencies | Quotes from interview informants |
|---|---|---|
| Organisation and culture | • 'Silo-working' mentality/protection.<br>• Transactional orientation vs. partnerships (many suppliers vs. a few strategic ones).<br>• Lack of consensus.<br>• Lack of information sharing, visibility, and collaboration. | 'The oil and gas industry has traditionally been very transactional-oriented. It has had a lot of suppliers and has changed suppliers, always starting with blank sheets.' (I.7)<br>'[Culture is] the biggest challenge with everything [...]people come from different companies, they have different views on what's right and what's not. There's no consensus on what's right and what's not, what's best practice. They don't trust each other, and they don't share information.' (I.8) |
| Operations handling | • Over-engineered processes.<br>• Slow and fragmented decision making/sharing.<br>• Operational bias/different ways of working. | 'It's been more about bringing projects on stream and producing oil, and so you can easily accept inefficiencies in the chain.' (I.7)<br>'The biggest issue in today's value chain is lack of visibility, it's cognitive bias, because everyone has their way of seeing it. […] I think that, the oil and gas business, they overengineer everything, instead of thinking easy. A value chain in oil and gas should and can be easy.' (I.8) |
| Technology related | • Lack of data and software interoperability.<br>• Legacy systems.<br>• Lack of a holistic architecture to support interoperability.<br>• Lack of IT understanding and several different understandings. | 'It's a very traditional transactional-based system, fragmented, a lot of handovers. Not very well integrated, not very efficient.' (I.7)<br>'It's like drawing a house. If you want to build another floor, you need to change something within the foundation. And the architecture hasn't really been well thought through.' (I.8) |

***'TO-BE' – The desired offshore supply chain system structure***

Based on the information provided by the informants, the desired 'TO-BE' is a system that communicates and collaborates based on the timely and seamless exchange of quality-assured data among stakeholders within and across the organisation. Operational data is to be used in the creation of simulations of the whole value chain, and as the trigger to operations in general, including the rationale behind the selection of vendors and other aspects of the supply chain. Supply chain support personnel expressed the desire to become pro-active instead of reactive, creating plans and operations support based on data from the activities occurring in the other parts of the value chain, such as drilling activities. This means utilising data to simulate costs, estimate logistical capacity, and create forecasts that allow streamlining operations to the suppliers involved so they can meet delivery timelines. Planning and activity execution data from offshore drilling activity are the necessary foundations for creating a streamlined supply chain flow that is not driven by lagging purchase orders but by realistic prognosis of activity levels based on data. The same data makes it possible to generate logistics capacity plans that can be used to optimise vessel capacity, voyages, personnel transportation, and offshore accommodation (Czachorowski et al., 2021). These findings were also verified later in the third cycle of this research, and discussed in section 3.3 and Czachorowski & Haskins (2021).

The findings related to the desired 'TO-BE' indicate that it relies heavily on technology adoption and organisational change to support collaboration and high-quality information being shared based on data exchange with minimal manual interference. Almost all of the informants in the study identified this need as a way to increase the quality of the data received and guarantee that all involved in operations can always receive the correct information. Some participants felt that the most important step is improving the software and applications where data is created and consumed, while others highlighted the need for unique identifiers throughout supply chain operations that could increase information visibility. However, it was identified that the participants' understandings of the concepts of data, information and data exchange varied significantly. Some viewed these concepts as cross-company collaboration, while

others saw them in relation to daily operations being conducted in applications and software, and therefore as related to data and software interoperability. Additionally, most of the informants seem to see a strong correlation between data and the application/software they use daily and generally cannot separate them. This impacts those in need of data, as any meaningful discussion of how that data is created, made available, and consumed is usually becomes a discussion about software and the tools and applications that could be adopted in operations. Therefore, it is important to have a clear definition and understanding about what is meant by the used terms and overall objectives, as the lack of a clear and common understanding jeopardises the success of the ongoing initiatives in the organisation and industry (Czachorowski et al., 2021).
The findings show that there is a need to reflect upon how the organisation needs to "*rethink and redesign its supply chain and logistics operations*" (Czachorowski et al., 2021, p.16) and what needs to be done to select and adopt the correct technology to remove inefficiencies in collaboration and streamlining data/information to its stakeholders (Czachorowski et al., 2021). Figure 11 shows the systemigram that illustrates the 'TO-BE' system, while Table 9 summarises the 'TO-BE'-related findings.

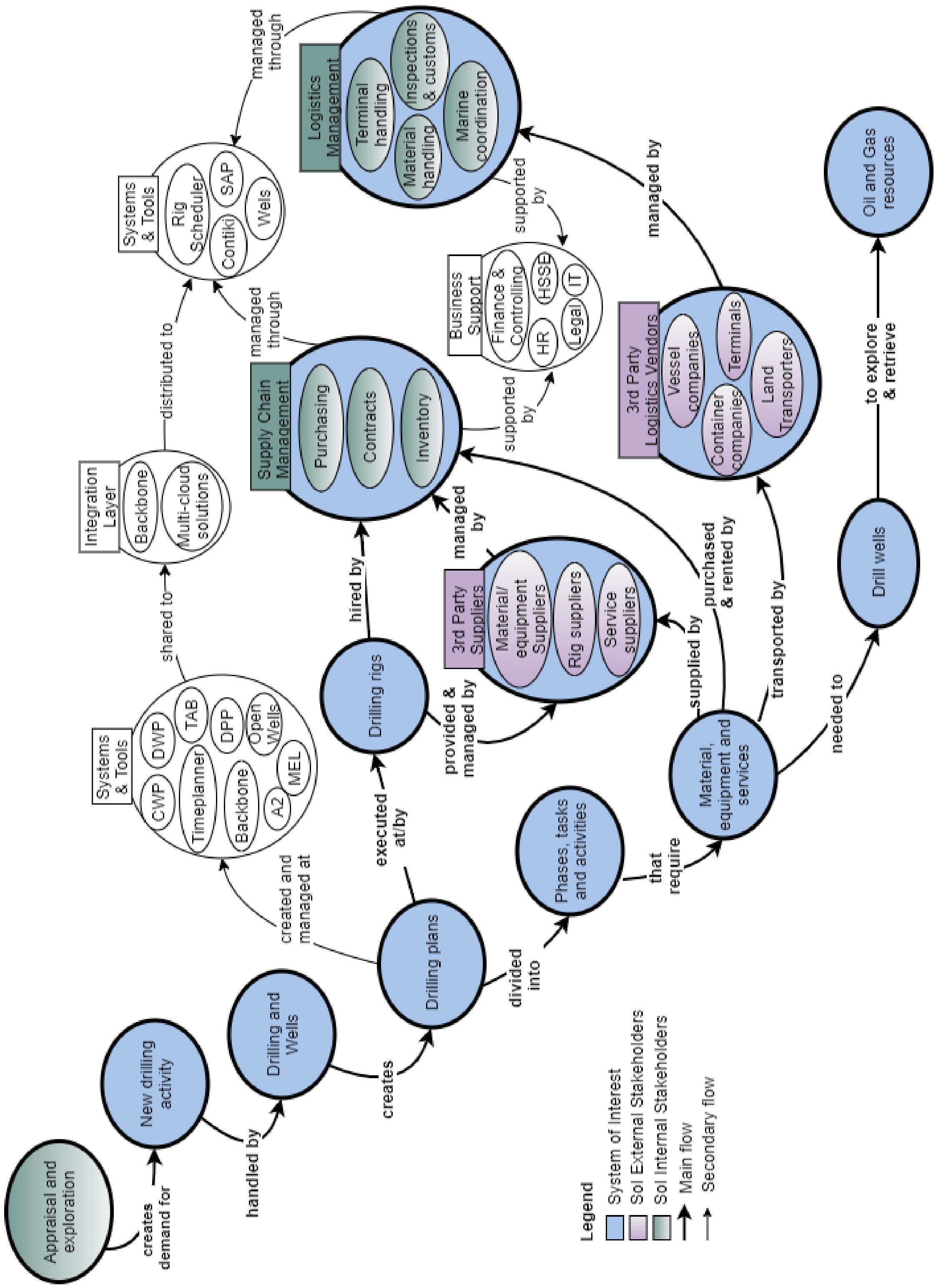


*Figure 11. Documented Desired 'TO-BE' Systemigram for Drilling Operations Supply Chain (Czachorowski et al., 2021).*

*Table 9. Summary of 'TO-BE'-Related Findings* (Czachorowski et al., 2021).

| Code | Major desired aspects | Quotes from interview informants |
|---|---|---|
| Organisation and culture | • Collaboration between operators and suppliers.<br>• New business models. | 'I think a couple of things need to happen. We need to have a longer-term contract with fewer members. Because otherwise these members won't invest in their relationship, necessary technology, and organization to do that. We need to become better at planning. That's partly a dual question, but it's mostly an organization and a culture wash.' (I.2)<br>'One thing is the culture, but it's also the right leaders who understand what we are solving. We also need to understand the big picture and why we want this. People are different.' (I.8) |
| Operations handling | • Higher level of information sharing/less data protection.<br>• Autonomous and semi-autonomous operational handling – focus on exception handling.<br>• Data-centred operations.<br>• Increased analytics and use of data to support decisions.<br>• A hub for sharing data and resources. | 'We want to create an efficient value chain. We know that we are, in a way, the driver of the value chain [...]our ability to have, in a way, a full overview of the activities in our value chain. That's extremely important in order for us to make sure that towards the end we are able to plan, we're able to execute activities according to plan, and we need information from the whole value chain.' (I.1)<br>'The expectation is that if we could have one base, and all the users of one base could use it, meaning the vendors, the transport, the operators... And you could share, [it would] make it easy for the base to handle, too. Instead of several systems, one system for each operator. They could also see all the cargo for all the operators on one day and not separately. So that would be very good.' (I.3)<br>'I'm really into the lean part of it [operations] because that's one of the challenges today. […] We lack the data to identify real improvement potentials, such as just-in-time, making sure we don't have stranded inventory, etc.' (I.4) |

| | | |
|---|---|---|
| Technology related | • Defined IT architecture, software ecosystem and information flow.<br>• Next-gen software and applications: modular and ready for interoperability.<br>• Next-gen technology: digital twin, blockchain, and modern analytics tools (i.e., machine learning). | 'The vision is that we will have a digital twin, having all our assets on the twin will, by itself, in a way, alarm the system, that will say "now/where I need a spare part" and it will initiate the work orders, it will send forecasts, work orders, etc. Initiate an order for procuring an item, and the item will be on the platform in front of the operator together with this job or documentation instructions, etc. At the time it's needed, in a way. And this will be, in a way, done by the system more or less, a hundred percent itself.' (I.7)<br>'[…] so with a smart contract and a blockchain type of framework, you're actually making instantaneous payments. Because now you've got this certificate that says that this item has been delivered and when it's being shipped. You can actually create the mid layer that allows data access without having to care about the specific data system in each vendor. So, you actually have potential to change quite a lot in the industry, both from an infrastructure perspective, from a commercial perspective, and from a routine autonomy type of perspective.' (I.2)<br>'It is necessary to disrupt. You can't just do, kind of, these incremental improvements. You have to look for disruptive technology, disruptive thinking.' (I.6) |

Reaching this long-term solution through the implementation of the 'TO-BE' vision represents a DT in the 'back-office' to strengthen its relationship to the 'front-office'. The research identified and suggested five main areas that need addressing in order for this transformation to occur, presented in Table 10.

*Table 10. Main areas identified and suggestions for transformation* (Czachorowski et al., 2021)

| Main areas | Suggestions and findings |
|---|---|
| Communication and interoperability | The operational silos in which work is conducted and software silos must be dissolved so that communication among business units, processes, software, and stakeholders can be optimised and automated. It is necessary to focus on the notion of the exchange of machine-understandable data so that the manual processes can be automated, and communication improved. |
| Infrastructure investment | There is a pressing need to replace monolithic software with more modern tools that are adequate for the general needs of interoperability and communication. Modern tools with standard application programming interfaces for data exchange and easily configurable data models are key for achieving interoperability. |
| Data vs. software | There is general confusion regarding software and data, denoting a reliance on the software used in daily operations instead of a focus on the data needed to execute the transactions. This misconception needs to be addressed before monolithic software can be replaced with more modern tools and data mapped for this purpose. |
| Knowledge and skill gap | Changing software, tools, data usage, and communication rely on people with the right competency and skills to do so and then personnel with the correct skills to work in an upgraded setting. While the technical aspects of this change can be addressed by hiring specialised companies to develop and implement tools, people in the organisation are the key to accurately defining business requirements and how/which processes must be addressed and changed, if needed. Without addressing the level of skill necessary to understand and execute these tasks effectively, most development and implementation efforts are likely to fail. |
| Organisation and culture | Having the right people to perform the right tasks during development and implementation is dependent on reorganising the available human resources to perform the tasks to be executed, or possibly going to the market to find the right resources with the right competency. Also, successfully adopting new software, tools, and new ways of working means that people must be open to alterations and change, and that they adopt and welcome the transition. Strong resistance may jeopardise the whole transformation. |

## 3.2 Article 2: Results and discussion

The objective of the study presented in this article was to identify, define, classify, and present design elements to be adopted in supply chain operations for promoting BMI in the offshore E&P. As presented in Czachorowski (2021), the study's assumption was that the adoption of the suggested elements in diverse parts of the organisation would help the offshore E&P supply chain and, consequently, help the industry to address the UN's SDG's (see Figure 12 and Table 11).


*Figure 12. Supply Chain Management and Sustainable Development Goals Relationships* (Czachorowski, 2021).

*Table 11. Summary of Potential Contributions to Sustainable Development Goals (Czachorowski, 2021).*

| Sustainable Development Goal Number | Main potential contribution |
|---|---|
| 14 | Minimise the impact of drilling and platform operations. Water and waste management of platforms and vessels |
| 13 | Managing $CO_2$ emissions |
| 12 | More efficient management of inventory leads to better purchasing behaviour and less consumption |
| 9 | Inventory sharing throughout the supply network reduces the production of new items that rely on global natural resources |
| 7 | Less stranded inventory leads to less scrapping, leading to higher savings and potentially reducing the final cost of energy provided. |

The proposed elements were identified through an MA as previously explained in Section 2.3.2.2. Tukker's (2004) business model typology was applied to identify and classify which elements pertain to the classic business models category and which ones pertain to the new business models one. Figure 13 shows the results from the adoption of this framework, divided in three categories: (1) the operator owns and/or manages all parts of its supply chain; (2) the supply chain operations are purchased/offered as a service (that is defined by its use); and (3) the assets and others in operations are shared within the supply chain, towards the outcome of the service (from Czachorowski, 2021, p. 5). The classic business models in the industry are represented in the first category, while the other two categories are related to new business models.

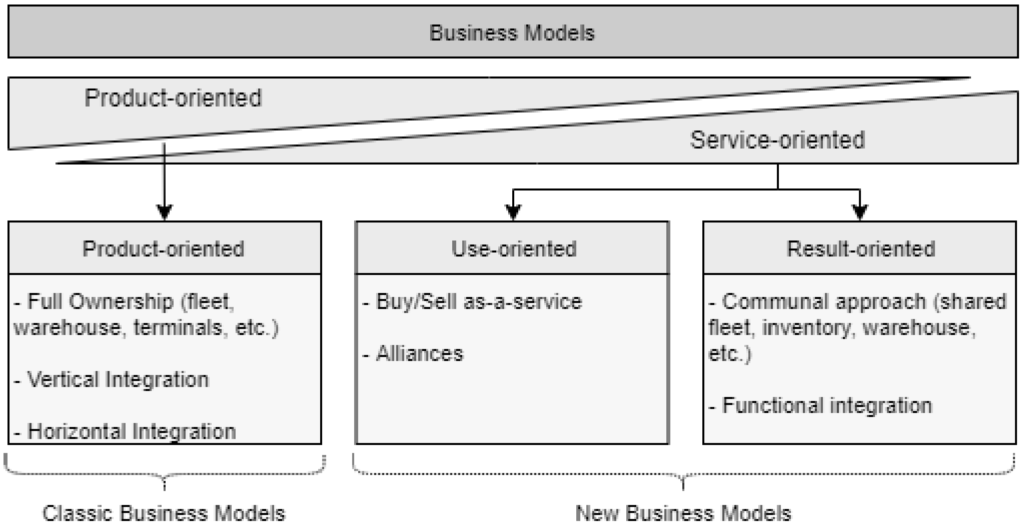


*Figure 13. Tukker's (2004) Typology Applied to the Offshore Exploration and Production Supply Chain (Czachorowski, 2021).*

The identified elements intended for designing BMI were grouped according to a list of predefined characteristics, divided into three categories – (1) technology, (2) organisation, and (3) the human element – adopted from Bocken et al. (2014) to address the sustainability dimension explored in the study (Czachorowski, 2021). Morphological boxes adapted from Kley, Lerch and Dallinger (2011), presented for each of the above categories, were used to present the elements and their characteristics. Each box follows a presentation logic that follows in respect to the infrastructure and organisational changes that are necessary for the adoption of the element(s). In each box, the elements situated towards the left have lower complexity and less changes are needed for their adoption. The elements towards the right-side of the box have higher complexity and require more changes for their adoption. These elements that are situated more to the right in each box are proposed as the final goal for organisations, even though this might not be possible initially due to the complexity of these elements. Therefore, the elements in the left part of the boxes are suggested as temporary solutions during the BMI process (Czachorowski, 2021). The following paragraphs in this thesis bring each morphological box (Figure 14–15), and a summary is presented regarding what each box and its elements signify. Subsequently, a discussion of the elements suggested in the 'new business models' category in light of their value proposition, creation, and capture, and how they address sustainability is provided, based on Czachorowski (2021). Article 2, available in part II of this thesis, provides a complete explanation of each morphological box and its elements, and a complete discussion regarding sustainability, value proposition, creation, and capture.

**Technology-related elements:**

Figure 14 portrays a morphological box with elements and their characteristics in relation to technology and its adoption, application and use in the offshore E&P. The elements are indicated to increase system and data interoperability, which may give a higher automation level, serving as value to the business model if the alternatives are to be adopted. For each level of characteristic, the elements are intended to increase efficiency and stability and resist human errors caused by the automation introduced by the adoption of the elements (Czachorowski, 2021).

| Characteristics | Design Elements | | | |
|---|---|---|---|---|
| Operations handling & software iteration | Manual Operations | Semi-Autonomous | Automated | Intelligent |
| Infrastructure | On-Premise | On-Premise/Cloud | Data Warehouse /Cloud | Cloud |
| Information Flow | Manual / Siloed | Point-to-point integration | Event-based | Orchestrated |
| Communication Flow | Manual (email, phone, etc.) | Semi-automated | Automated | |
| Data Collection | Manual input | Hand-held devices | Sensor-based /Beacons | Sensor/beacon + robots |
| Data Analysis | Manual (excel, etc.) | Historical data + actual | Machine learning and AI | |
| Cash Flow | Limited cost reduction | Reduced/shared costs | Fee-based (service usage) | |

Classic Business Models | New Business Models

Complexity and required level of change

*Figure 14. Morphological Box for Technology-Related Elements of Business Models* (Czachorowski, 2021).

**Organisation-related elements:**

The morphological box in Figure 14 presents design elements for the organisational characteristics and evolves with higher levels of interrelationship from left to right. The elements further to the left in the box are more internal to the organisation, while the elements further to the right of the box have a higher need for collaboration among stakeholders to be adopted and achieved. The organisation-related elements create opportunities for organisations to rethink and change inefficient processes and outsource activities that are not central to the organisation, thus generating value to the adopted business model. This value is extended to the other stakeholders that participate in the value chain as each stakeholder can focus on and innovate their core activities, and reduce operational costs through the elimination of activities that are not core to their operations (Czachorowski, 2021).

| Characteristics | Design Elements | | | |
|---|---|---|---|---|
| Structure | Closed/vertically integrated | Horizontally Integrated | Alliances | Communal |
| Planning Horizon | Short-term | Mid-term | Long-Term | Very Long-term |
| Operational Planning Strategy | Reactive | Proactive | Strategic | |
| Soucing Strategy | High number of suppliers | Few strategic suppliers | Pre-certified suppliers + market bidding | |
| Procuring Invoicing /payment strategy | Manual Purchase order and invoicing | Semi-automated Purchase order and invoicing | Contract/activity triggered – auto Purchase Order and invoicing | |
| Inventory strategy | Owned | Owned + rented | VMI (Vendor Managed Inventory) | Strategic items/parts at the supplier |
| Warehouse / terminal strategy | Owned | Leased/rented | At the supplier | |
| Contract Strategy | Long-term | Spot | Frame-agreement | Strategic / Incentive-based (ex. MLC[1]) |
| Transport Sourcing Strategy | Owned | Long-term rental (FFA) | Spot market and/or Pool | Fully shared (freight-based) |
| Transport Operations | Manual set-up | Pre-established routes/date plan | Activity and cargo based through Algorithm determination | |
| Transport Strategy | Exclusive vessel | Shared vessel (intra-company) | Shared vessel (agreed multi-company) | Freight/deck space based (ex. log. hub) |
| Cash Flow | Limited cost reduction | Reduced/shared costs | Fee-based (service usage) | |

Classic Business Models — New Business Models

Complexity and required level of change

*Figure 15. Morphological Box for Organisation-Related Elements of Business Models* (Czachorowski, 2021).

**Human element-related elements:**

Figure 16 portrays a morphological box with the business model elements suggested for the management of the human element in the offshore E&P. As explained by Czachorowski (2021), the human component in this context is two-fold, being: (1) workers positioned offshore (in offshore structures, such as drilling rigs and platforms), and (2) workers positioned onshore (in offices, handling the planning and coordination of the activities to be executed or in execution offshore). Therefore, both domains must be taken into consideration when evaluating the impact that changes in business models have on humans and their place in the organisation (Czachorowski, 2021). As in the previous morphological boxes, this one also the consequences of adopting the elements far to the left or far to the right are different. While the suggested elements far to the left are more traditional in how they handle the human element, the ones far to the right propose an increase in work specialisation and a reduction of commitment by the human elements to one organisation or specific contract. Thus, the introduction of these elements proposes a change in where and how humans interact and execute their activities in the organisation (Czachorowski, 2021).

| Characteristics | Design Elements | | | |
|---|---|---|---|---|
| Operation Handling | Full Interaction | High interaction | Low interation | No interaction |
| Work Organization | Business Unit-centric | Asset/Platform centric | Alliance centric | Per contract |
| Work Specialization | Low (manual input / workers) | Medium (technicians, business analysts) | High (divers, offshore drilling superintendent) | Very High (drilling engineers) |
| Work Schedule | Fixed hours | Fixed rotation | Flexible/ad-hoc | Activity and/or contract based |
| Work Location | Onshore office | Offshore | Onshore Control centers/terminals | Flexible |
| Contract/ Payment strategy (Cash Flow) | Fixed contract | Temporary contract (short and mid-term) | Flexible/ad-hoc (hourly rates) | Activity based (agreed price for an activity) |

Classic Business Models | New Business Models

Complexity and required level of change

*Figure 16. Morphological Box for Human-Related Elements of Business Models* (Czachorowski, 2021).

The elements in the three morphological boxes presented previously are intended to be adopted as pieces of a business model in organisations, where they can be recombined to create or innovate the business model to suit the organisation's objectives and help address sustainability at different levels of the organisation. The flexibility given by this set-up enables organisations of different types and sizes to implement changes through the adoption of new elements that foster innovation, technology adoption, and the organisational changes that promote a better environment to the humans involved in it. Also, their combination enables the organisation to address sustainability and the SDGs in different ways, without the need for the organisation to adopt traditional SBM archetypes that might not suit the organisation, or for substituting their business model entirely (Czachorowski, 2021). Therefore, if one element is desired but cannot be implemented at once, another one can serve as an interim stage while the organisation makes the transition towards the desired element as the expected end-state. The elements classified under the 'new business models' category are the ones suggested for adoption by the offshore E&P industry in the management of its supply chain operations. It is expected that the adoption of these elements creates an opportunity for the organisation to change how they conduct operations, shifting the conduction of daily activities from manual to automated execution. This change is expected to generate stability in day-to-day activities and their execution, increasing collaboration among stakeholders, information-sharing, and reliability of the information exchanged. This change is expected to generate opportunities for the organisations and stakeholders to remove operational inefficiencies and generate value from their reorganisation and adoption of technology (Czachorowski, 2021). A summary of how the suggested elements address the value proposition, creation, capture, and to the UN's SDGs is presented in Figure 17.

| Value Proposition | Value Creation and Delivery | Value Capture | SDGs |
|---|---|---|---|
| An automation-based, data-based and integrated approach to conducting supply chain operations to upstream oil and gas, deriving a communal approach to asset usage and capacity handling. | Through a communal approach, sharing resources leads to a more efficient resource allocation, decreasing the number of resources needed and their usage to conduct operations. | Cost reduction through better utilization of resources;<br><br>Increased profit/revenue opportunities from selling stranded capacity (e.g. extra space in vessels) | Focus on SDGs #13 (Take urgent action to combat climate change and its impacts) and #14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) |

*Figure 17. Value Proposition, Creation, Capture, and Contribution to Sustainable Development Goals from the Elements Proposed in the 'New Business Models' Category* (Czachorowski, 2021).

## 3.3 Article 3: Results and discussion

The roadmapping process was conducted in the study presented in Article 3 to create a strategic technology roadmap, which was intended as a planning tool to help the Operator achieve the proposed vision and enable the continuous DT of its supply chain operations with a focus on drilling execution. In addition to the workshops conducted during the roadmapping process, the results presented in Articles 1 and 2 were used as a basis for the roadmapping process, providing secondary data and additional context to understand the organisation's goals and to have a clear vision of the desired end-state for operations. Sections 2.3.3.3 and 2.3.2.3 present detailed explanations of the T-plan roadmapping process and the data utilised.

Initially, a thorough investigation of DT and roadmapping literature was executed to understand what drives a successful DT. The results from this investigation indicate that the success of a DT essentially depends on three factors: (I) identifying and adopting the most appropriate technology and digital tools that can support the organisation attaining its goals and vision; (II) transforming operating and business models to guarantee the success in transitioning and adopting these new technologies and tools; and (III) creating an ideal strategy to implement the selected technology and tools and successfully communicating this strategy with the involved stakeholders (Czachorowski & Haskins, 2021).

In the sequence, the investigation conducted through the roadmapping process allowed the identification of the unit of analysis to be used for the roadmap process, resulting in four groups – market, services, components, technology, and resources (Table 12) – based on Phaal and Muller (2009). The full investigation, literature review, and detailed explanation of the units of analysis can be found in Article 3.

*Table 12. Roadmap – Definition of the Units of Analysis* (Czachorowski & Haskins, 2021)

| ID | Type | Description |
|---|---|---|
| M | Market (Internal Well Development and drilling activity Phases – support to Decision Gates (DGs) – from DG0 to DG4) | M1: Appraise & Select (SP) (DG0–DG1) |
| S | Service (Services Provided by Supply Chain to Well Dev.) | M2: Plan and Select Well Concept (SP) (DG1–DG2) |
| C | Components (Applications supporting the services and markets) | M3: Well Design and Execution Plan (P2P) (DG2–DG3) |
| T | Technology (Technology supporting applications and their interconnection) | M4: Execute and Complete Well (P2P) (DG3–DG4) |
| R | Resources (Supporting resources) | S1: Strategic Planning (SP) |

The resulting roadmap (Figure 17) was constructed from the combination and relationship among these units using a systemic and holistic approach. This combination and relationship define the strategy to guide the decision regarding what type of solution is needed and what needs to be developed, implemented, and adopted over time to digitally transform the supply chain operations that the drilling activities successfully (Czachorowski & Haskins, 2021). The summary of the results from the research previous cycles, presented in Articles 1 and 2, guided the logic for the combination of the units of analysis that have been identified previously. A version of Figure 17 contains the name of proprietary and customized digital products recommended to achieve the desired results, but not yet fully approved by the case company.

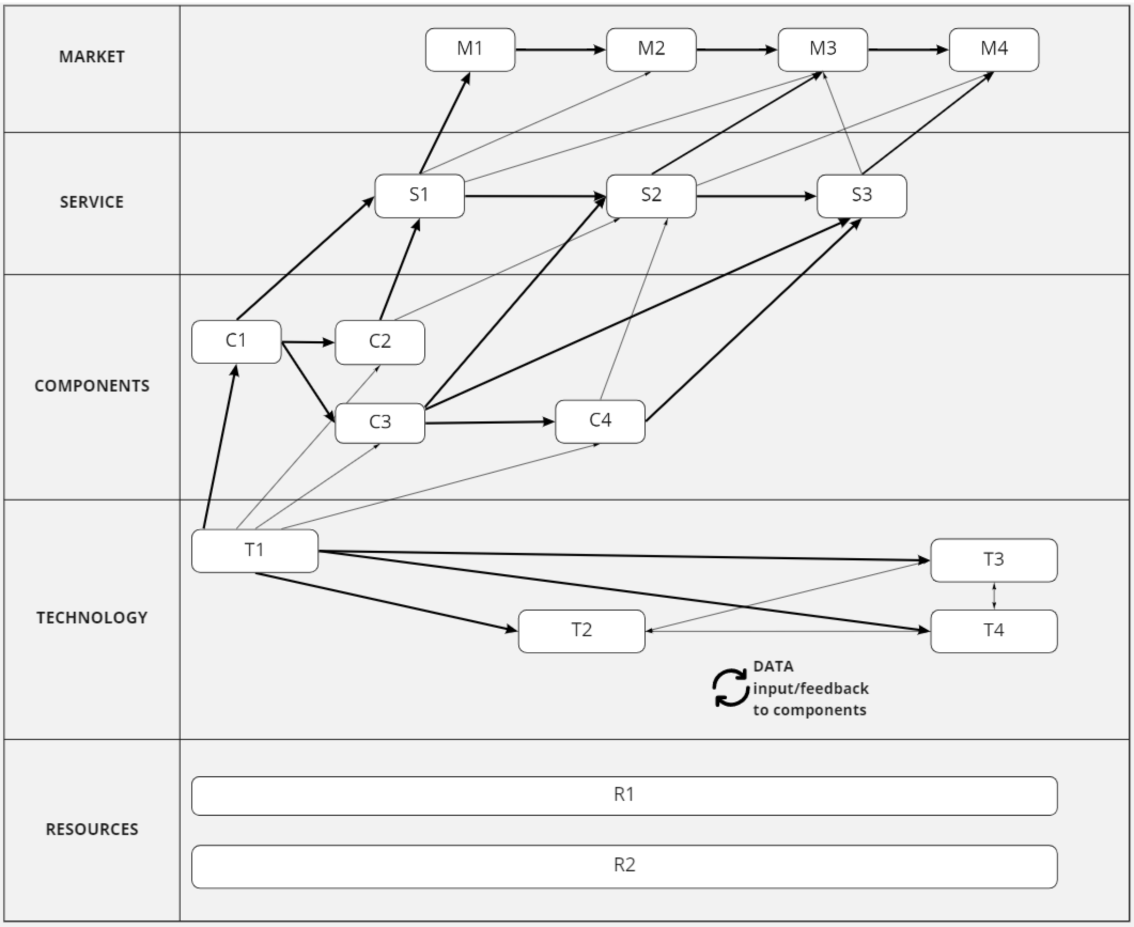


*Figure 18. Strategic Technology Roadmap for Drilling Activities and Supply Chain Support for DT* (Czachorowski & Haskins, 2021). *See table 12 for legend.*

In summary, by following the roadmap, it is expected that a new way of working will emerge where humans involved in the drilling and supply chain activities will no longer need to manually input data into software and applications, with a few exceptions. The data needed for operations would be fed via the consumption and exchange of machine-understandable data (for example, data from scanners, sensors, and other applications), and exchanged automatically via application programming interfaces and hubs. Therefore, data from operations planning and execution would feed and trigger other applications and processes (for example, certain equipment operating at a prespecified threshold triggers an invoice payment) and serve as input to other technologies for visualisation and simulations (such as digital twin and 3D simulations) (Czachorowski & Haskins, 2021). Humans would then work on the analysis of parameters and make decisions based on simulations' results and recommendations if necessary. To define which technology items should be included in the roadmap (the technology units), a set of criteria provided by the operator guided the definition and choice of what technology, and digital tools were selected for the roadmap (Table 13).

*Table 13. Operator's General Architectural Principles (source: E&P Operator)*

| ID | Principles | Description |
|---|---|---|
| 1 | Security by design | Software and integrations are designed to be secure. Compliance with the company's list of security controls is mandatory for all digital solutions based on the data classification they store, transfer or process. |
| 2 | Off-the-shelf/as-a-service | Cloud-based/cloud-agnostic, commercially available off-the-shelf, as-a-service software is preferred for tailor-making. |
| 3 | Right place, time, and quality | Master data ownership and management ensures that data is of the right quality, is distributed from the right source and is available whenever needed. |
| 4 | Interoperability | Data flow in standard formats via standard protocols, in an event-driven fashion whenever possible, to ensure modularity, loose coupling and multi-cloud compatibility. |
| 5 | Convergent evolution | The business domain solution landscape evolves independently but shall adopt common guidelines to adapt to the enterprise-wide ecosystem. |
| 6 | Collaboration | Data is liberated and accessible to all parties that play a role in our ecosystem to allow for a distributed, adaptive, and open environment. |

# 4 Chapter – Conclusions

This chapter presents the conclusions from this research, first returning to the research objective and questions presented in Chapter 1 and then providing the overall conclusions reached from the research. A summary of the research contributions from this research is presented, followed by suggestions for further work, and closing with concluding remarks.

## 4.1 Answers to the Research Objective and Questions

The main objective of this research was to investigate the DT of the offshore E&P supply chain operations support, with emphasis on drilling activities related to well construction. The second objective was to contribute to the success of this DT through the presentation of potential alternatives based on information collected during interviews and workshops, and a strategic roadmap as a guide for their implementation. To reach this objective, a thorough investigation of the operator's operational structure, its goals, and the potential alternatives to reach these goals was conducted, guided by three research questions. The remainder of this subsection provides a general discussion of this research in light of its research questions and research objectives.

***RQ1: What is the current Offshore E&P supply chain structure and what are its challenges to supply chain operations handling?***

SE and soft SE methods and approaches have provided a foundation upon which this research has been designed and executed. The identification of the needs pointed by the stakeholders during the workshops, and the integration of the data collected from these and multiple sources have relied on systems techniques such as systemigrams and other tools for understanding the underlying problems within this organisation and reaching consensus among different perspectives.

The results from this research indicate that the operator's current supply chain operations are fragmented into silos within and across the organisation. Daily supply chain operations are inefficient, and communication is poor between those managing supply chain and logistics, as critical supply chain information exchange relies on manual work to overcome the lack of interoperability in the IT support platform. This may be due to the current overengineered processes and monolithic software in the operational setup. All interactions appearing in the 'AS-IS' operations rely on manual interventions, and the same applies to software – in the supply chain context, all information input to any software is manual, as is the information exchange to other software. Any current data that is generated in any software (for example, transactional data) also relies on a manual interaction to be made available for the next step in the supply chain and is only made available upon request or through established agreements and processes. Therefore, the quality of the data available is jeopardised by the several manual dependencies and interferences made during the execution of the supply chain processes. At the same time, data is not always retrieved from the source where it was generated, which involves a high-maintenance process to reconcile information throughout the many applications that use it. Finally, there is a constant risk of major data breaches, either intentionally or by mistake, just as major operational vulnerabilities exist due to the reliance on people to maintain up-to-date and correct data (Czachorowski & Haskins, 2021; Czachorowski et al., 2021). Czachorowski et al. (2021) summarized the situation by saying that:

> 'In short, information and financial flows are broken and rely on human resources to fill the gaps through manually inputting information in many different software applications throughout the network. The majority of interactions happen via telephone and email with little support from overengineered processes to compensate for the lack of interoperability, resulting in low inventory control and the lack of standardized master data structure, governance, plan structure, and operational forecasts.' (Czachorowski et al., 2021, p. 12)

The consequences of the documented processes are subeffective, risky, and expensive supply chain and logistics operations throughout the whole value chain, with low levels of interoperability. This results in slow responses to events, inefficient allocation of inventory, an inability to take advantage of shorter lead times, and sub-optimal fleet utilisation (Czachorowski et al., 2021). In addition, exploration, production, and maintenance business units are not interconnected and suffer from the same issues. This ineffective arrangement presents challenges and constraints that hinder supply chain efficiency and addressing them is a necessity for any enhancement in effectiveness or efficiency for the operator. The workshops revealed that *"information exchange is a major barrier to operations efficiency, and that this is due to two main factors: (1) the lack of data and software interoperability and (2) the lack of agreement surrounding the way these issues are to be solved"* (Czachorowski et al., 2021, p. 11). In the drilling context, the software installed throughout supply chain operations is mostly monolithic, with low levels of integration. Because different groups manually manage different parts within and between organisations, software-based communication is minimal or non-existent. Consequently, the ability to plan and communicate plans across the network is restricted and directly impacted by this limited access to information across stakeholders.

The collected data exposed three root causes for this situation: (1) the organisational culture for handling operations; (2) the historical lack of urgency to invest in the supply chain operations due to high profit margins from the exploitation activities; leading to (3) the failure to invest in technology for supply chain operations (Czachorowski et al., 2021). The reason behind the first root cause is the traditional ways of working, as working in silos is culturally recognised as the way work has always been fulfilled. Additionally, avoiding interfering or blending into other business units has always been culturally entrenched in operations handling. Concerning the second and third causes, many of the workshop participants and interviewees summarised their views by saying that the industry has been in a positive financial situation that allowed it to overlook the supply chain operations inefficiencies, as investing in drilling and extraction efficiency offered greater returns. This is in line with Forbes-Cable and Liu (2019), who pointed out that despite it being a 'digitalisation laggard', the oil and gas industry is looking to improve as a follow-up action from the downturn in oil prices. Although the operator has been adopting technology at a faster pace than previously, the focus has been on drilling productivity and drilling efficiency, and decision making has not necessarily been based on a systemic approach. As a result, supply chain operations rely on manual interventions and are an expensive overhead burden on the profitability of the firm. These findings are in line with the conclusions published in a report by DNV (2021) that surveyed more than 1,000 oil and gas executives and senior professionals. The results from the survey show that similar challenges are perceived across the industry, such as too many silos, resistance to culture change, and insufficient specialised software. The report also shows that digitalisation is understood as a fundamental factor in improving the oil and gas industry, but that initiatives connected to it are not focused on operational support (that is, the supply chain) despite the problems being acknowledged. Additionally, reports published by KonKraft (2018, 2020), a collaboration arena that promotes competitiveness in the NCS for the Norwegian oil and gas industry, energy, shipowners, and labour associations, suggest that the industry recognises that it needs to improve operations' visibility and efficiency through a higher degree of collaboration within its network to share information, streamline plans, and possibly share assets and resources (transport vessels, loading terminals, etc.).

***RQ2: What is the desired end-state for supply chain operations support with focus on the offshore E&P drilling activities?***

The results from the AR cycles indicate that technology and organisational change is at the centre of the transformation desired for supply chain operations. The Operator's ultimate end-state vision for its supply chain operations consists of a system that works mostly by itself based on automation, software and data interoperability, and data as the trigger to operations. Data is at the centre of this system, being constantly collected from multiple sources (sensors, RFID tags, etc.), exchanged via integrations and platforms through machine-understandable formats (such as JSON), and utilised to trigger operational activities (purchases, payments, etc.), generate simulations and feed digital twins, and generate forecasts and future operational prognoses (Czachorowski & Haskins, 2021; Czachorowski et al., 2021). The availability of data throughout operations is intended to feed digital twins that can simulate scenarios based on the input given by the data being received from operations. This data could potentially be used as parameters that, if tweaked, could indicate the best alternatives to reach certain objectives, such as reducing operational cost in certain areas; choosing the most carbon-effective vessel routes to deliver material offshore (IPIECA, 2019); or simulating operations in case of uncertainties (such as port strikes and lockdowns) and fostering technology-driven initiatives, such as what companies experienced during the COVID-19 pandemic (Schrage, 2020; Stackpole, 2021; Sunil & ManMohan, 2004). Data associated with other technologies are in the desired end-state, such as the intention of using smart contracts or blockchain-type frameworks that could potentially handle financial elements of the supply chain, while maintaining confidentiality, as suggested by Gausdal, Czachorowski, & Solesvik (2018); Johng, Kim, Hill, & Chung (2018); Korpela, Hallikas, & Dahlberg (2017).

In the case company, the vision for operations is that as certain thresholds and parameters are reached, certain financial agreements are triggered, such as invoice payments and operational bonuses. This type of settlement would reduce operational reconciliation that relies on manual input (for example, a person looking for a contract to determine the parameters or conditions that allow an invoice payment to be approved), thus reducing bureaucracy and accelerating financial activity. Based on such infrastructure there is potential for more autonomy which may change many aspects of operations. Finally, forecasts and prognoses constructed from data are to be used as the basis for planning operations at an earlier stage than in the present case and are intended as a first step towards changing existing business models that are based on purchase orders to new ones based on the indication of future needs (Czachorowski & Haskins, 2021; Czachorowski et al., 2021).

The vision of the end-state for supply chain operations expressed by the stakeholders involved in the research addresses different organisation levels, with focus spread into cultural, organisational, operational, and technological elements, in line with De la Boutetière et al. (2018), Everaard (2019) and Forbes-Cable and Liu (2019). In conclusion, the effort needed to recognise the full value of this vision, the 'TO-BE' model, represents a DT in supply chain operations to strengthen its relationship to the areas that it provides support to, especially drilling operations. Nevertheless, this vision may be optimistic due to the lack of a common understanding about what this vision means at different organisation levels, to the different stakeholders, and the implications that this vision has in each part of operations. Therefore, to progress to a successful DT, a more holistic approach is needed in order to evaluate the implications and consequences of the implementation of digital solutions and to create a common understanding among all stakeholders (Czachorowski & Haskins, 2021; Czachorowski et al., 2021).

***RQ3: What alternatives can be adopted and what new technology offers the potential for promoting operational efficiency, sustainability, and the progressive digital transformation of the Offshore E&P supply chain?***

Results from this research indicate that many alternatives, particularly technology and digital solutions, are available that could potentially promote operational efficiency and sustainability and drive the successful DT of the offshore E&P supply chain. Regarding technology and digital solutions, five main areas were identified: (1) interoperability layer, (2) data science and automation, (3) digital twin and simulations, (4) ledger technology (such as blockchain), and (5) traditional IT infrastructure (such as on-premises data centres and servers, and physical components such as computers and screens) (Czachorowski & Haskins, 2021).

The interoperability layer area comprises (a) the management of application programming interfaces and the orchestration of the events that push and pull data across platforms and systems; (b) graph-based and SQL databases that store data; and (c) cloud services that allow access to data anytime, from any location, with reduced costs and added scalability and flexibility. The data science and automation area comprises (a) business intelligence and data analysis capabilities to understand the operational data that has been created and made available; (b) machine learning and artificial learning solutions that can reduce the amount of manual work needed from humans and provide additional insights from data that a human potentially would take too long to notice (such as prevention of accidents, or low inventory levels vs. critical stock reposition); and (c) Internet of Things, including the sensors and beacons needed to capture information. The Internet of Things is particularly interesting for the supply chain because it can promote automation and allow the use of robots (for instance, a container scanned into a terminal or port can trigger the movement of cranes and of inventory robots that will transfer or store the cargo). The third main area, digital twins, is interesting because it allows the visualisation of the entire operations, evidencing the entire system, but also the links within the system, allowing their inspection at many levels of granularity without the need to physically inspect parts of the system. It also provides the possibility of visualising in 3D the mental models that people have when interacting with operations, which can help build additional skill and competence and prevent hazardous situations (Czachorowski & Haskins, 2021).

This greater level of insight from data can also help with sustainability issues. Forecasting operations and simulating them in a digital twin and through the use of the previously mentioned technologies could help find the optimal operational balance for the least environmental impact, as suggested by Czachorowski (2021), IPIECA and IOGP (2020), and Santamarta et al. (2017). For example, the simulation of operations could give insight into how much $CO_2$ will be emitted per BOE, allowing for adjustments in operations specifically for this purpose. The same can be applied to logistics for finding the optimal vessel capacity loading and optimal routes and speed for lower emissions and fuel consumption and the optimal utilisation of equipment, materials, and other items that are either in an inventory or to be purchased, thus reducing the utilisation levels of raw material and equipment that would otherwise be left stranded in a warehouse or scrapped altogether.

Finally, ledger technology, specifically blockchain, could be possible in the future to support supply chains. The enterprise-oriented version of the technology has the potential to assist in reducing bureaucracy related to finance-related items and ownership (such as cargo ownership and immutable payments registered automatically in the ledger upon certain conditions that allow easier and faster audits indicated by Barton, Haapio, Passera and Hazard (2019), El Ioini and Pahl (2018), and Iansiti and Lakhani (2017). However, this technology needs to mature within the providers of the technology so that it can be more easily adopted by general organisations.

Although technology is currently the greatest enabler of many solutions, it does not operate organisations alone. The way technology, tools, and solutions behave dictates processes and operational changes and adaptations that lead to new and improved ways of working and business models, as suggested by De la Boutetière et al. (2018), Harbert (2021), and Parviainen, Tihinen, Kääriäinen and Teppola (2017). Nevertheless, the people involved in these operations must have the knowledge of how these technologies and solutions work and the competence to identify how to apply them in the organisation. It is necessary to have people with the right skills in order to be able to identify which processes can or must be changed and to envision how they can or should function once the technology and solutions are in place. Therefore, digital competency is of the utmost importance, but creating a valuable outcome for the organisation relies on being able to understand the business and organisation in its entirety and, in certain details, to be able to transform it, as suggested by Brown (2021), De la Boutetière et al. (2018), and MIT Center for Digital Business and Capgemini Consulting (2011). Finally, the ability to create and communicate digital strategies is at the centre of successful DTs. It is necessary to explain solutions and their effects in one or more parts of the organisation and towards stakeholders, and to engage stakeholders. Ultimately, DT involves leveraging the desired capabilities in an organisation that the adoption of certain technologies provides so that they create significant and substantial change and impact. This research suggests strategic roadmaps as the alternative to meet this necessity, while also proposing the key role that soft SE has in facilitating the success of DTs.

## 4.2 Summary of Research Contribution

The main contributions from this research are threefold: (1) for the industry, (2) for academia, and (3) for policymaking.

(1) Industrial contributions:

- The research presents a description and visualisation through the adoption of rich-picture techniques of the desired 'TO-BE' supply chain support operations, providing the convergence of ideas and goals of multiple stakeholders into one vision for the Operator that can also be used as a benchmark for other operators. Reaching, defining, and visualising a 'TO-BE' state is a long and time-consuming process, so having such results made available in a methodological sound manner can provide benefits and save resources.
- The research suggests alternatives that can help reach the desired 'TO-BE', with emphasis on innovation and sustainable objectives that the industry must meet.

- The research suggests alternatives that the industry can adopt to innovate its business models in order to help transition to new ways of working.
- The research presents a roadmap derived from the information collected in the operator. This roadmap presents the next steps to be taken to help reach the desired 'TO-BE' vision, including elements that require development focus and prioritisation to help in the success of the operator's DT journey.

(2) Academic contributions:

- The research helps to enrich existing literature and practice by disseminating empirical information from the industry that is mostly new to the existing offshore E&P and the upstream supply chain academic literature.
    - Information about how the industry operates in general is available in academic literature and via reports from research institutions, but detailed information from operators, their goals and what they are doing to reach these goals is not as easily available, and this research provides detailed insights from one large operator in the European market with a strong presence in the NCS. When available, detailed insights from the industry's operators are mostly made available for purchase via research and consultancy institutions and not as open knowledge. In addition, although most research institutions are accredited and trusted, the reports they provide have not followed the scientific rigour that academia requires and are generally published via the institutions themselves and therefore do not undergo scientific peer review.
- This research presents new and different applications of soft SE, helping to enrich its body of knowledge and literature. One application in particular, technology roadmapping, provides a practical contribution to the field, as it offers the hands-on adoption of the methodology in a traditional and engineering-oriented industry, resulting from the application of a scientific process and with peer-reviewed disseminated results.
    - The utilisation of soft SE and SE approaches to develop a customised roadmap can help to create a visually rich strategic tool that can support

unique communication needs. By utilising the techniques made available by these approaches, the information collected from stakeholders can be streamlined into a common message so that the content of the roadmap can be aligned to the requirements of the roadmap's intended audience.

(3) Policymaking:

- The empirical knowledge from the industry revealed through this research may contribute to the creation, verification, and/or validation of policies aimed at the offshore E&P industry. Although the results of this research are not aimed to be generalised to the whole industry, the information revealed in this research is in line with the generalised industry tendencies exposed by the accredited research institutions that were used as sources of data collection in this research. The information revealed through this research gives explicit direction regarding how the operator is positioned in relation to important issues, such as sustainability, and the direction that operations are heading in relation to technology creation and adoption, digital solutions, and technological innovation. Such information can be useful in relation to policies aimed at sustainability and human/work relationships within the E&P industry.

## 4.3 Critical Reflections: Research Journey

The journey of this research started with the investigation of Blockchain adoption in a digital transformation project in the researched organization, following the candidate's personal interest on the topic, which had been explored in the candidate's master's dissertation. The project's initial main aim was to investigate the requirements for Blockchain application to the Maritime Offshore Industry and the consequences of such, verifying the factors that drove to the decision of applying the technology, the outcomes, results, and value creation measurements from the technology application.

However, soon after this research started, the candidate realized that the digital transformation project ongoing in the organisation was much richer, and that a broader investigation could be beneficial not only to the research, but could possibly also lead to discoveries relevant to other industries and academia, coming from an organisation that actively seeks innovation. Therefore, the research was restructured from its initial proposal to the one presented in this thesis. This change was fortuitous because shortly thereafter a blockchain approach was put aside by the organisation as too complex and too dependent on external partners for its success.

As the research progressed, it became clear to the candidate that there were some commonalities in certain aspects of the transformation pursued by the organisation when discussing it with various stakeholders. These were the: (1) focus on data, (2) on automation and the removal/reduction of the human element from operations, and (3) recognition that the efforts required fell under the definition of digital transformation.

(1) The focus on data was noticeably company-wide and strongly enforced and fostered by the top management, which is reflected in the organisation's culture through communications and directions given by middle-management. The aim is to foster a data-driven decision-making culture, where decisions are based on facts rather than experience and 'gut-feelings'. It became clear after some time, however, that the word 'data' has very different meanings and perceptions from person to person, and how this data-focus is pursued in different ways by teams and management direction. To illustrate this case, many individuals refer to data but mean a certain software, creating a lack of clarity regarding data, processes and software, and the inability to define a specific data element. Some clear consequences are perceived from these challenges, such as misunderstandings in relation to what data elements were needed for certain projects and how these data elements were to be made available to those searching for it. Some reflections arise from these situations: (a) the importance of an over-arching plan that narrows the transformation down to an architecture with clear guidelines related to data, its availability, governance (e.g., master data, versioning, etc.) and record keeping (i.e., documentation); (b) the necessity of adopting and stating clear definitions before and during the transformation process to avoid misunderstandings.

(2) The focus on automation and the removal/reduction of the human element from operations was also noticeably present during conversations with various stakeholders during the research. For example, some individuals desired a process

could assist in this automation, which was not a surprise, since the work environment is very dependent on humans to execute operations, and on the good relationships fostered with suppliers, vendors and other partners that participate in the execution of drilling operations activities. At the same time, it was recognized that humans can become a bottleneck to operations for various reasons, such as speed in processing information, availability limitation (e.g., sick leave), and human errors. However, it was noticed that the removal or limitation of the human element and dependency did not necessarily mean removing people but offered the opportunity for relocating people to more meaningful tasks where humans can have a stronger impact and purpose. Therefore, the human element could not be linked to cost reduction necessarily, but instead to the willingness to gain efficiency where machines and technology may help and reduce cost from this change instead. However, it is a question still to be answered whether this shift of position and responsibility related to the human responsibilities and adoption of automation have the effect in efficiency as desired.

(3) Early in this new direction (away from blockchain) the project recognized that the efforts required fell under the definition of digital transformation The effects of DT in the SC network related to the organisation and the effects on the external partners in the organisation's DT is another question still to be answered. Most of the focus surrounding DT is related to the internal aspects of organisations, such as culture, and internal barriers and drivers, but organisations do not operate alone, and value creation can be linked to external partners extensively. The dependency and interrelationships are especially important in SC, so it would be interesting to analyse what are the impacts to the external partners in the network where certain organisations are pursuing a DT – do they need to go through a DT as well? Do their processes also change and possibly become more efficient if that happens with the organisation? If there are no possible gains for these partners, will they be willing to help if needed without any gain for themselves? Therefore, the external influence from the network may become more important in guiding the decisions that the organisation take in order to create value than the internal aspects, as large part of

its success may depend on the ‘success of others’ to succeed itself. The opposite is possibly also true – if the others in the network do not collaborate, the organisation may not succeed to the same level it was expecting to because of this dependency.

## 4.4 Suggestions for Further Work

The main suggestions for further work are summarised as follows:

- Return to the operator within certain periods (one year, two years, etc.) to verify the progress of initiatives, the outcomes achieved, and whether the implemented suggestions and business models’ elements have provided value to the organisation.
    - A comparison of operations at the time of this research and the state at the time of return can possibly be measured both qualitatively and quantitively, such as in terms of cost reduction, level of automation reached at certain parts of operations, level of emissions in logistical operations, and so on by comparing the data collected from this research and future values. This presupposes that baseline measures will be appropriately archived and available for future analysis.
    - Verify whether the existing business models were changed by adopting any of the proposed alternatives and conduct an analysis of what was changed, how and the effects of the change.
- Evaluate the benefits of the suggested strategic technology roadmap proposed in the research to verify whether the assumed benefits were realised and what would be done better and/or differently in the roadmapping process.
- Verify which suggestions were adopted by the operator and apply a quantification method to evaluate the extent of the effect of the adopted suggested alternatives in improving supply chain operations.
- Verify the possible consequences of the DT journey with the external partners in the organisation’s network.

## 4.5 Concluding Remarks

Like a living organism that needs healing to function normally, the offshore E&P industry needs to fix its issues in order to survive the challenges that it faces as the world changes. Climate change dictates the urgency that must be given to adhering to more environmentally friendly ways of operating, showing that paying attention to emissions from operations and optimal use of resources is no longer optional. The urgency revealed by increased global temperatures is leading governments to increase regulations and foster renewable sources of energy that may create competition to the E&P industry. Still, the global energy demand triggered by population needs, such as fuel, heating, electricity, and production of food and other consumables, is too high for renewable sources of energy alone to meet. Therefore, oil and gas are expected to be continuously needed as a source of energy for some time. At the same time, financial factors and demand volatility have created fluctuations in oil and gas prices in the past couple of decades, which has an impact on the industry's profitability in general. This impact is especially high in the E&P industry as the operating costs in this industry are generally higher than in other industries due to the complexity of reaching and exploiting the offshore oil and gas reserves, often due to deep waters, remoteness and isolation of fields, and rough weather conditions. However, the industry must be responsible in terms of how it operates, not only because of regulations or profit but as a participant in society that must contribute to reverse the course of climate change, work toward targets set by the UN SDGs, and responsibly extract and use natural resources.

The Norwegian E&P industry has risen to the challenge in the past few years, with many propositions and initiatives to tackle these challenges, and the case company is an active partner focused on helping to solve these challenges. Nevertheless, solutions for these challenges includes resolving issues that are present in daily operations. Still, many of the proposed and introduced initiatives address parts of operations in isolation or work as patches that provide a quick superficial fix to only parts of the issue and therefore do not resolve the issue entirely or help address the root causes of the industry challenges. It is necessary to think of operations, inspect them, and treat them as a whole system, interconnected within and across stakeholders, which must work together and collaborate in a symbiotic relationship similar to those found in living organisms. Adopting such systemic thinking and approach, this research delved into the case company's operations to look for the causes of the issues and identify what a 'healthy system' looks like. Understanding the current 'AS-IS' was the first step in a diagnosis, and the identification of the desired 'TO-BE' allowed the creation of a vision that illustrates the idea of a healthy system and to identify possible solutions and necessary measures to reach this state. Finally, to connect the current operational state to the vision and provide a guide on how to reach the vision, a strategic technology roadmap was created, intended as the guide to a DT aiming to address the system. Each smaller part of the roadmap is intended to fix one of the system's parts, but the entire system is used as perspective so that each fix works in tandem with the whole. This roadmap was intended to be perceived as the 'lifestyle change' that the industry needs so it will no longer treat problems individually and rather seek a long-term solution.

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# APPENDIX A

**INTERVIEW GUIDE – Winter 2018/Spring 2019**

**Expected overall duration: around 1h.**

**Interview Objectives:** This questionnaire was created following the guidelines presented by Creswell (2009) and Frankfort-Nachmias (2008) with the intent of collecting in-depth information from internal and external stakeholders regarding their understanding and vision of today's "AS-IS" and their expectations of an ideal "TO-BE" supply chain operation support with emphasis on the support provided to the offshore drilling operations. The questions in this questionnaire were constructed to seek answers to the following research questions:

RQ1: What is the current Offshore E&P "AS-IS" supply chain operations support structure and what are its challenges to supply chain operations handling?

RQ2: What is the desired "TO-BE" state for supply chain operations support, with emphasis on the support given to the offshore E&P drilling activities?

RQ3: What alternatives can be adopted, and what new technology offers the potential for promoting operational efficiency, sustainability, and the progressive digital transformation of the offshore E&P supply chain?

**Interview Steps:**

1. **Introduction to interviewees:**
    - **a.** Acknowledge and thank the participants for their time and willingness to participate in the interview.
    - **b.** Present the objectives of the interview and what they can expect from the interview by presenting the structure of the questionnaire (state the number and type of questions).
    - **c.** State the expected overall duration of the interview.
    - **d.** Inform the candidates of the intention of recording the interview and ask for their consent (present written form for signature).
    - **e.** Inform the candidates that they can request that their rights regarding privacy and provided data.
2. **Start the interview.**

**STAKEHOLDERS INTERVIEW GUIDE**

"Ice-breaker" and background information:

1. What is your current position, how long have you been working in the company, and how long have you been working in your current position?
   - Follow-up question for *external* stakeholders: How long have you had a relationship with the operator? And with the operator's Log & SC?

"AS-IS" oriented - overview and issues:

2. What is the relationship that your current position has with SC & Log?
   - Follow-up question: How familiarized/involved are you with the SC & Log operations?
3. How would you categorize/consider the SC & Log operations?
   - Follow-up question: Is there something missing in operations?
4. How familiarized/involved are you with the SC & Log operational issues?
   - Follow-up question: What would you say are the biggest issues?
   - Follow-up question for *external* stakeholders: Does these issues impact your work/your organization? If so, how?
5. Focusing on these issues: why do you think these issues are present today? How did we get here?
6. In your opinion, why have these issues not been solved yet?
   - Follow-up question: and what do you think is needed to solve them?
7. What do you think about the communication among the stakeholders in operations and related to drilling activities?
   - Follow-up question: Are they clear/transparent?
   - Can you trust the information you get from the parties you interact with?
     - Why?
     - Why not?

"TO-BE" oriented - overview and wishes:

8. Do you consider yourself a technology-oriented person?
   - If so, to which extent?
   - If not, why not?
9. What technologies or possible solutions have you heard of that caught your attention in the context of SC & Log?
   - What would you say your understanding of the technology(ies) is(are)?
     - What is your understanding of its (their) purposes?
     - And the consequences of its use/application?
10. How familiarized/involved are you with ongoing initiatives related to technology development/improvement in the company and their goals?
    - Follow-up question: what are your thoughts about them? In your view, what are the reasons behind them? (why are they needed)
11. How do you visualize the daily work in the future after one or more initiatives are implemented?
12. What are your expectations from these digital initiatives?

   - Positive and negative, if any.
13. In your view, how do these initiatives relate to the issues in SC & Log?
   - Follow-up question: are they enough to solve the issues?
   - Follow-up question: what is needed to succeed?
14. Why digital solutions/digital transformation/digitalization?
15. And regarding the non-technological solutions/improvements – are there any and what are your views about these?
16. Any other comments you would like to make?

# APPENDIX B

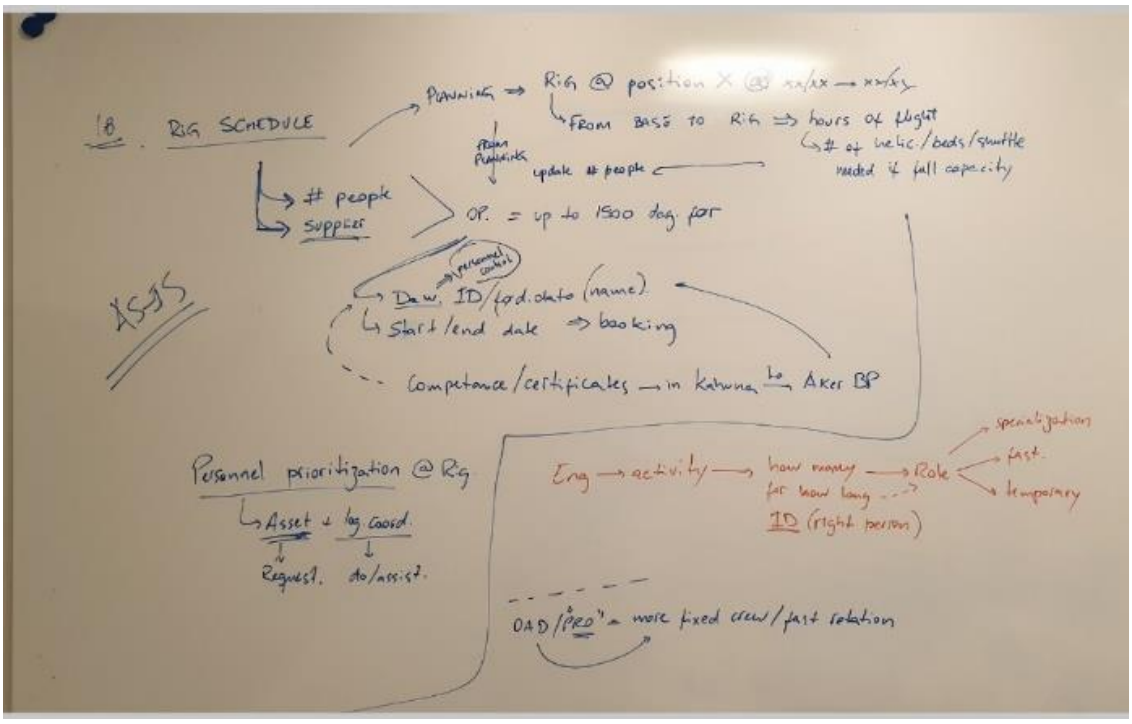


*Figure B1. Example of a physical white board used in cycle 1 workshops (from the operator's facilities)*

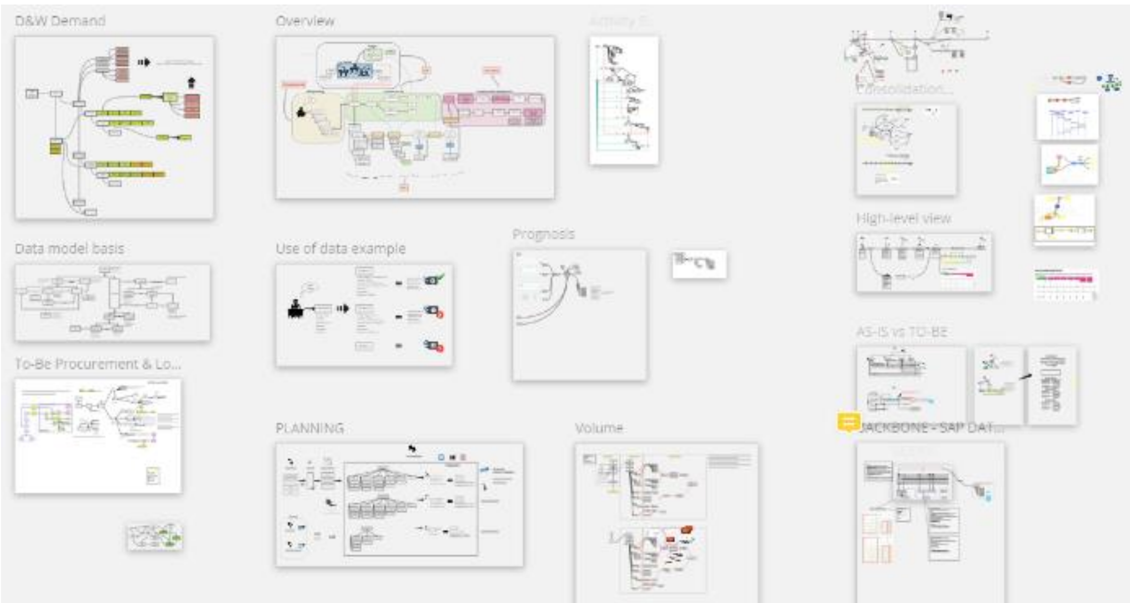


*Figure B2. Example of a virtual board used in cycle 1 workshops (from the operator's Miro account)*

# APPENDIX C

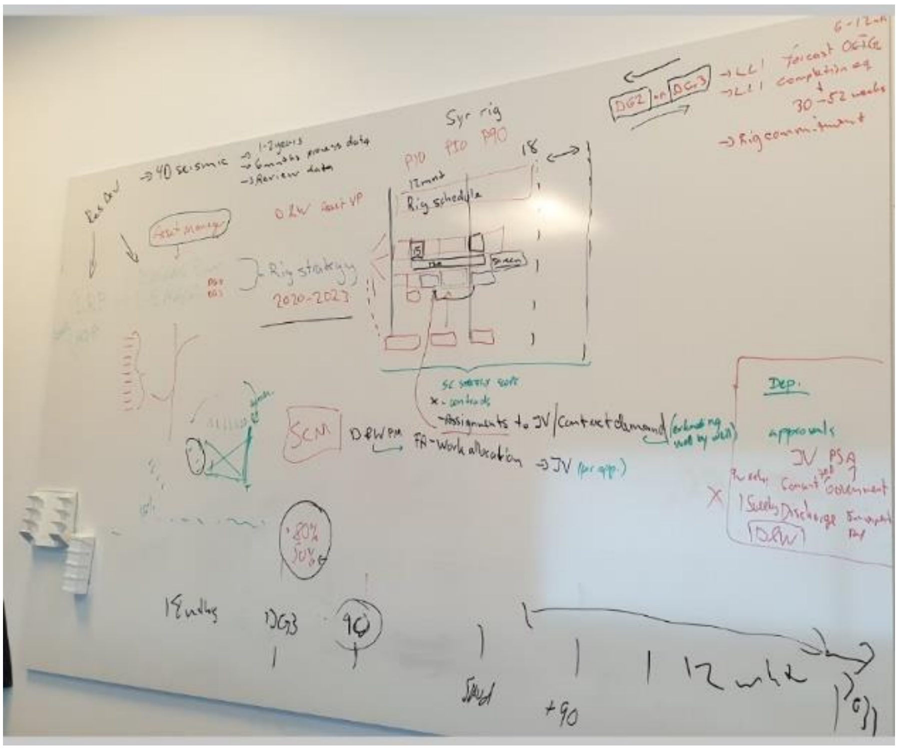


*Figure C1. Example of a physical white board used in cycle 2 workshops (from the operator's facilities)*

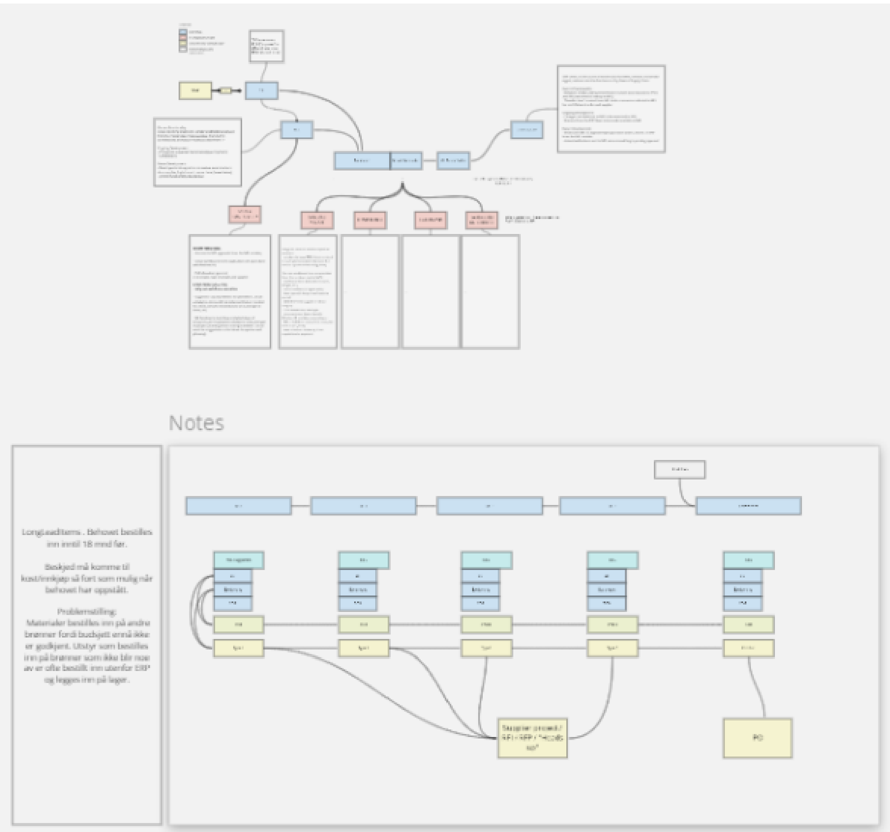


*Figure C2. Example of a virtual board used in cycle 2 workshops (from the operator's Miro account)*

# APPENDIX D

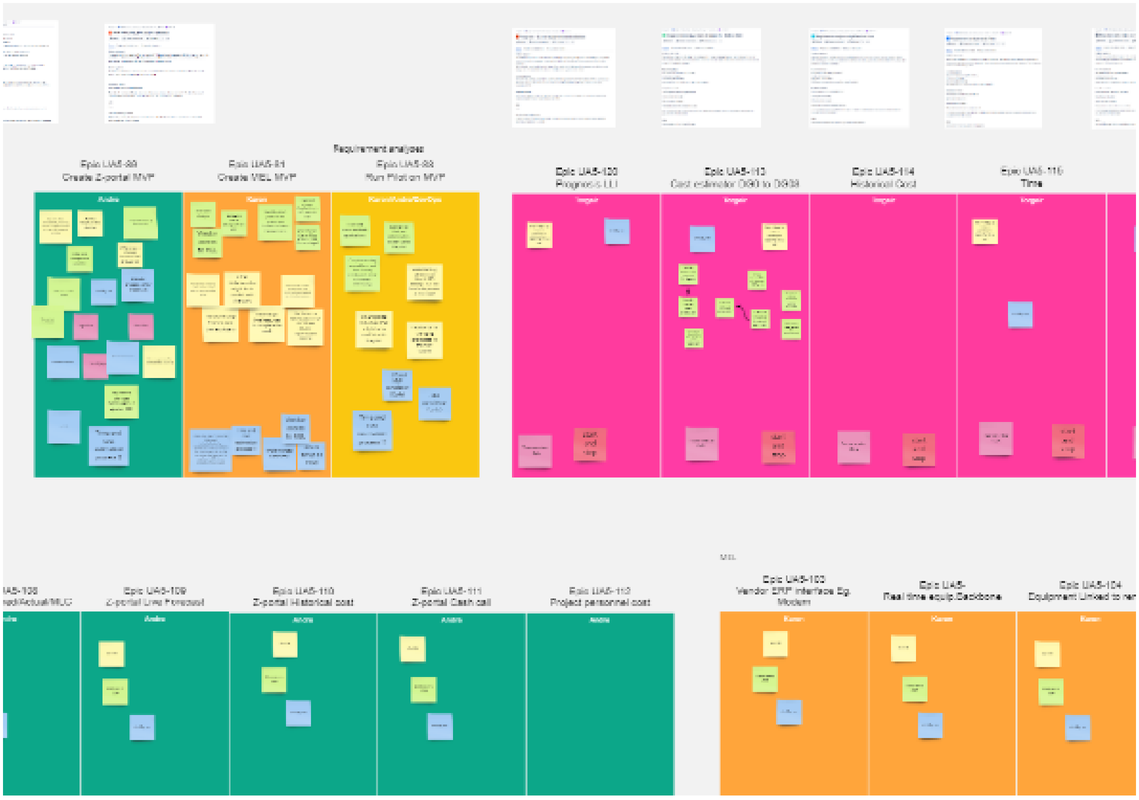

*Figure D1. Example of a virtual board used in cycle 3 workshops (from the operator's Miro account)*

# PART II

# Article 1

Czachorowski, K.V., Haskins, C., Mansouri, M. (2021). Minding the gap between the front and back offices: A systemic analysis of the offshore oil and gas upstream supply chain for framing digital transformation (in review).

Omitted from online edition, not yet published

# Article 2

Czachorowski, Karen V. (2021). Cleaning Up Our Act: Systems Engineering to Promote Business Model Innovation for the Offshore Exploration and Production Supply Chain Operations. Sustainability 13, no. 4: 2113. https://doi.org/10.3390/su13042113

*sustainability*

MDPI

*Article*

# Cleaning Up Our Act: Systems Engineering to Promote Business Model Innovation for the Offshore Exploration and Production Supply Chain Operations

**Karen V. Czachorowski**



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**Abstract:** Oil and gas offshore exploration and production (E & P) will remain necessary to meet increasing global energy demands. However, appraising and exploring these resources has a major impact on sustainability and faces many challenges. Improving the supply chain operations that support E&P activities presents opportunities to contribute to the United Nations (UN) Sustainable Development Goals (SDGs), but relies on organizations being able to adopt new strategies and technology and, innovate their current business models. Business model innovation (BMI) has not been actively pursued in this industry, partially due to the traditional operation management and due to the complexity in changing established models or adopting full-fledged archetypes. Thus, the present study proposes a more flexible and granular approach to BMI by defining elements to be adopted rather than proposing business models archetypes. To define the elements, an application of systems engineering (SE) is adopted through a morphological analysis (MA). They are presented in morphological boxes in three dimensions—technology, organization, and the human element— inspired by sustainable business model (SBM) literature. The elements are proposed as "bricks" for BMI where they can be adopted and re-arranged as necessary, providing granularity and flexibility to facilitate BMI for organizations of varying sizes.

**Keywords:** offshore exploration and production; offshore supply chain operations; business model innovation; sustainable development goals; morphological analysis; systems engineering

**Citation:** Czachorowski, K.V. Cleaning Up Our Act: Systems Engineering to Promote Business Model Innovation for the Offshore Exploration and Production Supply Chain Operations. *Sustainability* **2021**, *13*, 2113. https://doi.org/10.3390/su13042113

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## 1. Introduction

The offshore exploration and production (E & P) industry will persist as a relevant source of energy for many years as the global energy demand continues to increase [1–3] and the renewable sources of energy are not sufficient to suppress the demand within plausible cost and at large scale [3–5]. This industry contributes with resources that generate electricity, heating, and other sub-products that are used as inputs in the fabrication of plastic, rubber, solvents, and many other items [1,5,6]. Additionally, its petroleum subproducts constitute the main source of fuel for almost all transportation modes utilized in the transport of people and goods worldwide [5–7]. However, emissions from burning fossil fuels impact the environment directly, resulting in global warming and climate change [8–11]; also, minimizing the impact of industrial activity lies within the United Nations (UN) Sustainable Development Goals (SDGs), a set of interconnected directions to guide the international community towards a sustainability agenda [10].

Offshore E & P is an industry that plans, builds, and operates offshore structures in the open sea to extract and retrieve resources through the execution of industrial activities that range from the search for oil and gas and its exploration, to transportation to shore and all steps in between [12]. Its value chain is divided into three major groups: upstream, midstream, and downstream. The upstream consists of exploration and production (E & P) activities that involve field appraisal and development, drilling, operations, maintenance,

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and decommission activities. Oil refining is handled midstream, while wholesale, distribution, and marketing are part of the downstream. As a general rule, upstream ends at the extraction of crude oil and its transportation to another destination [8,13]. The present study focuses on the E & P activities conducted offshore. These E & P activities are supported by supply chain operations (hereby called SC) that are conducted by a vast network of suppliers, terminals, vessels, and others operating in an intricate web that involves a large amount of money, hazards, and possible environmental impact [14–16]. Figure 1 shows this relationship. Building and delivering platforms and their parts, materials, equipment, and offshore personnel are challenging tasks that depend on numerous stakeholders that are directly and/or indirectly interrelated and inter-dependent to successfully perform the tasks [1,14,15].

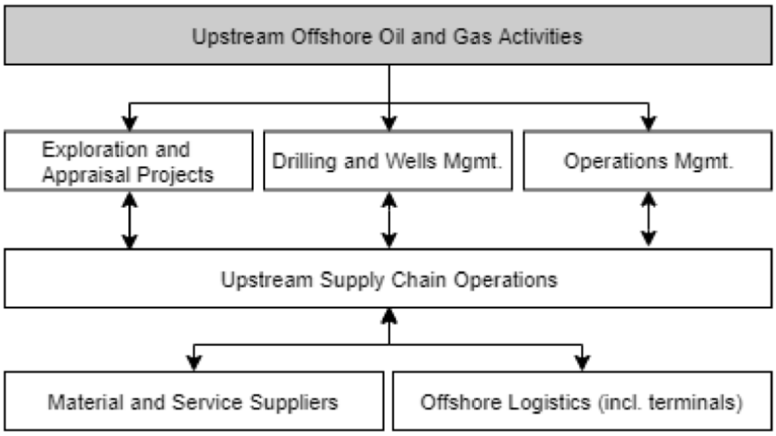



**Figure 1.** Offshore exploration and production (E & P) activities and its supply chain operations support.

Offshore E & P SC operations increased in complexity as the search for resources moved from shore and shallow waters to reach resources in deeper waters and more remote locations with extreme operating conditions [1,8,13]. In turn, the added complexity contributes to additional safety and environmental risks [1,17]; a higher level of environmental impact, such as carbon dioxide ($CO_2$) emission [1,18]; and other concerns that have subjected the industry to strict regulation. Therefore, improving these operations can help the industry achieve its SDGs, as suggested in Figure 2.


**Figure 2.** Supply chain management and Sustainable Development Goals (SDGs) relationships [9].

Despite many initiatives to contribute to SDGs, the industry is failing to meet its goals [4,19], especially $CO_2$ emission reduction [19]. The existing business models are recognized as the reason because traditional organizational frameworks hinder the industry from succeeding in its improvement efforts [20–22]. Instead, many have suggested that business model innovation (BMI) and the adoption of sustainable business models (SBMs) as a solution [23–25]. However, the literature available on BMI techniques seem to disagree in regard to what is the best approach [24,26,27]. In addition, changing, innovating, and adopting new business models may demand a near-complete organizational restructure [26,28,29], which can be challenging for established organizations and a major task for smaller ones. Therefore, a more flexible and granular approach to BMI has also been recommended [26,28].

The present study addresses this recommendation through the identification and proposal of design elements to be adopted in the BMI process instead of creating another business model archetype. Addressing complex structures, such as the offshore E & P SC operations' ecosystem, can benefit from a systematic approach [30,31]. As the industry is already familiar with systems engineering methods, a morphological analysis [32–34] was conducted to identify and define the elements proposed in this study, and Tukker's [35] product–service system framework is applied to identify the classic and the new business models in the industry. The present study's assumption is that, by adopting the identified elements at different levels in the organization, they work to improve the offshore E & P SC operations and thus contribute to the SDGs. The identified elements are examined in morphological boxes, as presented by Kley, Lerch, and Dallinger [36], and are presented in three main dimensions—technology, organization, and the human element—inspired by the SBM archetypes proposed by Bocken, Short, Rana, and Evans [37]. Figure 3 shows the conceptual framework adopted in this study.

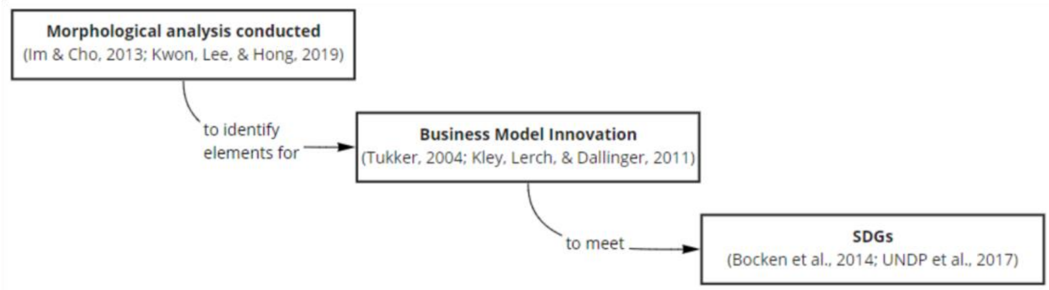



**Figure 3.** Conceptual framework and study contribution: relationship between morphological analysis (MA) and SDGs.

The study then continues as follows. This section continues to present a literature review on business models and BMI in the context of offshore E & P and its supply chain operations. Section 2 presents the morphological analysis conducted; Section 3 presents the identified elements to be adopted for BMI in morphological boxes and discusses their characteristics. Section 4 discusses how the proposed elements related to "new business models" typology can address SDGs and value proposition, creation, and capture in the context of offshore E & P industry. Finally, Section 5 presents conclusions and future research directions.

Business models and business model innovation. Existing business models have been widely discussed, particularly addressing value realization from technology innovation [20, 38,39]. Even though many definitions exist in terms of what a business model is [27], the present study adopts the concept that a business model is a structural tool for companies to operate, manage, assess performance, and innovate their business [37,40,41]. Focusing on technology, Chesbrough [42] argued that there are four functions of a business model: (1) to articulate the value proposition for users, (2) detect a market segment where the technology has a purpose, (3) state the value chain involved in realizing the offering, and (4) evaluate the cost structure and profit potential from the offering(s). Trott [43] complements these definitions by saying that a business model is the framework for an organization to realize profit through the successful creation, marketing, and value delivery to its customer. As such, the business model framework consists of three elements: (1) value proposition, (2) value creation and delivery, and (3) value capture [37,41]. Value proposition concerns the product and/or service offered in order to generate financial return, and which consumer segments are in focus [37,44]. Value creation and delivery concerns the resources utilized to deliver the value proposition, including the performed activities, partners, distribution methods, and technology [37,41]. Finally, value capture concerns how revenue is captured, including cost reductions [37,40,41].

According to Chesbrough [42], beyond describing how an organization works and generates value, these elements present opportunities to capture value from innovation. Zott et al. [27]

affirmed that business models are vehicles for innovation in organizations and subjected to innovation themselves to fulfill that role. Consequently, a business model is not a static framework that an organization must follow, but a transient, dynamic system that must change and adapt so that the organization remains viable and successful in the long term [28,45]. This continuous change process is referred to as business model innovation [28]. Innovating business models go beyond the creation of new products and services. It requires managers to break their cognitive barriers towards going beyond their own or their organization's culture of conservatism and passiveness towards adopting new elements [39,46]. Business model innovation depends on the evaluation of how the business model's components work towards the organization's desired outcome, and a few tools are available to assist this process, such as the business model canvas by Osterwalder and Pigneur [41], the St. Gallen business model navigator [39], and the triple-layered business model canvas [47], which focuses on designing sustainable business models.

The offshore E & P industry has a traditional approach to business models, and disruption of these models requires penetration of a high barrier imposed by conservatism and vested interest [48–50]. Yet, technological advances and regulations are having an effect in fostering the disruption of the traditional business models either by necessity or competitive advantage [50–52]. Many changes in the oil and gas industry occur in response to specific situations, such as low oil prices, and external pressure such as legislation and other regulations [48,50,53]. Thus, in times where challenges are constantly threatening "business as usual", innovation provides opportunities and casts light on possibilities for the industry. Early initiatives proved the possibility of success in changing business models through innovation, such as through coopetition and the creation of joint ventures and alliances [54–56]. A good example comes from the oil and gas industry in Norway, where an alliance allowed Aker BP's, a Norwegian operator, to deliver the Valhall Flank West exploration platform in 14 months and under budget, from the first steel to first oil [57]. This approach to the sharing economy proves that re-thinking how to conduct operations together with suppliers and even competitors can have a long-term positive impact on securing cash flow and stability in low markets, even if profits may be slightly lower. It translates the idea of selling/buying a specific service, rather than managing the whole supply chain. Such innovative initiatives affect business models as they disrupt many parts of the industry. Other innovations include the use of drones for delivery and inspection, robots for performing risky tasks, automation for operational efficiency, 3D printing, etc. [21,22,53]. While not all of these initiatives are fully mature, they show that stakeholders can become cooperative partners with a higher degree of resource sharing to create a service-oriented culture and a communal approach to offshore E & P SC operations. They are also good examples of why and how re-evaluating existing business models is necessary.

## 2. Materials and Methods

The purpose of this study is to define elements that can be adopted for BMI in the offshore E & P SC, identified through a morphological analysis (MA) [32–34,58]. According to Martin [58], a morphological analysis is conducted to perform a systematic classification and assessment of possible combinations of alternatives that can, together, provide a certain function. To identify the elements to be included in the analysis, business models, BMI, SBMs, offshore E & P, and E & P SC literature was examined (collected from databases such as Scopus and Web of Science, among others); and information available from oil and gas related organizations (such as IPIECA and DNV-GL, among others) was collected through publications and reports made available by these organizations.

In the sequence, the identified elements were classified through the application of Tukker's [35] business model typology, which lead to the identification of the elements that belong to classic business models and those that belong to new business models.

Tukker [35] classified a business model by the way it generates value, placing it within a range that starts at value generation mainly from products (tangible) towards value generation from services (intangible). At an operational level, the value generation process moves from being product-oriented towards being use-oriented and result-oriented [35]. Applying this framework (Figure 4) to the offshore E & P industry supply chain results in three main categories: (1) the operator owns and/or manages all parts of its supply chain; (2) the supply chain operations are purchased/offered as a service (defined by its use), and (3) the operations have a communal approach, where assets and others are shared within the supply chain, towards the outcome of the service. The first category represents the classic business models in the industry, whereas the other two range towards new business models.

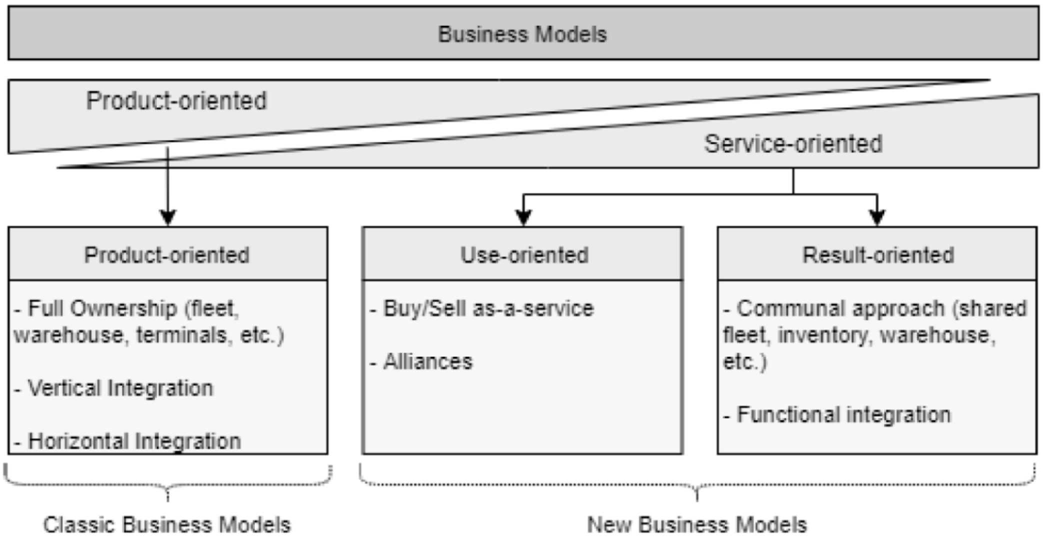



**Figure 4.** Tukker's [35] typology applied to the offshore E & P supply chain (SC).

To present the elements and their characteristics, the concept of morphological boxes is applied, adapted from Kley et al. [36]. Subsequent to a morphological analysis, morphological boxes "represent a creative way to illustrate all the potential solutions to existing problems in a structured format by defining different features with several configurations with regard to a problem" [36] (p. 3395). Figures 5–7 present three morphological boxes with the identified design elements for business model innovation. Addressing sustainability, these elements are presented based on a list of characteristics related to the three dimensions adapted from Bocken, Short, Rana, and Evans [37]; that is, technology (Figure 5), organization (Figure 6), and the human element (Figure 7). Each box follows a logic in its presentation regarding the infrastructure and organizational changes needed for adoption—the elements more to the left are less complex and require the adoption of less extensive changes. On the other hand, the elements more to the right are more complex and thus require more changes. The proposed elements placed most to the right of the morphological boxes are suggested as an ultimate goal for organizations to adopt, although their complexity means it might not be possible for organizations to adopt them at first. For this reason, the other elements situated to their left in the boxes are proposed to be adopted as interim stages during business model innovation. After presenting the elements to each factor, I discuss how the elements classified in the new business models typology address sustainability and their value proposition, creation, and capture.

## 3. Results

### *3.1. Technology-Related Elements: Characteristics and Contributions to SDGs*

The morphological box in Figure 5 presents elements and their characteristics related to technological development and deals with different aspects of technology use and application in the offshore E & P industry. From left to right, the presented elements increase system interoperability, proposing a higher level of automation as a value for a business model if the alternative is to be adopted.

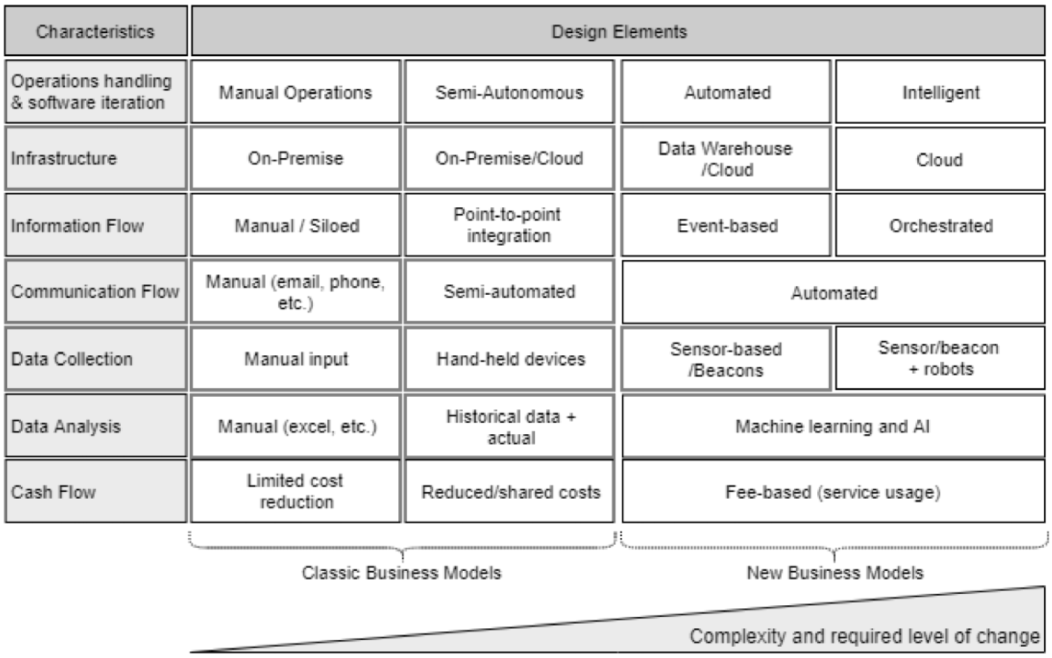



**Figure 5.** Morphological box for technology-related elements of business models (adapted from [36]).

The first row of design elements depicts technology applications to conduct basic operations and the reliance on manual interaction with systems and software. It ranges from operations being conducted manually, where human resources are needed to input, verify, and exchange information and data throughout the software portfolio in order for operations to be fulfilled. On the other extreme of the array, the presented element is understood as an intelligent element, where the data collected from operations using digital technologies are utilized as input for the system to conduct its own operations, based on algorithms and possibly machine learning and artificial intelligence. Manual interaction can still occur, but it is shifted from data input towards data usage for the supervision of operations, higher-level decision-making and operations' reporting indicators. The next characteristic, infrastructure, evolves from left to right to support the level of automation proposed in line with other elements. The same logic applies to the other characteristics and their elements.

The last element, cash flow, proposes how operational cost is reduced by each element as they help diminish the manual interference to daily activities, manual errors, and other potential issues caused by the lack of integration between activity, process, and software. Its first element relates to the possible level of cost cutting when operations are conducted mostly manually, and technology infrastructure and administration is mostly managed in-house. Once the elements evolve towards interoperability and automation, the cost reduction possibilities increase, as operations are not reliant on manual interactions and cost migrates to payment per service usage. The elements presented for each characteristic introduce stability, efficiency, and resistance to human error due to the increased automation levels they proportionate.

### *3.2. Organization-Related Elements: Characteristics and Contributions to SDGs*

Similar to Figure 5, the presented design options for the organizational characteristics (Figure 6) evolve from left to right with higher levels of interrelationship. In this dimension, the further to the left the element is, the more internal it is to the organization and silo based. The further to the right, the higher the level of partnership and collaboration with stakeholders is necessary and achieved. The presented organizational elements offer value to the business model by providing the opportunity for organizations to change processes that are inefficient and outsource activities that are not core to the organization. This also creates value to the other stakeholders in the value chain, as each stakeholder can become more specialized in its functional area, to innovate and reduce cost by eliminating non-core related activities.

| Characteristics | Design Elements | | | |
|---|---|---|---|---|
| Structure | Closed/vertically integrated | Horizontally Integrated | Alliances | Communal |
| Planning Horizon | Short-term | Mid-term | Long-Term | Very Long-term |
| Operational Planning Strategy | Reactive | Proactive | Strategic | |
| Soucing Strategy | High number of suppliers | Few strategic suppliers | Pre-certified suppliers + market bidding | |
| Procuring Invoicing /payment strategy | Manual Purchase order and invoicing | Semi-automated Purchase order and invoicing | Contract/activity triggered – auto Purchase Order and invoicing | |
| Inventory strategy | Owned | Owned + rented | VMI (Vendor Managed Inventory) | Strategic items/parts at the supplier |
| Warehouse / terminal strategy | Owned | Leased/rented | At the supplier | |
| Contract Strategy | Long-term | Spot | Frame-agreement | Strategic / Incentive-based (ex. MLC[1]) |
| Transport Sourcing Strategy | Owned | Long-term rental (FFA) | Spot market and/or Pool | Fully shared (freight-based) |
| Transport Operations | Manual set-up | Pre-established routes/date plan | Activity and cargo based through Algorithm determination | |
| Transport Strategy | Exclusive vessel | Shared vessel (intra-company) | Shared vessel (agreed multi-company) | Freight/deck space based (ex. log. hub) |
| Cash Flow | Limited cost reduction | Reduced/shared costs | Fee-based (service usage) | |

Classic Business Models (first two design-element columns) — New Business Models (last two design-element columns)

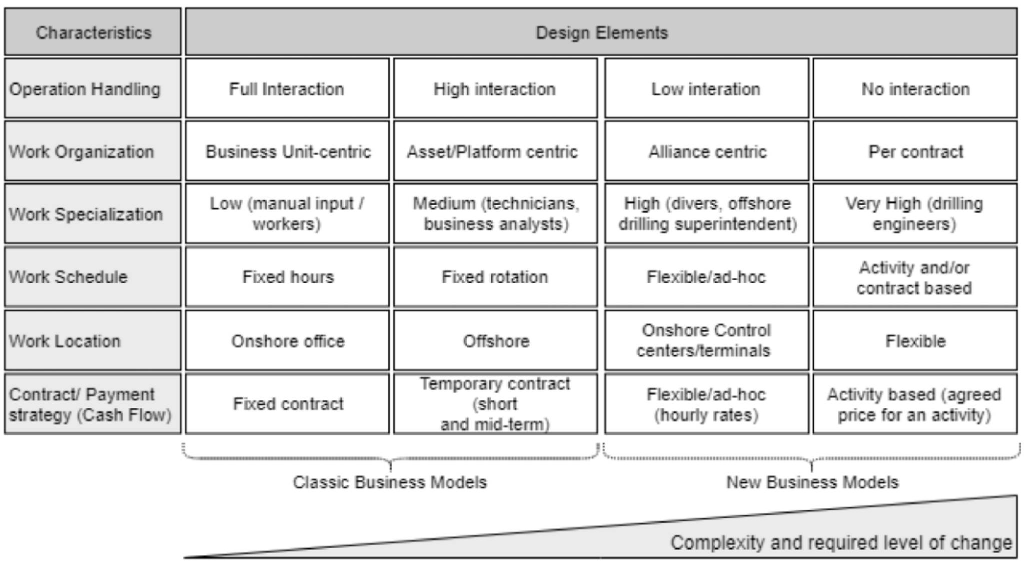
Complexity and required level of change

**Figure 6.** Morphological box for organization-related elements of business models (adapted from [36]).

The first characteristic in Figure 6 specifies the organizational structure of the offshore E & P SC, ranging from closer operations handling within the operator (owned vessels, warehouses, etc.) towards partnerships, alliances (strategic suppliers are preferred) and sharing assets and other resources. For example, if the structure consists of alliances involving strategic suppliers, the sourcing strategy will consist of selecting these suppliers that already have certifications and contracts relevant to the operations to be conducted. This logic also applies to the invoicing and payment strategy to be adopted, as well as to the inventory, warehouse/terminal, contract, and transport sourcing ones. Accordingly, the operational planning strategy is replicated through the organizational structure adopted. Following the same example, if the suppliers involved are pre-selected and certified through supply chain processes by the business units responsible for that process, a longer activity span can be planned towards that partnership/alliance, which provides a longer-term planning range. This directly impacts operations, as a longer planning range produces visibility and better resource allocation. Transport, operations, and sourcing strategies are also interrelated and highly dependent on the structure adopted. Continuing to follow the above example, a fewer number of selected suppliers participate in the majority of operations, which makes it possible to share a higher level of information and data within the network that can be used for operations optimization and cargo allocation, reducing the manual input to handle operations. Therefore, data from operations becomes the trigger and input towards reserving space and capacity for sourcing transport (that is, transporting something from A to B for a fee) and handling transportation resource sourcing (that is, the number of vessels needed to deliver items related to an activity). The way in which these elements are combined and selected directly impacts the value capture element proposed—cash flow. If the operational elements adopted relate to a closed structure, the cost reduction opportunities are limited as there is lower flexibility in terms of pooling suppliers and negotiation. On the other side of the array, costs are related to the used services, depending on operational optimization and resource usage.

### *3.3. Human Element-Related Elements: Characteristics and Contributions to SDGs*

In the offshore E & P SC context, the human element is two-fold, consisting of (1) the people working on the offshore platforms, drilling rigs and FPSOs (floating production storage and offloading), and (2) the people working onshore planning and executing commands towards the operations execution. Hence, both aspects need to be considered when evaluating the impact on the human element and its place in the organizational structure and business model. The morphological box in Figure 7 presents business model elements related to the management of the human element.



| Characteristics | Design Elements | | | |
|---|---|---|---|---|
| Operation Handling | Full Interaction | High interaction | Low interation | No interaction |
| Work Organization | Business Unit-centric | Asset/Platform centric | Alliance centric | Per contract |
| Work Specialization | Low (manual input / workers) | Medium (technicians, business analysts) | High (divers, offshore drilling superintendent) | Very High (drilling engineers) |
| Work Schedule | Fixed hours | Fixed rotation | Flexible/ad-hoc | Activity and/or contract based |
| Work Location | Onshore office | Offshore | Onshore Control centers/terminals | Flexible |
| Contract/ Payment strategy (Cash Flow) | Fixed contract | Temporary contract (short and mid-term) | Flexible/ad-hoc (hourly rates) | Activity based (agreed price for an activity) |



**Figure 7.** Morphological box for human-related elements of business models (adapted from [36]).

The proposed human-related elements related to operations handling, work organization, specialization, and schedule can nearly or completely eliminate the human involvement in supply chain operations. However, this is not necessarily the intention. The idea is that these elements change how and where humans interact and fulfill activities in the organizations. Hence, when related to humans directly, the presented elements show increased specialization and reduced commitment to one specific contract/organization from left to right in Figure 7. This creates value to organizations by being able to work with highly skilled professionals without worrying about talent retention. However, this does not mean that the link to the organization should be weaker; it simply provides the organization and the professionals with the opportunity to work with multiple parties if they want, and gives flexibility to the professionals to elect the best possible places to work, addressed by the work schedule and location elements. This allows organizations to reduce personnel costs as they will not have to maintain several idle people that do not have constant activity in the company simply to avoid missing the skilled professional to another organization, addressed by the contract/payment strategy element.

## 4. Discussion

There are many ways in which the offshore E & P industry can contribute to the

SDGs [9], although most efforts are directed to minimizing the impact of drilling and platform operations [1,9,19], such as water and waste management [1,59], and managing $CO_2$ emissions [1,3,60]. However, many opportunities exist in the management of the supply chain operations conducted to support the upstream activities.

In the offshore E & P industry, the supply chain is a complex "ecosystem" that includes many internal and external stakeholders that must comply with many different legislations and overcome many challenges. The SC operations are conducted by specialized suppliers, supply bases, terminals and warehouses (referred to hereafter as support companies) that provide vessels, transportation and storage, manning, and other services, usually managed by the operator hiring them [14,61,62]. The vessels involved in the offshore E & P SC to complete these activities are major contributors to $CO_2$ emissions in the offshore E & P industry [1] and most sustainable initiatives in this context are linked to the reduction of $CO_2$ emission from the vessels utilized in transportation, optimal vessel and route allocation, vessel fuel usage, and route optimization for transportation [14,63,64]. Lately, the adoption of technology for this purpose has been widely discussed, such as the implementation of 3D printing of spare parts for local supply to avoid transportation; and the adoption of Blockchain, Internet of Things (IoT), and digital twins for supply chain transparency [19,65,66]. For vessel and deck space optimization, the adoption of big data analytics and machine learning/artificial intelligence has been widely discussed [67–69].

However, there are many other ways in which supply chain operations can improve to contribute to SDGs, such as a more efficient management of inventory to increase inventory usage and reduce new parts purchasing, reducing double-purchases, fostering inventory sharing throughout the supply network, and other initiatives that could be adopted to reduce the production of new items that rely on global natural resources [4,70,71]. A more collaborative approach to supply chain handling can also provide results; instead of each operator managing their own vessels, these can be pooled to promote sharing vessel deck transportation capacity, leading to a better vessel capacity allocation and an overall reduction in the number of vessels and vessel voyages required to transport cargo [4,70,72]. Table 1 summarizes potential areas of change that would effectively contribute to meeting SDGs.

**Table 1.** Summary of potential contribution to SDGs.

| SDG Number | Main Potential Contribution |
|---|---|
| SDG 14 | Minimize the impact of drilling and platform operations; water and waste management in platforms and vessels |
| SDG 13 | Managing $CO_2$ emission |
| SDG 12 | More efficient management of inventory leads to better purchasing behavior and less consumption |
| SDG 9 | Inventory sharing throughout the supply network reduces the production of new items that rely on global natural resources |
| SDG 7 | Less stranded inventory leads to less scrapping, leading to higher savings and potentially reducing the final cost of energy provided. |

Therefore, a more flexible and granular approach to setting and meeting goals toward SDGs is suggested for designing business models that can support innovation, technology adoption, and other changes without having to restructure the whole business model and/or organization. The objective of the present study is to present elements that can be more easily adopted and replaced as wished by organizations to create new business models. Systems engineering methods are ideal to support this objective as they promote a systematic approach to solving an array of complex issues in systems present in several domains. The SE method adopted in this study—morphological analysis—provides this systematic approach and supports non-quantified modeling that allows an in-depth analytical exploration to solve a complex issue [30,31,73]. Specifically, the present study used SE methods to identify and propose design elements for BMI. The resulting elements presented function as "construction bricks" that, once combined, allow the creation/innovation of a business model that fits the organizations' objectives and addresses sustainability at the same time at different intra- and inter-organizational levels. This flexibility enables organizations of different types and sizes to implement design elements that address sustainability without having to replace their entire existing business model or implement traditional sustainable business model archetypes. Therefore, if one desired element cannot be implemented initially, another one can be utilized instead as an interim state, while the desired element works as a final goal. Beyond sustainability, the elements are proposed to foster technology adoption where it is needed, organizational innovation and collaboration as value creation. These elements are presented according to Tukker's [35] typology, categorized as "classic business models" and "new business models". The elements included in the latter are suggested for the offshore E & P industry to adopt to manage its supply chain operations. Once combined, these elements address SDGs in different ways, and their recombination by the organizations can be re-adjusted to meet organization's strategies and purpose. How these elements address business models' value proposition, creation, and capture and contribute to the SDGs is summarized in Figure 7 and discussed in the sequence.

*4.1. Value Proposition*

The elements value proposition is to offer the integration of offshore E & P SC operations through suitable technology to allow the stakeholders to reach a communal approach to operations handling. By integrating operations, operators and other stakeholders can make better usage of their own operational data, which provides insight regarding the items to be purchased and transported and the services needed. Consolidating this demand through data collection and predictive analysis provides opportunities for the support companies to adjust their fleet according to the demand and forecast with a higher accuracy, which, in turn, allows the support companies to adjust the level of service to the capacity needed. Thus, vessels and other resources can be pooled and shared instead of each operator renting its own. The proposed elements also address the interconnection among vessels, ports/terminals, platforms, other stakeholders and the human element in the industry. This is essential to prepare the industry for implementing innovation and other technological developments such as autonomous vessels, cranes, ports, etc. These are in constant evolution but cannot be adopted if the industry is not ready to adapt. The autonomous assets must be able to intercommunicate to work beyond their technical aspects—an autonomous vessel still needs to dock, just like an autonomous crane still needs to know what it will lift, from where, and where to place the cargo. However, manual interference is not the solution, as machines must be interoperable through machine understandable languages. Hence, the automated and "intelligent" elements in this category define the solutions offered and the stakeholders involved towards operations' completion.

*4.2. Value Creation*

The elements create value creation through the adoption of automation and intelligent elements to promote a more efficient handling of the supply chain operations and to allow supply chain partners to offer a better service to its customers. Re-thinking how the stakeholders collaborate, communicate, and work is a necessity not only for the stakeholders themselves, but also for the industry to incorporate and benefit from the innovations brought from technological advances being presented to address efficiency, safety and environmental concerns. Even though the elements emphasize integration and automation, people are not eliminated from the system. People have unique characteristics, such as creativity, negotiation, and problem-solving, that extend beyond what was coded into a software for conducting operational tasks. However, people are being used as a cog in the system, whereas they should be placed where interpersonal skills are needed the most, leaving the machines to do what they do best and enabling people to do what they do best: create, develop, and innovate. Hence, technology is part of this change, and technological efforts to digitalize the synergies among the network participants are needed for them to work together. Similarly, it is just as necessary for the offshore E & P domains to extend their willingness for technology to go beyond machines and engineering to reach supply chain operations, so that innovative ways of working can be developed and implemented, thus creating value throughout the organization's value chain.

### *4.3. Value Capture*

The elements capture value by reducing costs and waste through better utilization of resources, such as fleet, vessels, inventory, personnel, etc. This promotes operational efficiency and reduces operational costs, increasing revenue and additional profit opportunities for organizations. Using inventory as an example: better inventory visibility enables a more efficient management of inventory and purchasing, which enables the use of the available items instead of unnecessary double-spending for "emergency" purposes, thus reducing the overall quantity of general and unused inventory. With less stranded inventory, less scrapping is executed, and more money and taxes are saved and made available to be used elsewhere, potentially reducing the final cost of energy provided.

### *4.4. SDGs*

The "new business models'" elements address SDGs by changing how work is conducted, as summarized in Figure 8. This shift from manual work to automation reduces human interactions in operations, resulting in fewer error opportunities that could lead to accidents, thus enhancing safety in offshore logistics operations. Together with automation, increased collaboration allows streamlining planning and provides operational synchrony. This results in better use of resources such as vessels, leading to a higher level of vessel deck capacity usage and a reduced number of voyages from and to the offshore platforms, contributing to safety and addressing environmental concerns due to reduced chances of spillage and reductions of $CO_2$ levels, in line with the UN's SDGs. Finally, better purchasing and inventory handling reduces the number of items that need to be purchased, which reduces the need for transportation and fabrication. With fewer items to produce, less raw material is needed, reducing the depletion of natural resources.

| Value Proposition | Value Creation and Delivery | Value Capture | SDGs |
|---|---|---|---|
| An automation-based, data-based and integrated approach to conducting supply chain operations to upstream oil and gas, deriving a communal approach to asset usage and capacity handling. | Through a communal approach, sharing resources leads to a more efficient resource allocation, decreasing the number of resources needed and their usage to conduct operations. | Cost reduction through better utilization of resources;<br><br>Increased profit/revenue opportunities from selling stranded capacity (e.g. extra space in vessels) | Focus on SDGs #13 (Take urgent action to combat climate change and its impacts) and #14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) |

**Figure 8.** Value proposition, creation, capture and contribution to SDGs from the elements proposed in the "new business models" category (adapted from [37]).

## 5. Conclusions

Potential new and adaptive business models that can lead to the success of innovations and their diffusion are yet to be widely explored. In the meantime, new products, services, and technology are constantly being released to the market. This gap between technological advances and organizational needs must be addressed if the industry is to succeed in a demanding future, where regulation is increasingly challenging due to environmental worries, technology develops faster than ever, and a globalized world created a complex industry that requires pioneering alternatives to overcome constraints and competition. The offshore E & P industry must research, develop, and adopt not only technical innovation, but also have a holistic approach to business model innovation that will help understand which innovation and technological initiatives will promote sustainability and value creation in the organizations and their industry context. The existing business models that are available no longer meet the industry's needs to overcome its challenges and address sustainability and SDGs. However, finding and adopting business model archetypes that can handle such complexity and allow adopting innovative solutions might not be possible. At the same time, the existing archetypes might be too complex or robust for organizations to adopt as they imply changes necessary throughout the whole organization.

This conceptual study has applied systems engineering methods to explore the business model innovation possibilities in the offshore E & P industry and its support ecosystem. It offers a more flexible and granular approach to business model innovation through the adoption of SE to propose elements to be adopted interchangeably that can be adopted at different organizational levels and timeframes and can function as interim or final stages for the organization. Through examining business models typology and the conduction of a morphological analysis, possible elements for business models' innovation are identified according to classic and new business model typology and presented against three dimensions: technology, organization and the human element. The elements are presented in morphological boxes and can be combined and reorganized to change and build different business models. Given the limitations that more established firms may face in adopting certain elements, this study proposes elements as pieces for the organizations to adopt instead of full-fledged archetypes, providing modularity and granularity to organizations to replace certain parts when necessary without having to change the whole business model many times. The presented elements show different levels of complexity and organizational change for their adoption, and the more complex ones are suggested as an ultimate goal for adoption in business model innovation.

By adopting the elements in the new business model category, the expected end-state for the offshore E & P SC is an ecosystem that includes stakeholders in the network as collaborative partners to deliver higher operational standards. These include taking responsibility not only for operational execution, but also over safety and the environment, thus addressing sustainability and SDGs in offshore E & P operations. How these elements propose, create, and capture value has also been discussed. These elements create value through giving organizations an opportunity to become more strategic as they shift the daily activities from manually conducted to automated, conferring stability and reliability to activity execution and, therefore, generating value from technology application and organizational restructuring. Through more efficient information sharing, information propagates to stakeholders in the value chain more quickly, which can change how the stakeholders conduct their activities as well, taking the opportunity to remove inefficiencies from their part of the operations. Finally, as the different design elements are adopted by offshore E & P companies through business model innovation, a new method of collaboration within the industry can surge and evolve the industry to an ecosystem that addresses sustainability, innovation, the organization, technology application, and focus on their consequences to the human element. The measurement of the extent to which these presented elements address sustainability is a limitation of this study and is suggested as future research.

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