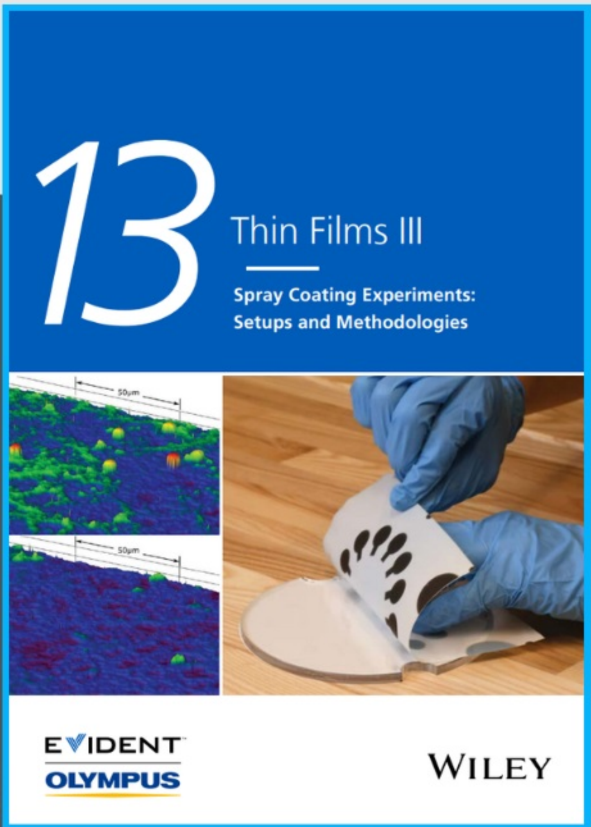
Spray Coating Experiments: Setups and Methodologies



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REGULAR ARTICLE

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

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Abstract

The offshore oil and gas upstream supply chain operations are part of a complex system with many stakeholders and intricate relationships. Traditionally, these operations are managed manually, which leads to inefficiencies. Despite the innovative and engineering-orientated approaches adopted in other technical operations of the industry, the supply chain activities remain unchanged, relying heavily on legacy systems. However, cutting-edge technology opportunities are available for adoption in supply chain management systems in the oil and gas industry. Such a transformative upgrade relies on first understanding the operational inefficiencies and preparing an accurate picture for how these operations should be performed. This study adopts a systemic approach to examine the oil and gas offshore supply chain operations of a case company to identify areas for improvement. The objective is to address the following research questions: (1) what is the current "AS-IS" supply chain operations support; and (2) what is the desired "TO-BE" state for these operations. This research adopts a soft systems lenses applied in an action research project to capture and analyze existing operations. The research revealed that information exchange is a major barrier, and that technology and organizational gaps are the primary hindrance for a digital transformation. The conclusion is that there is a need for a higher level of data exchange and increased data quality in any proposed transformation.

KEYWORDS
index terms: exploration and production, oil and gas offshore drilling, supply chain operations, Systemic analysis

1 | INTRODUCTION

The offshore oil and gas industry is one of the main sources of energy globally, and one of the main sources of fuel for all transportation modes that connect markets and transport people worldwide.[1,2] Offshore drilling platforms in the open sea extract fossil fuel resources that contribute to the supply of energy and petroleum derivate products.[2–4] Stopford[5] includes the offshore industry as a part of the marine resources group, including offshore oil, gas, renewable energy, and minerals. These offshore activities begin with the exploration (search) for oil and gas (upstream), exploitation (production) of reservoirs and eventual transportation (midstream) to shore for further downstream processing.[6] The upstream activities are executed by the Exploration and Production (E&P) companies that appraise and search for the oil and gas resources, which then are extracted, refined, and distributed by the companies downstream.[7] In upstream companies, the operations conducted offshore include the appraisal of potential reservoirs, their exploration through well-drilling activities, and the operationalization and maintenance of established platforms and wells.[2,3] This study is situated in a firm providing upstream services with a focus on the drilling activities conducted offshore and the supply chain (SC) support for these activities.

The offshore oil and gas industry has historically benefited from high profits resulting from high commodity prices and high energy demands.[3,8,9] Since 2015, however, a confluence of factors has caused prices to plummet to new lows.[10] Even though energy demand remains high,[11–13] there is higher pressure for industries and countries to transition from fossil fuels to cleaner forms of energy,[7,11,14] which increases the competition in the energy sector for market share. At the same time, high levels of oil supply, such as seen in from 2014 to 2016[13,15] and dramatic decreases in demand, directly result in lower oil price, such as experienced during the pandemic in 2020.[14,16] These events drive the industry to operate at lower profit margins, which increase the dependency on its ability to reduce both capital and operational costs to remain profitable.[9,13,17] Despite projections by energy experts suggesting that the global oil supply will not be enough to meet the energy demands of the next decades and that more oil resources are needed,[18] the offshore oil and gas industry has a disadvantage in relation to its competitors. Offshore operational costs are higher than most of the onshore equivalent operations due to the complexity related to costly appraisal and the remoteness of its production facility locations and the additional costs for the supply chain and logistical support they require. Therefore, improving the supply chain operations, removing inefficiencies, and reducing operational costs are high priority initiatives to sustain the industry's position and profitability in a competitive and complex energy market.[19]

In Norway, oil and gas offshore operations (metaphorically, the "front office") are highly innovation and technology-driven, implementing many initiatives that promote energy efficiency, safety, and sustainability, such as electrification of platforms, shore-based drilling operations, remotely operated robots and others.[9,15,17] At the same time, the supply chain activities that support these operations (the "back office") remain outdated, still working based on manual data input, spreadsheets and bloated overhead that directly impacts the costs of operations.[20–22] However, due to the increasingly low profit margins and pressure for more sustainable operations previously detailed, the industry can no longer overlook the inefficiency of its supply chain operations.[9,17,20,23,24]

The offshore industry is poised to look at supply chain operations holistically and to reap the advantages of modern computing power, tools, and their adoption strategies by taking advantage of the current wave toward digital transformation.[19] Rather than mimic human activities with computers, these modern tools and solutions allow the industry to rethink its whole approach to supply chain operations and implement the appropriate tools and solutions while revisiting operational processes and workflows. Yet, the interconnectedness among the parties involved in the supply chain activities, stakeholders and tools means that even small changes by one actor can have consequences for the others in the ecosystem, resulting in a set of very complex tasks that the existing supply chain operations models (e.g., SCOR) cannot support as they either are too generic or not robust enough to support the transformation that the upstream oil and gas supply chain requires. For these reasons, this study adopted a systemic approach to examine the supply chain operations through the lenses of soft systems rather than a piecemeal identification of existing inefficiencies that undermine the industry profitability and operational excellence, and to determine how these operations can be improved. Two research questions guide this study:

(1) What is the current offshore E&P supply chain structure and what are its challenges to supply chain operations handling?

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

This study reports on results from the first two cycles of an action research project conducted in an E&P Norwegian operator on the Norwegian Continental Shelf (NCS). The objective of this study is to identify how to tackle the inefficiencies in the current supply chain operations that support the drilling activities conducted offshore. The paper continues as follows: Section 2 contains the literature review findings; Section 3 presents the study's methods and data; Section 4 explores the results and the study's implications and finally, Section 5 offers conclusions and the way forward.

2 | BACKGROUND

The offshore drilling activities to retrieve oil and gas resources rely on the support of supply chain operations as illustrated in Figure 1. This supply chain is defined by the flow of goods from an upstream supplier through manufacturing (midstream) and downstream, through distribution channels to the end customer. Its management includes the related information, systems, integration, planning, research and development, operations, and total system/value analysis.[25–27] This paper focuses on the upstream offshore operations as shown in the upper left side of Figure 1.

From a high-level perspective, the offshore oil and gas supply chain resembles those servicing continuous operations, such as manufacturing industries.[3] Yet, it has a higher complexity due to the type of activities that need to be executed, the type of items that require purchasing, and the transportation of materials and equipment to the remote locations where these activities occur. In the Norwegian offshore oil and gas industry, these supply chain operations are part of a multi-faceted network that involves a variety of parties and stakeholders, and requires compliance with ever-growing regulations, resisting challenges from other industries and overcoming uncontrollable events, such as weather and health emergencies.[2,7,11] Additionally, the accessibility to the platforms heavily impacts the supply chain network design, procurement and logistics, such that technology becomes a decisive factor for how operations are to be

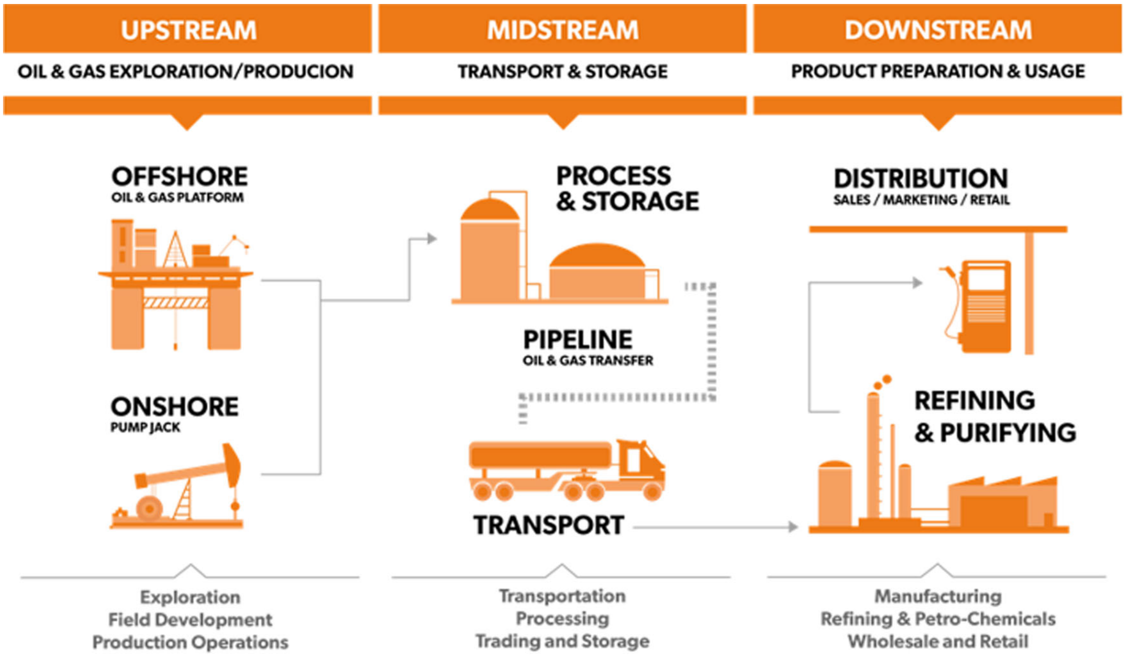

FIGURE 1 Overview of oil and gas industry's value chain[28]

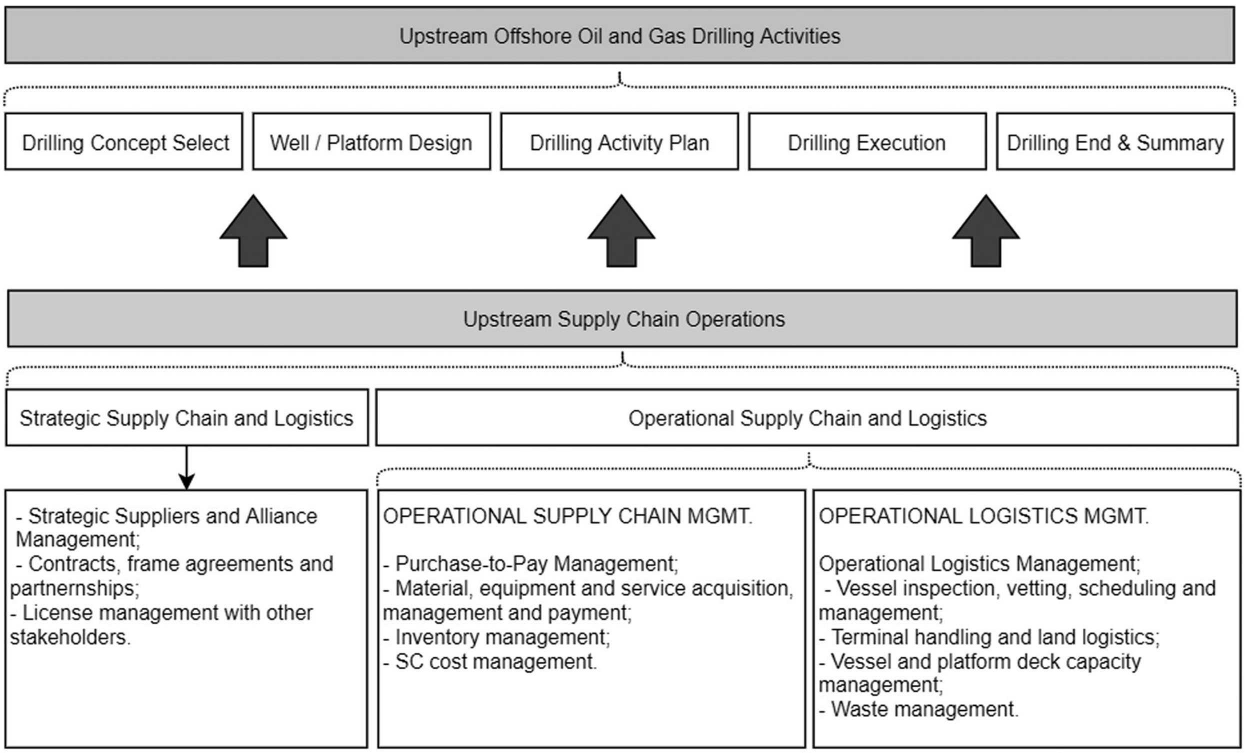

FIGURE 2 Supply chain operations in the context of offshore drilling activities[30]

executed and managed.[2,3,21] The logistics operations to deliver and retrieve materials offshore require the use of specialized terminals and vessels, and many times, are situated in extreme conditions, such as frozen waters and winter storms, that pose threats to the ability to complete the operations and to the well-being of the workers involved.[2,7,29] Figure 2 illustrates in more details the upstream supply chain operations that support the upstream offshore oil and gas drilling activities.

There are many supply chain models and frameworks to design, manage and improve operations, such as the traditional Supply Chain

Operations Reference (SCOR) developed by the Supply Chain Council (SCC) in 1996.[25,27,31] This model is well recognized both in academic literature and industrial practices and is proposed as a strategic tool to design, plan and operate supply chains and decrease their complexity.[31–33]

Despite being rooted in industrial practices and offering a standard for supply chain practices SCOR and similar models are focused on production and consumer supply chains without consideration of flexible, lean, and agile strategies.[34] Many of the stages or relationships presented in these models do not exist or are different in the oil and gas context, and thus, these models are not robust enough to support the holistic examination of the oil and gas supply chain. Still, there is no recognized model in literature that addresses this industry holistically.[6,35] Ahmad et al. (2017) offer a framework to address this gap, but within a sustainability context. Raut et al.[36] and Gardas et al.[37] suggest determinants and criteria for successful supply chain management in oil and gas, but in a sustainability context instead of looking at operations holistically. Nevertheless, the goal of this study is not to address this lack of suitable models, but to provide a more effective way to examine the oil and gas supply chain.

Rebs et al.[38] found that a majority of models they investigated dealt with macroscopic levels of analysis while models for intra- and inter-organizational supply chains were less prominent and they make the case for applying a systems thinking perspective in a conceptual framework. They promote the importance of multi-level frameworks to grasp the whole complexity of supply chains and the interrelationships between the different levels of analysis, such as recommended by Fabbe-Costes et al.[39] The effectiveness lies in inclusion of all stakeholders' perspective and adoption of a lens through which we can examine the impacts of collective interactions among all actors of the system with an organizational network perspective. Hence, this study adopts systems thinking approaches and methods for this purpose, as presented in the next chapter.

3 | METHODS AND DATA

3.1 | Overview

This study is constructed from the first two cycles of an action research project conducted in an E&P Norwegian oil and gas operator on the Norwegian Continental Shelf (NCS), hereafter referred to as the Operator. Action research (AR) is a method that integrates theory and practice to solve complex problems in organizational or social arenas where the researcher works together with the persons experiencing those problems.[40–42] AR adopts a view that the world changes constantly, and this change influences both the research and researcher. Through simultaneous research and participation, AR supports theory and knowledge creation and problem-solving to achieve both practical and research objectives.[41–43] Since the initiation of AR with a proposal by Lewin[44] involving a spiral of steps, many approaches for conducting AR have emerged, and this study adopts the four-stage approach proposed by Kemmis et al.[42] Action research employs soft systems methods,[41,45] which are ideal to examine the supply chain under consideration in this study rather than adopting and adapting the traditional models available.

Soft systems methods (SSM) include visual techniques for exploring the perspectives of multiple stakeholders. This involves activities, such as "rich picture" creation, to build a visual "map" of people's perceptions of a complex problem; identifying possible transformations and visualizing the required actions to achieve the change; and finding accommodations between stakeholders to agree the most desirable and feasible way forward.[46,47] Using these tools helps stakeholders learn collaboratively about complex situations and generate better mutual understanding of their different viewpoints on desirable and feasible change.

By using soft systems methods techniques for investigating complex and challenging problems it may be possible to discover the most appropriate solution for them through an analytical approach to situations that include various participants and systems with little or no direct links between them. Systems thinking is a concept derived from systems theory[48,49] that allows recognizing and understanding relationships, cause and effect, connections, interdependencies and feedback to describe systemic behavior and assist solving complex problems.[49–51] Using systems thinking we begin to understand the multifaceted nature of the world through systemic reflection and through the ability to think critically in complex situations.[51–53]

Tools available from systems science help us to explain and represent our observations both temporally and spatially.[54] To visually present the results related to this study's objectives, that is, identifying the current system state ("AS-IS") and desired end-state ("TO-BE"), we adopt the systems thinking tool called the systemigram.[51,52] A systemigram supports describing complex systems' construction and functionality[51,55,56] through understanding their entities and relationships among them. When applied to this study, they provide an understanding of how the offshore drilling supply chain operations are interrelated to other parts of the organization and beyond.

3.2 | Study cycles and data collection

The study was conducted at the Operator facilities from July 2018 to December 2020, divided into two research cycles. The first cycle started in the second quarter of 2018 and was completed in the fourth quarter of 2019. The second cycle began upon the completion of the first, in the first quarter of 2020, and lasted until the fourth quarter of the same year. Both cycles were divided into four stages, namely, Plan, Act, Observe and Reflect, conducted sequentially (Figure 3). Each phase had a specific objective and a set of activities for its completion, as detailed in the sequence.

3.2.1 | Cycle 1

Each stage of the cycle had specific objectives and a set of activities executed to achieve them. In cycle 1 (Figure 4), these

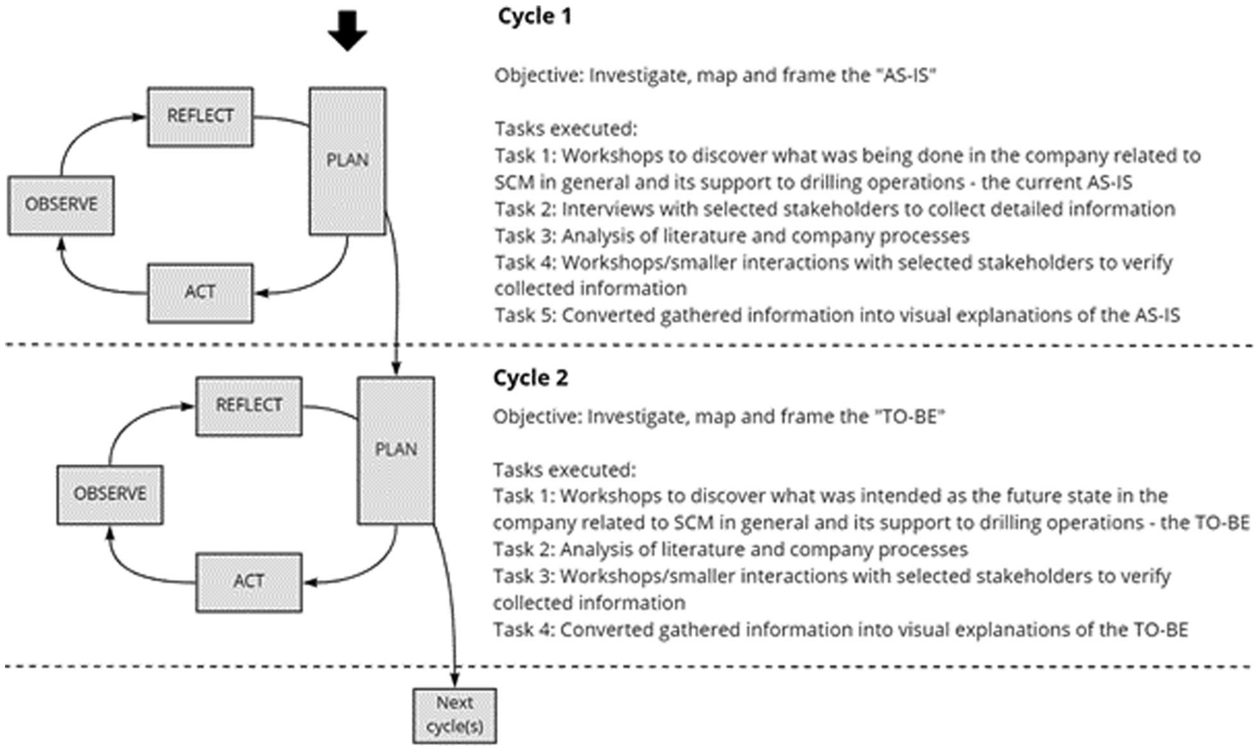

FIGURE 3 Scheme of action research cycles, stages, and tasks (based on[42])

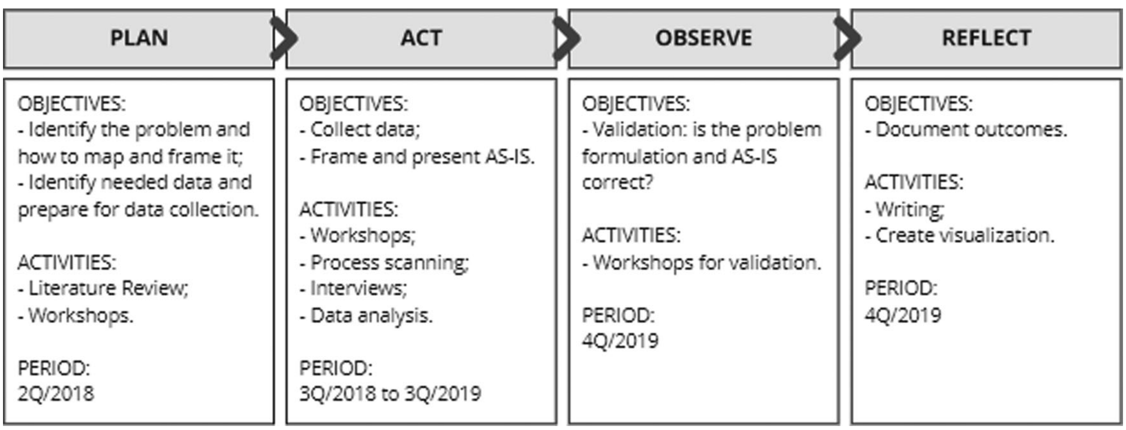

FIGURE 4 Cycle 1 - detailed phases

activities were conducted to collect and analyze data, scan the Operator's processes within the researched context, and validate and document (writing and visualization) the information gathered.

Following an approach selected to collect evidence from multiple sources and secure research reliability through data triangulation,[57] data was collected through four activities: (1) literature review; (2) workshops where participant observations were recorded; (3) semi-structured interviews with the supply chain and logistics departments, their internal customers and additional stakeholders; and (4) a review of the organization's operational processes, software/applications and their overlap, collected through an analysis of the organization's internal tools. Details are summarized in Table 1.

Cycle 1 Literature review

The literature review was conducted to establish the academic foundation for the research through a search for peer-reviewed academic articles using Boolean search terms in academic databases, mainly Scopus and Web of Knowledge. The search keywords were variations of these terms: oil and gas, digitization, oil and gas supply chain, Norwegian oil and gas operations. Additional reports by accredited institutions that research this industry were included in the review

TABLE 1 Cycle 1 – Detailed data collection and validation activities (data analysis and documentation excluded)

Cycle phase	Year	Quarter	Number of workshops	Interviews	Interviewee's category (see Table 2)
Plan	2018	Q2	15	–	–
Act	2018	Q3	26	–	–
Act	2018	Q4	47	8	Decision Makers, Internal Stakeholders and End User
Act	2019	Q1	43	1	External Stakeholders
Observe	2019	Q4	12	–	–
TOTAL			143	9	

TABLE 2 Informants profile – Interviews

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

(e.g., DNV, KonKraft, Gartner, Capgemini). The findings from the literature review are summarized in the background section of this article.

Cycle 1 Workshops

The workshops were conducted in the form of meetings ranging from 1 to 5 h with one or more Operator employee and others involved in the conduct of drilling and supply chain operations. Some meetings were conducted face-to-face, while others were conducted digitally via Microsoft Teams software. In this cycle, a total of 76 individuals participated in at least one workshop, but many individuals participated in more than one. Some of these participants were the same as the informants selected for formal interviews conducted in cycle 1. However, the workshops were conducted with a loose agenda and without a formal structure to allow the participants to contribute freely. To foster active participation, all the physically conducted workshops had whiteboards and multiple pens available, sticky notes and the participants were encouraged to collaborate by working together. A similar approach was adopted in the digital workshops, but using the Miro software, which is a whiteboard platform that allows multiple users to collaborate in sketches and drawings in real time (miro.com).

Cycle 1 Interviews

In cycle one, nine semi-structured interviews were performed face-to-face with informants in different roles connected to the drilling and supply chain operations. The interview guide was adapted after the first interview to improve the flow. The interviews had two main objectives, which were (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. Even though this second objective relates to cycle 2, it was included in the same data collection process during cycle 1 for time optimization purposes. The selection of informants was based on four criteria, which were used later to classify the collected data, as follows: (a) decision makers – persons authorized 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 finally (d) external stakeholders – supply chain stakeholders outside the organization. The informant attributes are based on their work scope, being: (1) general operations, (2) supply chain operations and (3) logistics operations. The informants' profile is presented in Table 4, additional information is not given to maintain anonymity.

All interviews were recorded following informed consent given by the informant that their identity would be anonymized and that no proprietary data would be disclosed in the study following ethical considerations.[58] Analysis of each interview started with a full transcription of the recordings, first through the Trint software, then revised manually. The transcriptions were analyzed by deductive coding[57] through Nvivo software, adopting a predefined code set, namely, (1) organization and culture; (2) operations handling; and (3) technology related aspects.[59] These codes aligned with variations of these three patterns and were selected based on the information collected from the literature and from the workshops conducted prior to data analysis. Each code partitions the content of the informant's perception of the topic, the problems, and the expectations. This same code set was adopted to classify information collected during the workshops in each cycle (see Tables 4 and 5).

Cycle 1 Operational processes scanning

To understand how supply chain operations are managed daily, a thorough exploration of the company was conducted in cycle 1 through an analysis of two of the organization's internal tools, that is, the Business Management System (BMS) and workflow definition software. Together, these tools support all activities involved

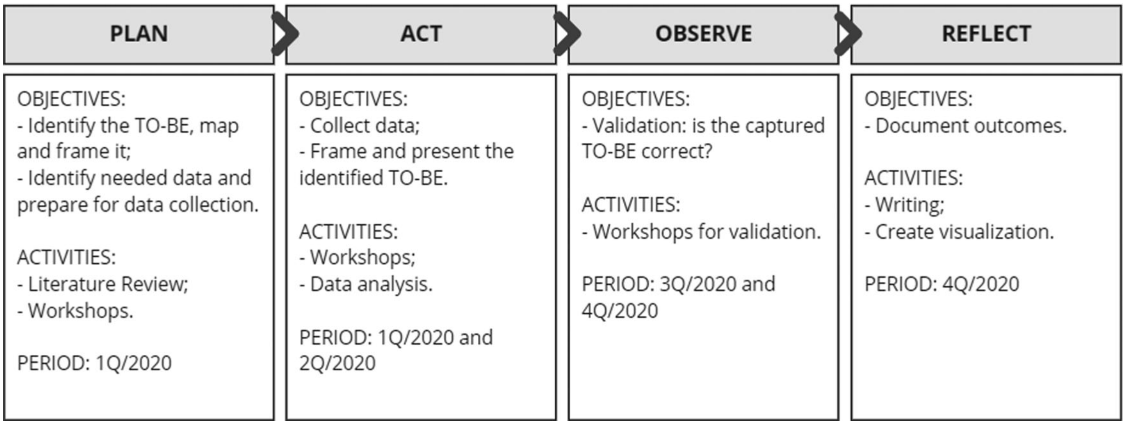

FIGURE 5 Cycle 2 - detailed phases

TABLE 3 Cycle 2 - Detailed data collection and validation activities (data analysis and documentation excluded)

Cycle Stage	Year	Quarter	Nr. of Workshops
Plan	2020	Q1	5
Act	2020	Q1	42
Act	2020	Q2	40
Observe	2020	Q3	21
Observe	2020	Q4	28
TOTAL			136

in the organization's supply chain processes, their main data elements, their reference systems, and the applications where the processes are conducted. The information about the processes was collected in the following sequence: first, the processes not related to supply chain were excluded, then the supply chain was grouped as follows: 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 as they are not part of the study's scope.

3.2.2 | Cycle 2

As in cycle 1, each stage in cycle 2 had specific objectives and a set of activities to achieve them. In cycle 2 (Figure 5), these activities were organized to collect and analyze data (Plan and Act), and to validate and document (Observe and Reflect) the information gathered.

In cycle 2, data was collected through two activities: (1) literature review and (2) workshops where participant contributions were recorded. Data collection in cycle 2 followed the same approach of collecting evidence from multiple sources. The details are summarized in Table 3.

Cycle 2 Literature review

The literature review was a continuation of the activity described in cycle 1.

Cycle 2 Workshops

The workshops for cycle 2 were conducted in the form of meetings with one or more Operator employees but were mostly conducted digitally due to the restrictions imposed by the pandemic after 1Q2020. Due to this, the workshops were slightly reduced in duration and ranged from 30 minutes to 3 hours. In this cycle, a total of 47 individuals participated in at least one workshop, but many individuals participated in more than one. While many of cycle 2 participants also participated in cycle 1, but 4 individuals participated in cycle 2 who did not participate in cycle 1. The information provided in these meetings was coded using the same code set adopted in cycle 1 and the workshops also followed a similar loose agenda and informal structure. The participants were encouraged again to collaborate actively in the workshops, and due to the digital nature of the meetings, this collaboration was done using the Miro whiteboard platform.

3.2.3 | Validation

Activities to validate the results of this study took place within the workshops in both cycles during the "observe" phase (Figures 4 and 5 and Tables 1 and 3). In these 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 recommended and accepted. The participants for both these validation rounds were selected randomly from the pool of participants who had been involved in the previous data collection phases, depending primarily on their availability to participate in the workshops.

The results that follow are based on the accumulated information collected in each cycle, and the processes, while typical of those found elsewhere, are not meant to portray a generalized set of practices or activities for the industry.

4 | RESULTS AND IMPLICATIONS

4.1 | "AS-IS" – capturing the current state

The results from the first cycle of this study indicate that the Operator's daily supply chain operations are inefficient and fragmented into silos, and communication is poor between those managing supply chain and logistics. In addition, exploration, production, and maintenance business units are not interconnected. The Operator is present in circa 14 fields with different levels of participation and has more than 600 suppliers globally, including its logistics vendors. Managing these is a daunting task, and management of logistics operations has many specificities that require extra resources. The workshops conducted in the first cycle gathered the perspectives from many different stakeholders. The participants actively utilized the whiteboards available to visually identify the many stakeholders, processes, applications, and their interactions. The various views ranged from a holistic view of operations to detailed views of specific interactions.

Many examples of complex operations were uncovered during the workshops, but the transportation aspect is one of the most important and complex. Offshore locations depend upon the availability of specialized vessels that must be sourced, usually through long-term lease contracts, and approved for sailing and use in pre-defined operations. Once a vessel has been identified, the transportation of items can be scheduled and verified. Finally, their day-to-day operations must be managed according to specific legislation, including loading/offloading, routes, specialized personnel availability, and other details. Currently, these are managed by multiple department units incurring a high overhead cost and supported by scores of different software and applications. Daily, marine coordination, vessel management, vessel inspection, vessel vetting, ocean transportation, ocean transporters and vessel companies must work together to fulfill a given objective, but each of them has a specific role, set of tasks, responsibilities and external interconnections related to the transportation of goods offshore.

For example, vessel inspection comprises the activity of inspecting vessels, which is performed by certified bodies under the coordination of vessel vetting. Vetting verifies and approves the vessels that can be used in the operations, which are rented from vessel companies and managed by the vessel management group (including bunkering). Spot and ad hoc transportation are also performed by ocean transporters. These operations are a combination managed under ocean coordination/ transportation, which is part of marine coordination (see Logistics in Figure 6). This last entity comprises additional activities related to marine and underground operations. This example shows the intricate communication that happens on a daily basis to manage these operations.

The final documented version of the "AS-IS" systems state is summarized in a systemigram (Figure 6) that illustrates the system participants, the key stakeholders and their relationships and the business context of the operations conducted within the system. The systemigram shows the flow of task interactions, focusing on supply chain and logistics support operations. Each oval is a node, and the shaded oval nodes with wider borders represent a different system-of-interest (SoI), for example, third parties. Examples of the tools adopted in the execution of these operations are shown in the systemigram, however, some information related to these tools are confidential and cannot be discussed further. Additionally, at the time of writing this paper, no decisions were made by the company regarding the exact tools that would be adopted or remain in use, or how to address some of the interfaces and interactions among these methods and tools. The major interconnections are presented by wide bold arrows, while the non-bolded shapes and thinner arrows represent secondary nodes and flows. The sub-nodes within each larger node are presented in different colors and shaded patterns that indicate whether they are internal or external stakeholders; those left blank or without patterns are complementary nodes. The color and pattern scheme is presented in the figure's legend. The white bubbles show candidate systems and tools used to manage the different activities not shown in the diagram, or the fact that these tools are also data-syncs that hold archived information, probably also used for decision-making. Reading a systemigram starts at the top-left corner, indicating where the supply chain operations demand begins with the results of field appraisal and exploration. The reading continues towards the bottom-right corner where a final node indicates a successful operational objective with feedback to the Logistics SoI.

All interactions shown in the "AS-IS" systemigram rely on manual interventions, both when exchanging information within sub-nodes or with the other nodes in the system. The same applies to software – in the supply chain context, all information input to any software is manual, just as is the information exchange to other software. Any current data that is generated in any software (e.g., 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 jeopardized 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 using 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 data updated and correct.

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. In the drilling context, the software installed throughout the operations are mostly monolithic with low levels of integration. Add to the mix the different groups manually managing different parts within and between organizations, and software-based communication is minimal or nonexistent. As a consequence, the ability to plan and communicate plans across

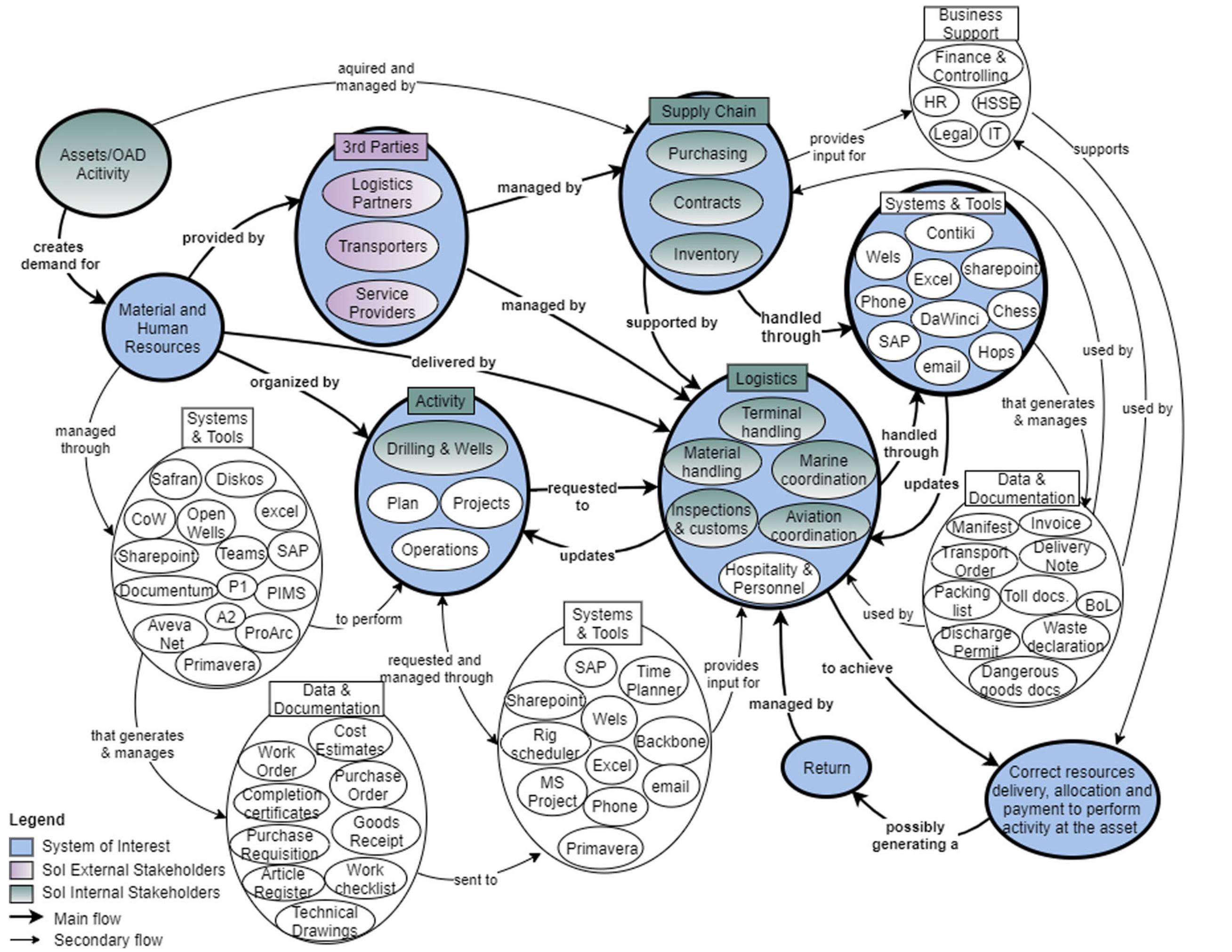

FIGURE 6 Documented and validated "AS-IS" Systemigram

the network is restricted, directly impacted by this limited access to information across the stakeholders. As one informant explained: *"it's a rather fragmented operation (…) we're always in a kind of emergency situation and that basically tells me that there's not sufficient planning horizon, we're not smoothly operating it"* (I.2). The same informant continues stating that:

> "… from a coordination perspective, my impression is that we lack a bit of data, and planning is not what it needs to be (…) I think that the logistics today is a patch Band-Aid (…) there's too little transparency as the data is not flowing sufficiently to give you an angle of attack into these more challenging questions" (I.2).

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 throughout the network. Most interactions take place via email and telephone with the meager support of overengineered processes to compensate for the lack of interoperability, resulting in low inventory control, lack of a standardized master data structure, governance, plan structure and operational forecasts. This is validated by the informants: *"it requires a lot of human interaction and a lot of interaction between us, our assets, and also the vendors"* (I.3) and *"we're putting humans in to patch processes, that are not really working (…) the situation has been normalized, we have a feeling that this is the way it is (…) this is poor practice but we're calling it best practice"* (I.2). The consequences of the documented processes are sub-effective, 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, inability to take advantage of shorter lead times, and sub-optimal fleet utilization.

The data collected exposed three root causes for this situation as follows: (1) the organizational culture in how operations are handled; (2) the historical lack of urgency to invest in the supply chain (back-office) operations due to high profit margins from the exploitation (front-office) activities; leading to (3) the failure to invest in technology for supply chain operations. Regarding addressing the first cause, one informant explains:

> "… like many traditional industries, we work in silos. And there is a culture for not to blend in or interfere with other business units' issues. But now we are encouraged through the cultural model to (…) go into other views and domain and ask some good questions and to encourage collaboration" (I.4).

Another informant complements this by stating: "… maybe people are protective. They know how it should be solved, maybe they're not used to getting inputs from others and have the correct arena to have those discussions" (I.3). Concerning the second and third causes, many of the workshop participants and interviewees summarize it by saying that the industry has currently been in a positive financial situation that allowed it to overlook the supply chain operations inefficiencies, as investing in drilling and extraction efficiency offered bigger returns.

> "Our industry has been complacent with regards to improvement because we have never needed to, because there has been too much cash. So, if you compare us to automotive or, other types of industries where they have lived in low margin businesses for decades, they have had to develop these (supply chain) methodologies and processes that are very clear, and business focused. We have not had (to do) that because we have always had too much money." (I.4)

> "… the oil companies have been used to kind of pushing barriers within their technology. Drilling further, deeper, faster. But when it comes to all the supporting systems, of course this is not core technology. So why should they be the best in the world on that? I guess that, when it comes to the core of what they're doing, they have the brightest engineers, their best people. So, it makes sense that they are front there but on the things we're talking (about) here, logistics for instance, there's no reason to why oil companies should be best practice and, best in the world." (I.6)

> "… this is developed over 50 years, so there is a combination of things just happening. A lack of relevant technology, lack of interest and funding for actually doing things, investing in making something for the future, especially on the supply industry side." (I.6)

The major issues and inefficiencies identified from the workshops and interviews are summarized by code set with quotes in Table 4.

4.2 | "TO-BE" – Documenting the desired state

During cycle 2 the focus was on mapping the desired "TO-BE" supply chain operations to the ones that support drilling activities. The workshops conducted in each cycle were a significant source of information, and in cycle 2 participants were asked to describe what is desirable for the Operator and for the industry as a whole. As before, many participants engaged in drawing what they envisioned as their desired operational support, at both a holistic and detailed level. The reader should keep in mind that this is their perception of how to improve their current situation and does not imply an idealized solution.

The results confirm that technology and organizational change is at the center of the transformation desired for supply chain operations. Virtually all informants and workshop participants specify the need for a higher level of data exchange and the ability to retrieve and send data without manual interference as a way to increase data quality. Some mention that improving the software and applications where data is created and consumed is the most important step, while others identify the need for common and unique identifiers throughout supply chain operations to increase information visibility. However, the understanding of how and why to do this varies a lot. Many informants think of data exchange in the sense of cross-company collaboration, while others think of it in relation to daily operations being conducted in applications and software, therefore, related to interoperability. Hence, it is important to understand and define very well what is meant by information sharing and communication. In many of the workshops, it is clear that upper management has started to enforce this need as a cultural change and started to spread this message, but those responsible for implementing this change have distinct views about this transformation. Lack of a clear vision jeopardizes the success of the ongoing initiatives in the organization and industry.

One consistent example of contention is the misunderstanding between "data" and "application/ software". The majority of the informants, both in the interviews and workshops, seem to make a strong correlation between data and the application/software they use daily, and in general, cannot separate them. This impacts the ones in need of the data, as any meaningful discussion of how that data is created, made available and consumed is usually derailed to a software discussion to define which tools and applications should be adopted in operations. At the same time, the organization is strongly enforcing data sharing, yet, because the general understanding of data is not consolidated, the message enforced by the organization gets lost or changed in its course and loses its intended effect. We also identified that the organization made training materials available to increase the knowledge about data and information management, however, the majority of the informants affirmed they had not taken any of these courses.

Based on these findings, it is possible to see that there is a need to reflect upon how the organization needs to rethink and redesign its supply chain and logistics operations and adopt technology to remove inefficiencies in collaboration and streamlining data/information to its stakeholders.[60] Likewise, the concept of prioritizing innovation in a perceived non-engineering-field like supply chain and logistic operations, within this engineering-oriented culture, represents a cultural shift at the organizational level. It was constantly repeated by nearly all informants and perceived in nearly all workshops and observations that efficient communication and information sharing is not rooted in

TABLE 4 Summary of "AS-IS" related findings

Code	Major issues and inefficiencies	Quotes from interview informants
Organization and culture	• "Silo-working" mentality/protection. • Transactional orientation vs. partnerships (many suppliers vs. a few strategic ones). • Lack of consensus. • 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) "(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. • Slow and fragmented decision making/sharing. • Operational bias/different ways of working.	"It has been more about bringing projects on stream and producing oil and, so you can easily accept inefficiencies in the chain." (I.7) "The biggest issues in today's value chain is lack of visibility, it is 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. • Legacy systems. • Lack of a holistic architecture to support interoperability. • Lack of IT understanding and several different understandings.	"It is a very traditional transactional based system, very able to say fragmented, a lot of handovers. Not very well integrated, not all very efficient." (I.7) "It is like drawing a house. If you want to build another floor, you need to change something within the foundation. And the architecture has not really been well thought through." (I.8)

the daily operations as a priority, therefore, a cultural change must happen in the organization and industry.[61] As one informant puts it:

> "I'm not really sure that the technology part of it is really the most difficult. I think it's more on the organization, on how we choose to work together - that we leave some of the old habits behind. And on the cultural side of that, we rely more on the suppliers, that we open up for the suppliers, that we give them the opportunity. So, I think the softer side is more complex than the technology." (I.1)

Other informants agreed, indicating that the adopted technology does not matter as long there is clear and efficient communication. Here, organizational changes are more important than the available technology. For these informants, whatever technology gets implemented, its success will depend on how the implementation is carried out and the willingness of the users to trust and adopt the technology. If the users are forced to be in a system that they do not believe in and trust, they will probably maintain their current working culture and habits, bypassing the system altogether. One informant summarizes this by saying that

> "*I take for granted that we are able to fix the technology, because I think that's sort of easy, in a way. The difficult part is to get the operators on board, so it is not a one-company effort and solution*" (I.4).

Despite the need for fine-tuning a vision for the future, the operators realized that the way offshore supply chain operations are handled is no longer sustainable and that it needs to change if it wants to overcome the present and future challenges. During the interviews, the informants summarized the need for transformation as follows:

> "We need fundamentally a new way of working and, that means we need to change our own organization, both in terms of the boxology and how we structure the company but, more importantly, with what sort of mindset we engage with our suppliers." (I.1)

> "The industry is coming to a "lose-lose" situation where (…) the unit cost for the oil companies, it's going up because the volume is going down, and this is a volume business. The supply industry is losing money because they are stuck in old business models. So, you have, in some way, to break up this, and doing more of what we did yesterday is not a recipe for doing that." (I.6)

This is in line with the findings published in a report by DNV-GL[19] based on surveys of oil and gas senior industry professionals and executives. The report surveyed more than 1000 professionals and its results show that similar challenges, i.e., insufficient specialized software, too many silos, and resistance to culture change, among others, are found across the industry. Moreover, the report results show that digitization is perceived as important in the industry but that it is still not really focused on the back office despite all the acknowledged problems. Similar results are presented by KonKraft (2018, 2020), a collaboration arena for the Norwegian Oil and Gas Industry, Energy, Shipowners and Labor Associations that aims to maintain the competitiveness of

TABLE 5 Summary of "TO-BE" related findings

Code	Major desired aspects	Quotes from interview informants
Organization and culture	• Collaboration between operators and suppliers. • 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 will not invest in their relationship, necessary technology, and organization to do that. We need to become better at planning. That is partly a dual question, but it's mostly an organization and a culture wash." (I.2) "One thing is the culture, but it is also the correct leaders that 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. • Autonomous or semi-autonomous operational handling - focus on exception handling. • Data-centered operations - increased analytics and use of data to support decisions. • 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, full overview of the activities in our value chain. That is 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) "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, both make it easy for the base also to handle. Instead of several systems, one system for each operator. They could also see all the cargo, for all the operators at one day, and not separately. So that would be very good." (I.3) "I am 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, as just-in-time, making sure we do not have stranded inventory, etc." (I.4)
Technology related	• Defined IT architecture, software ecosystem and information flow. • Next-gen software and applications: modular and ready for interoperability. • Next-gen technology: digital-twins, blockchain and modern analytics tools (i.e. Machine Learning).	"The vision is that we will have a digital twin, all our assets on the twin will by itself, in a way, alarm the system that will say "now/how 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 work or documentation instructions, etc. At the time it is needed, in a way. And this will be, in a way, done by the system more or less, a hundred percent itself." (I.7) "(…) So with a smart contract and a blockchain type of framework, you are actually doing instantaneous payments. Because now you have 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) "It is necessary to disrupt. You cannot just do, kind of, these incremental improvements. You have to look for disruptive technology, disruptive thinking." (I.6)

the Norwegian Continental Shelf. Through this consolidated entity, the industry as a whole recognizes that cooperation within its network needs to become more strategic by streamlining plans and sharing information through better integration within and across the systems to gain visibility and flexibility and improve efficiency. An Operator participant has expressed the ultimate "TO-BE" state as follows:

> "So, we have a strategy which is quite ambitious. (…) the biggest challenge is (…) how do we go about it? Changing the culture, changing our behaviors, opening up, sharing data, and generally creating buy-in from the industry. Because we are heavily dependent not only on our suppliers but also on our peers, which are the other operators. So, when we are an operator, we don't own the license alone, we own it together with other operators. So, everything we do, at least at a strategic level and a material level, we have to have buy-in and acceptance from our peers. So that is one challenge. The other challenge is (…) collaboration, and opening up, and being transparent and visible… We should not be naive; we need to make sure that we actually generate value and realize that value in our business, so we are not doing this just for the fun of it, but we do it with a very clear business perspective". (I.4)

The major aspects of the "TO-BE" system state identified from the workshops and interviews in cycle 2 are summarized by code set with quotes and presented in Table 5. Figure 7 presents a systemigram to visualize how stakeholders are envisioned to work together and exchange information.

The process to achieve the desired "TO-BE" system state has already started in the Operator firm through several rounds of investment allocated to reviewing processes and the development and implementation of tools to address the identified inefficiencies. However, a great deal of work is still needed to reach the desired "TO-BE" state. Yet uncertainties arise when informants are questioned about whether this end state can be reached, and more importantly, in a timely and cost-efficient manner. The lack of general agreement on basic concepts,

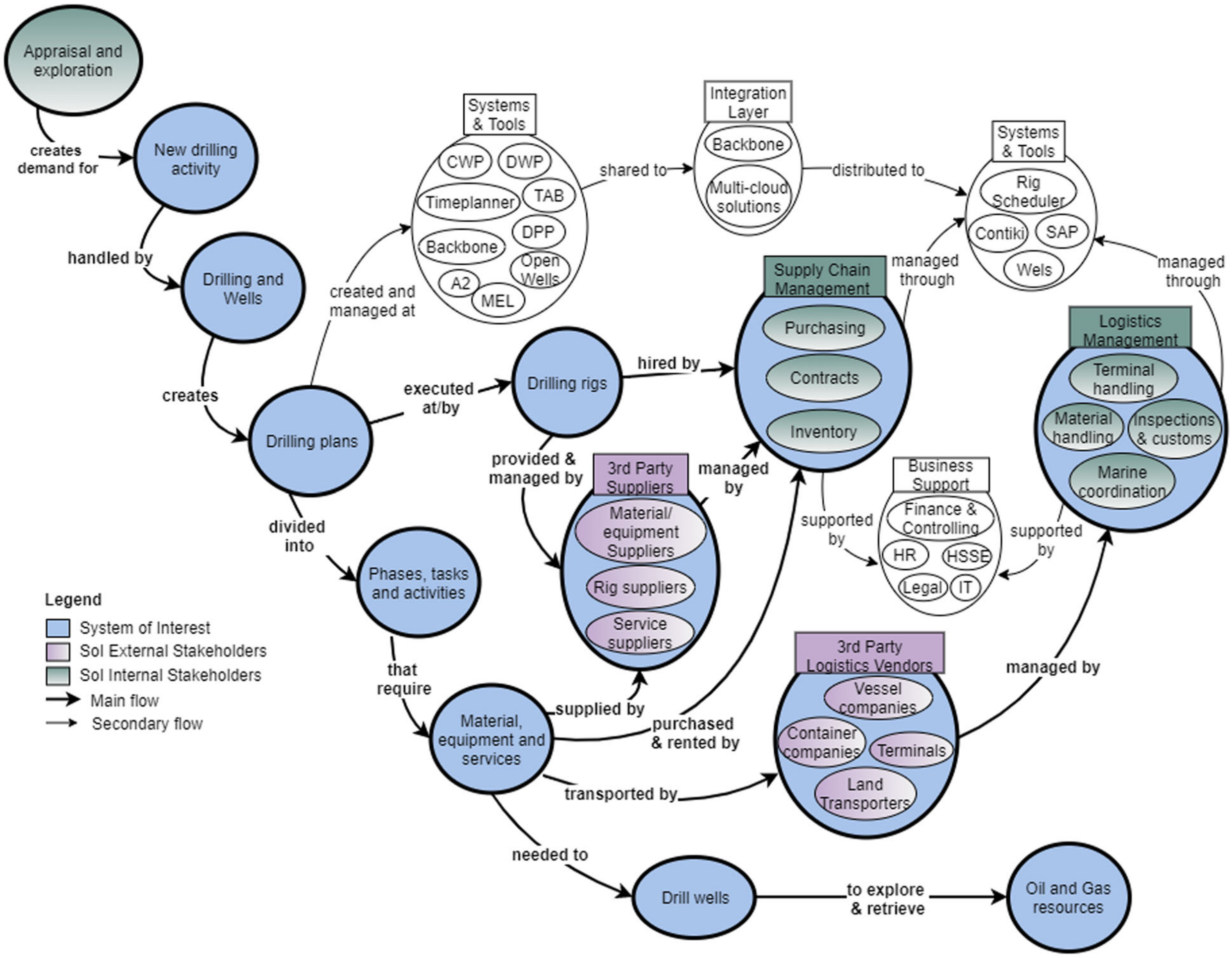

FIGURE 7 Desired "TO-BE" systemigram for drilling operations supply chain

such as data vs. software, represents a bottleneck to the success of any improvement or transformation. Therefore, the results presented in this study show that the "AS-IS" is no longer sustainable and the "TO-BE" is somewhat utopic due to the lack of common understanding of what the "TO-BE" means to all the parties involved. At this point in the progression toward a digital transformation, a more holistic approach is necessary instead of implementing scattered improvements to transform operations, and at the same time, to close the knowledge gap and update the skills of the people involved is a key factor for success.[60]

4.3 | Implications

The effort needed in order to recognize the full value of the "TO-BE" model represents a digital transformation in the "back office" and strengthening its interactions with the "front office". This study suggests preliminary areas that must be addressed so that this transformation can take place.

- 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 optimized 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 for replacing monolithic software with more modern tools adequate for the general needs of interoperability and communication. Modern tools with standard APIs (Application Programming Interface) for data exchange and easily configurable data models are key for achieving interoperability.
- Data vs. software: there is a 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 can be mapped for this purpose.
- Knowledge and skills gap: Changing software, tools, data usage and communication rely on people with the right competency and skill to do so, and then personnel with the skills to work in the upgraded environment. While the technical aspects of this change can be

addressed by hiring specialized companies to develop and implement tools, people in the organization are the key for 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 (e.g., through training), most development and implementation efforts are likely to fail.

- Organization and culture: Having the right people to perform the right tasks during development and implementation is dependent on reorganizing 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 change and to embrace the transition. A strong resistance may jeopardize the whole transformation.

5 | CONCLUSION

This study explored the oil and gas supply chain operations in the context of the offshore drilling activities, examined through the lenses of soft systems methods grounded in an action research project for an E&P operator on the NCS. To examine the supply chain operations and its inefficiencies, this study applied systems thinking methods to identify and schematically present the current system structure ("AS-IS") as well as the desired ("TO-BE") system state. The results of this research show that the current supply chain operations are fragmented into silos within and across the organization. Critical supply chain information exchange relies on manual work to overcome the lack of interoperability in the IT support platform, which may be due to the current overengineered processes and monolithic software in the operational setup. 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. 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 been based necessarily 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.

The results indicate that the Operator understands the severity of the limitations of its supply chain operations and has a vision for a desired end-state. However, the initiatives have been hindered by the sheer magnitude of effecting a big-bang digital transformation, and the knowledge and skills gap of the organizational stakeholders. These implications show that without addressing these disproportionate interactions, the organization and the industry are likely to fail in removing its supply chain inefficiencies and achieving a return of investment from the small initiatives already started.

This paper presented preliminary work that continued with an additional (third) research cycle, and results are provided in two papers.[30,62] The combination of all cycles, their results and insights are available in a recently published in doctoral thesis available in.[63]

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article, as no datasets were generated or analyzed during the current study.

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