

Identifying and prioritising sustainability integration strategies in oil industry logistics: A multi-dimensional analysis

Abdoulmohammad Gholamzadeh Chofreh^{a,*}, Feybi Ariani Goni^b, Zhipeng Yu^{c,*},
Bohong Wang^c, Mohd Afzal^a, Saeed Sadeghi Darvazeh^d, Mostafa Hajiaghahi-Keshteli^d

^a Department of Engineering, School of Engineering and the Built Environment, Faculty of Computing, Engineering and the Built Environment, Birmingham City University, Birmingham B4 7XG, UK

^b Department of Business Management, Faculty of Economics and Administration, Masaryk University, Czech Republic

^c National & Local Joint Engineering Research Center of Harbor Oil & Gas Storage and Transportation Technology/Zhejiang Key Laboratory of Pollution Control for Petrochemical Industry, Zhejiang Ocean University, No. 1 Haida South Road, Zhoushan 316022, PR China

^d Department of Industrial Engineering, School of Engineering and Science, Tecnológico de Monterrey, Monterrey, Mexico

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ABSTRACT

The oil industry plays a crucial role in the global energy supply. However, its operations pose significant environmental and sustainability challenges. Integrating sustainability into logistics processes is essential for enhancing efficiency, reducing costs, and minimising environmental impact. Despite growing awareness, the industry faces obstacles such as inadequate training, limited resources, security concerns, and insufficient infrastructure. To accomplish this, a mixed-method approach combining thematic analysis with multi-criteria decision-making techniques is adopted to identify and prioritise key sustainability integration activities within oil industry logistics. As a result of expert interviews and literature analysis, 23 sustainability integration activities were identified and categorised into three groups: upstream, midstream, and downstream. Based on expert evaluations, the Best-Worst Method (BWM) was used to prioritise sustainability integration activities in the quantitative phase. The three most important priorities are technological innovation (0.331605), cleaner production methods (0.094957), and sustainability in gas processing (0.101721). Based on the study, these factors used with value chain mapping, relevant training, and infrastructure improvements, can reduce emissions and waste while increasing efficiency and resilience across upstream, midstream, and downstream operations.

1. Introduction

The oil industry influences the development of the global economy (Yang et al., 2023). Crude oil and its derivative products are explored, extracted, refined, and distributed. As a leading industry, this sector could have a significant impact on environmental sustainability (Zhang et al., 2023). It is imperative that the oil industry adopts practices that reduce operational waste to fulfil this goal (Okeke, 2021). As mentioned by Basile et al. (2021), one such practice that can help reduce operational waste in the oil industry is the “use-refurbish-recycle loop,” which is facilitated by the concept of a circular economy. This concept will help companies in addressing stakeholders’ needs and reducing the environmental impact.

Ecological, social, and economic sustainability are all interconnected concepts (Goni et al., 2021). It is evident that all these factors are highly

connected with the extraction, production, and usage of the oil, meaning that the practices of the industries will adversely affect the environment in the long term. Through sustainable practices in the oil industry, renewable sources of energy are encouraged, and carbon emission is minimised (Ruggerio, 2021). The oil industry is capable of developing sustainable initiatives for extraction, transportation, and distribution through efficient logistics strategies (Foong & Ng, 2022). By means of innovative logistics solutions such as optimising the transport routes and emission reduction, the industry can reduce the consumption of energy, reduce emissions, and lessen the burden on the environment. With the innovations, such as real-time tracking and data analytics, the oil industry can reduce and monitor its carbon footprint (Karaman et al., 2020). Additionally, the use of eco-friendly transports, such as electric or hybrid cars, is making supply chain logistics more efficient, because it helps make better routes, cut mileage that is not needed and decrease

* Corresponding authors.

E-mail addresses: Abdoulmohammad.chofreh@bcu.ac.uk (A.G. Chofreh), zhipengyu@zjou.edu.cn (Z. Yu).

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fuel consumption (Meemken et al., 2021).

Sustainable strategies and logistics operations in the oil industry have been widely researched. For example, green innovations in exploration and production of oil (Yatimi et al., 2024) and the optimisation of logistic planning (Qiu et al., 2022). However, there are few studies exploring the relationship between logistics and sustainability in this sector. The objective of this study is to propose actionable recommendations to enhance logistics sustainability through targeted activities that create meaningful and enduring sustainable values. An analysis of thematic themes as well as a best-worst approach is utilised to identify and prioritise sustainability integration strategies in the oil industry's logistics.

To determine the logistics operations of the oil industry, both primary and secondary data were used extensively in this study. The primary data is gathered through interviews with experts, logistics professionals, and environmental specialists, which facilitate the exploration of their perspectives. The secondary data is collected from online books, journals, and websites that deal with sustainable initiatives within value chain logistics. As well as providing contextual and conceptual aspects of the research on sustainability processes in oil industry logistics, the qualitative approach has helped in gaining a deeper understanding. Finally, using the data gathered through the pairwise comparison questionnaire, the sustainability integration strategies have been prioritised. Value chain mapping has been determined as a pivotal tool in logistics systems, which enables the identification of the areas within the supply chain that can be further optimised. By incrementing accessibility and visibility at each stage, value chain mapping progresses the operational momentum within the logistics systems. Both exogenous and endogenous factors would significantly influence the design and efficiency of the supply chain operations in the oil industry, which would be great for underscoring the need for comprehensive strategic planning.

2. Literature review

An overview of the key literature in the oil industry relating to sustainability, value chains, and logistics can be found in this section. To provide foundational knowledge and insights into sustainability challenges, practices, and solutions in the oil industry, previous studies on sustainability in the oil industry are reviewed. The study examined the literature on value chains in the oil industry to take a holistic look at how exploration and production interrelate and influence each other. The logistics process of the oil industry is scrutinised to gain an understanding of the entire process as well as how to optimise the supply chain, ensuring that crude oil and petroleum products are transported efficiently from extraction sites to refineries, storage facilities, distribution centres, and ultimately to consumers. By optimising logistics, the oil industry can reduce costs and speed up delivery. The study also provides a summary highlighting the relationship between sustainability, value chain and logistics in the oil industry, and research gaps and inconsistencies in the literature.

2.1. Sustainability in the oil industry

The significant quantity of waste, along with environmental degradation, is continually increasing due to exploration, drilling, and oil spills (Yatimi et al., 2024). Sustainability has emerged as a way to transform the strategy, operational practices, and policy in an organisation (Chofreh et al., 2016), particularly in the oil industry (Cheng et al., 2023). Integrating sustainability practices into logistics within the oil industry requires effective project management to coordinate and implement initiatives (Chofreh et al., 2011) aimed at minimising environmental impact, optimising resource use, and ensuring compliance with regulatory standards. An oil industry that adopts a circular economy that includes a "reuse-refurbish-recycle loop" is likely to reduce operational waste, benefiting stakeholders while mitigating

environmental damage. A sustainable business model that creates more opportunities for the industry was emphasised in this study. According to Lu et al. (2019), the industry changes must be assessed from a technological point of view to track carbonisation's effect. Researchers found that blockchain technology is being used rapidly to solve problems related to three-dimensional scanning of underground reservoirs, oil and gas development programs, and oil and gas-related device design and maintenance. With this technology, the company can make more accurate decisions and map the carbon footprint, which further makes sustainability inevitable since these tools play a critical role in sustainable operations.

In the oil industry, the application of sustainability standards goes beyond following protocols and management cycles. It can help streamline logistics plans and improve efficiency (Ju et al., 2023). According to Shad et al. (2019), constructing a sustainability report is an affirmative tool for judging the effectiveness of sustainability standards. To minimise the carbon emissions throughout the supply chain, specific standards, such as carbon mapping, are established as the quality measures. The ISO 14001 standard focuses on social responsibility by providing a framework for managing the environmental impacts and promoting sustainable practices among the logistics and supply chain processes. The adoption of sustainability generally increases social responsibility operations, which indicates that sustainability is proportionately linked to social responsibility operations (Shad et al., 2019). This approach can help the oil industry to be more ethical and accountable. An integration of sustainability into production can also reduce the chances of oil spills and carbon emissions. Abdul Majid et al. (2021) explored that this integration can be enhanced by the use of advanced technology. Incorporating sustainability can be easier with the use of technology, which can help reduce errors and better manage issues.

The oil industry is always focused on incorporating sustainability into its activities. Nevertheless, the biggest problem is that many people do not understand what sustainability is (Bartos et al., 2024). Tambi et al. (2021) noted that poor training in the oil field can cause significant problems for sustainability due to unsafe practices. Hence, companies should put these sustainability practices into action and retain them for a long time. Tambi et al. (2021) argued that good adoption of technology depends on training staff properly. In this context, oil industry organisations must take proactive measures to implement both virtual and real-time training programs that leverage advanced technology. Maintaining momentum requires the integration of agile and collaborative training methods, enabling logistics operations to generate greater value. The training modalities should align with the employee's suitability, and the digital platforms can be employed to streamline and organise the training process effectively.

Environmental, social, and economic aspects of sustainability can be measured in the oil industry via a variety of important metrics. Several key indicators are used to measure sustainability in the oil industry, as provided in Table 1. Sustainability indicators are essential for guiding environmental stewardship, improving resource efficiency, managing risks, meeting stakeholder expectations, reducing costs, enhancing resilience, building reputation, fostering innovation, promoting transparency, and advancing sustainable development within the logistics of the oil industry. A rapidly changing global landscape demands indicators that can drive positive change and ensure the industry's long-term viability.

2.2. Value chain in the oil industry

The value chain process in an organisation is a critical pathway towards achieving efficiency and productivity across the entire operational chain (E&M Combustion, 2018). Fig. 1 shows the value chain process in the oil industry to provide a comprehensive view of the industry's operations and contribute to informed and responsible management of oil resources and supply chains.

Table 1
Sustainability indicators used for the oil industry.

Indicator	Explanation	Reference
Carbon Emissions	Monitoring greenhouse gas (GHG) emissions, particularly carbon dioxide (CO ₂) emissions, is crucial for assessing the environmental impact of the oil industry. Some of the key indicators are total emissions, emissions per unit of energy produced (carbon intensity), and the reduction of emissions over the course of time.	Atmayudha et al. (2021)
Energy Efficiency	The energy efficiency in the extraction, refining, and distribution of oil should be monitored for the sake of sustainability. This can be quantified with the use of energy used per barrel of oil equivalent (BOE) produced, or specific energy consumption.	Shinkevich et al. (2020)
Water Usage	Water usage and management practices evaluation in oil extraction and refining processes is essential. Indicators of the impact of the industry on the freshwater pools are illustrated by such figures as water consumption per unit of the produced oil or water recycling rates.	Cole et al. (2022)
Waste Generation	Monitoring waste generation and disposal practices helps assess the industry's environmental impact. The indicators include total waste generated, waste recycled or reused, and waste disposal methods (landfill, incineration, etc.).	Yeo et al. (2022)
Environmental Incidents	Tracking the number and severity of environmental incidents, such as oil spills or leaks, provides insights into operational risks and environmental management practices.	Zhang (2021)
Investment in Renewable Energy	Indicators related to investments in renewable energy projects or technologies by oil companies demonstrate their commitment to transitioning towards cleaner energy sources.	Rahman et al. (2021)
Community Engagement and Social Impact	Assessing social performance indicators such as community investment, local employment, and contributions to social development projects helps evaluate the industry's social responsibility.	Yuen et al. (2023)
Safety Performance	Monitoring safety metrics, such as occupational injury rates and compliance with safety regulations, is crucial for ensuring the well-being of workers and communities.	Mathisen et al. (2022)
Economic Contribution	Statistics on contributions of the industry to the economy, such as tax contribution, job creation and Gross Domestic Product (GDP) contribution, highlight its implications to the national and local economies.	Maitra et al. (2021)
Disclosure and Transparency	Indicators associated with reporting and disclosure practices, including compliance with the sustainability reporting frameworks (e.g., the Global Reporting Initiative (GRI) Standards) and reporting on transparency with regard to	Qothrunada and Handayani (2023)

Table 1 (continued)

Indicator	Explanation	Reference
	environmental and social impacts, should be provided, reflecting the industry's concern for accountability and transparency.	

The work of [Amorin and Mensah \(2022\)](#) elaborated that the process of the value chain in the oil industry can be divided into three main stages: upstream, midstream, and downstream. In addition, these three stages are subdivided into vital activities that assist in meeting the operational goals of the organisations. Among all these activities, upstream activities include exploration and production, middle stream activities involve storing and transporting, and downstream activities include refining and retail. It is claimed that understanding the value chain process can lead the industry to bring greater organisation and consistency into its actions. [Palacios-Mateo et al. \(2021\)](#) noted that the first stage of refining is when valuable oil is obtained through the use of chemicals. A value chain technique may aid the company in increasing its business speed. According to [Pinheiro Pires et al. \(2019\)](#), making use of modern technologies and biochemicals might help to improve the efficiency of refineries.

The process of exploring, drilling, and producing crude oil and natural gas is a part of the value chain process in the oil industry. An exploration activity identifies potential oil and gas reserves beneath the earth's surface using seismic surveys and other technologies. This stage focuses on the extraction of hydrocarbons from underground reservoirs. As soon as a viable oil or gas reserve has been identified, drilling rigs are used to drill wells into the earth's crust to confirm its presence and commercial viability. Depending on the geological characteristics of the reservoir, there are different types of wells, from vertical wells to more complex directional and horizontal wells. Following the drilling and completion of a well, oil and gas are extracted from the reservoir using pumps or natural pressure. Water is separated before being transported via pipelines or tankers to the processing plant.

As part of the oil industry's midstream activities, crude oil, natural gas, and refined products are transported, stored, and marketed wholesale. Pipelines, trucks, railcars, and ships are necessary midstream infrastructure to transport crude oil and natural gas liquids (NGLs) from production sites to refineries and processing centres. In addition to balancing supply and demand fluctuations, storage facilities ensure continuous delivery to downstream customers by storing oil and gas in tanks or underground caverns near production sites, refineries, or distribution hubs. The process of processing natural gas involves separating methane (natural gas) from other hydrocarbons and impurities. Processing plants fractionate NGLs into individual components for further use or sale.

The refining of crude oil and sending the petroleum products to buyers is done in the downstream activities of the oil industry. At refineries, crude oil is refined to make gasoline, diesel, jet fuel, heating oil, lubricants and a variety of different petroleum products. To make usable products from hydrocarbons, refining includes distillation, cracking, and various other chemical processes. Oil refineries send refined products to distribution terminals using pipelines, ships, barges, trucks, or railcars. Blending and storing different types of fuel, distribution terminals then provide the fuel at retail outlets, airports, to industrial clients, and individuals. Refined products supplied by distributors are offered by gas stations, airports, and industrial companies to the public. Organisations at this stage focus on retail sales, advertising and taking care of customers.

The value chain in the oil industry is highly interconnected, with each stage relying on the others to deliver oil and gas products efficiently and cost-effectively to end-users. Integration across upstream, midstream, and downstream activities optimises supply chain performance and enhances overall industry competitiveness.

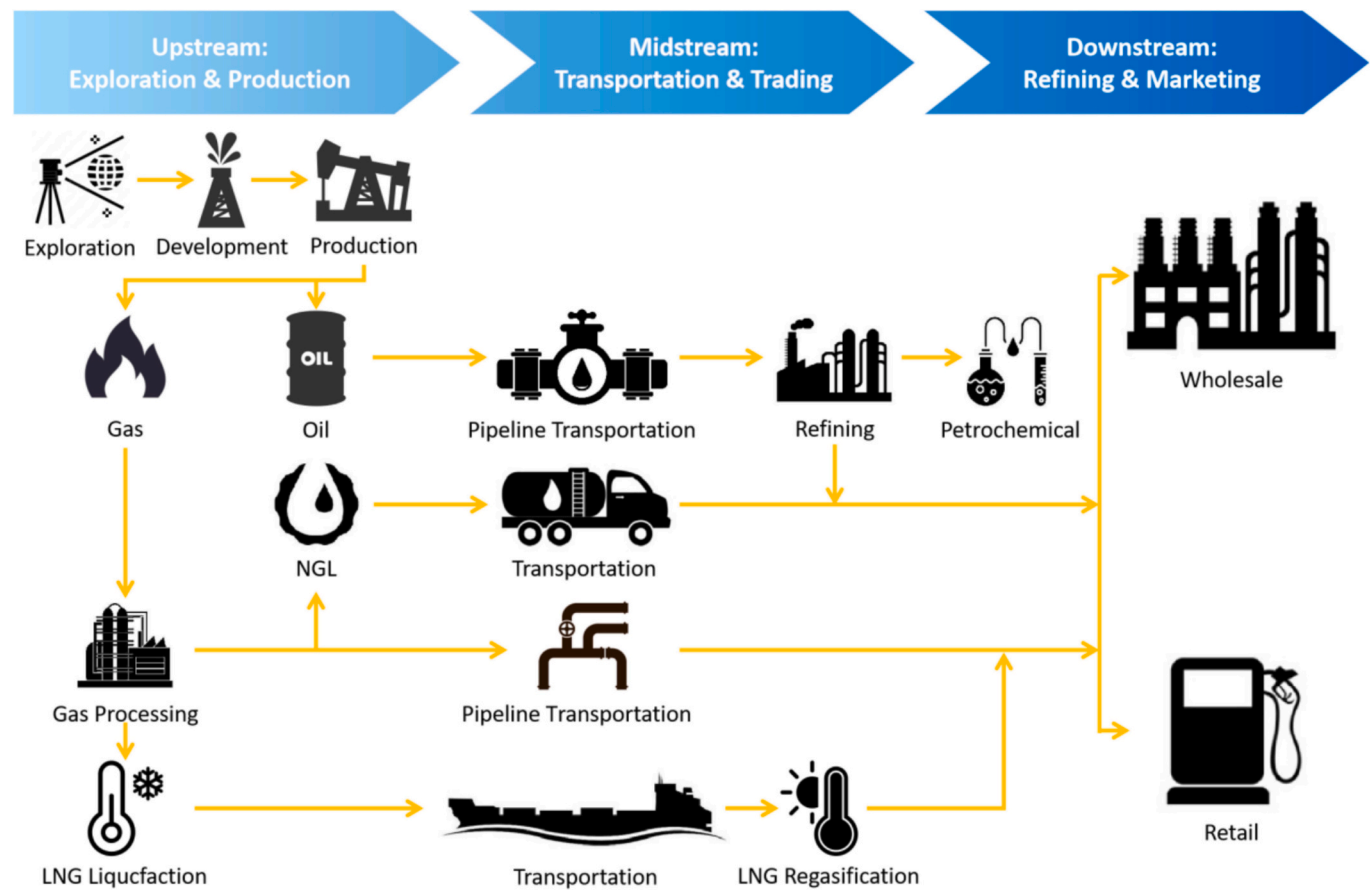


Fig. 1. Value chain process in the oil industry (adapted from E&M Combustion, 2018).

This study uses value mapping to analyse and optimise business processes to deliver value, specifically sustainable value, to customers efficiently. It plays a vital role in helping the organisation understand how to organise its logistics path. Value mapping offers a micro-level view by focusing on specific processes within the value chain to identify opportunities for improvement.

Fig. 1 depicts the importance of the upstream, midstream, and

downstream activities in enhancing the operational value of organisations. Beiranvand et al. (2022) focused that optimising the value chain involves a maximising value through the strategic alignment of the supply chain parameters. The analysis further indicates the identification of the core activities and gaining insights into the logistics scope are essential in pinpointing areas for the potential improvement, thereby enabling effective value chain optimisation. Apart from locating the

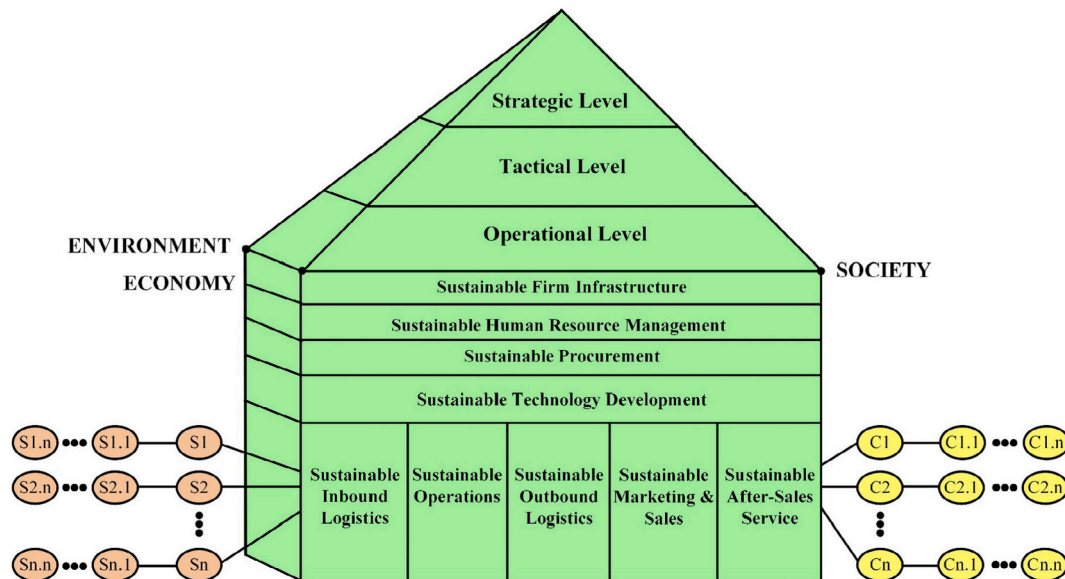


Fig. 2. An extended sustainable value chain (Chofreh et al. (2014)).

areas of sustainability, it can help the organisations in the industry of oil identify the more visibility into operations by the use of value process mapping. At the maximum benefit, it can help in tracing networks and working with data to that effect. Fig. 2 depicts the extended sustainable supply chain model integrating sustainability dimensions across the strategic, tactical, and operational level of an organisation. It highlights the role of sustainability in key functions including logistics, operations, marketing, and after-sales service, while aligning with firm's infrastructure, human resource management, procurement, and technology development to drive long-term value and responsible resource management.

It has been pointed out by some scholars that the use of blockchain in logistics can contribute value to the industry (Gurtu & Johnny, 2019). It was shown in the study that utilising blockchain can provide better transparency, as well as increase the agility in every stage of the supply chain. The offering of value helps create quality for the customers (Khan et al., 2022). Through blockchain technology, storage and listings can be managed, as well as transactions proven and stored reliably. Keeping sustainability as a priority throughout the chain allows all stream activities to be tracked perfectly.

Moreno-Garcia and Elyan's (2019) study signified that the digitalisation could be remarkably enhance the supply chain management by the streamlining operations and effectively delivering value parameters. Their study focused on the mapping of the carbon footprints and implementation of precise measurement techniques can further optimise value generation for end users. Incorporating the technology enables organisations to assess the refinery capacity more accurately, which facilitating the better decision making in the oil industry. Kaviani et al. (2020) emphasised on the value, which is derived from the integration of quality standards, effective methodologies and a robust regulatory framework. Consequently, the oil industry is poised for the substantial growth with the implementation of value-driven logistics synchronization and regulatory alignment.

2.3. Logistics in the oil industry

Logistics usually means organising and guiding transportation and shipping within a company (Karaman et al., 2020). Following Lisitsa et al. (2019), logistics activities in the supply chain involved: (a) transporting, (b) storing, and (c) distributing crude oil, refined petroleum products, and natural gas. It helps make sure hydrocarbons can move efficiently from the production area to places like refineries, terminals, and end-users. The study underscores that companies in the oil industry increasingly focus on outsourcing, enabling them to collaborate with competitors and enhance operational efficiency. Such collaborations extend to suppliers, some of whom hold a strong competitive position in the market. With the global demand for oil steadily rising, the role of logistics becomes increasingly critical in sustaining operational continuity. Okeke (2021) argued that the supplier power remains relatively high in the oil industry, as a limited number of suppliers dominate the market. Consequently, effective supplier relationship management is essential for optimising logistics performance.

The growing global demand for oil highlights another key logistical challenge, which is resource scarcity. Ayompe et al. (2021) studied that poor inventory management and limited forecasting capabilities can adversely impact the profitability of business. Thus, achieving seamless logistics operations necessitates robust tracking systems and the comprehensive mapping of the entire logistical process to mitigate the potential disruptions and to maintain operational momentum.

Since transporting, storing, and distributing crude oil and petroleum products have significant environmental, social, and economic impacts, logistics considerations in the oil industry are closely related to sustainability issues. The reduced carbon emissions, the minimisation of the use of natural resources, the enhancement of waste management, the ensuring of safety, and the demands of the regulations are aimed to be achieved within the course of the sustainable logistics practices. By

considering sustainability aspects in the logistics process, oil companies can achieve operational efficiency, risk mitigation, and even pave the way for a more sustainable usage of energy. This approach conforms to Torres-Rubira et al. (2023) study aimed at establishing the incentives for adopting the system of Safety and Quality Assessment for Sustainability (SQAS), which estimates the levels of sustainability involving quality, safety, security, and environmental needs among logistics providers in the distribution of European chemicals.

Besides this, due to the shifting nature of the global market, the oil industry would have to embrace some of the key trends in logistics to optimise the operational parameters (Qiu et al., 2022). The automation with the focus on demand and pull criteria, and the performance of forecasting analyses, is viewed as a trend. This can bring agility and resilience in the handling of inventory, facilitating organisations to monitor the flow of oil well enough. In logistics, there are advanced technologies that can be used in the development of customised solutions for the variations in the industry. To devise such a seamless logistics cycle, it is still vital to raise such concerns in the oil industry because it still has to establish a solid strategic front. These elements of logistics are necessary for an organisation to keep the process operating. All of these variables have their own way of affecting the process. Ali et al. (2020) emphasised that inventory management plays a vital role in logistics and is very much connected to warehousing. Inventory serves to control the movement of goods from one place to another. In this topic, mention is made of sustainable inventory practice because it enables companies to organise products efficiently. It is much more than a place to store oil in the oil industry. It lets us understand how much demand there is for a product. A well-organised approach to inventory in the oil industry lets companies regulate when and what is produced. The products are transported by methods that suit the requirements of the transportation (Al-Douri, 2020). During this part, oil spills and high carbon dioxide emissions can greatly harm the environment. With the role of transport being important in logistics, the oil industry should develop new plans to deal with this issue. In the opinion of Gyamfi et al. (2021), abiding by sustainability and all required rules in the industry increases the effectiveness of its transport segment. When transporting oil from one place to another, tracking devices have become an important tool for measuring the overall carbon emissions. The element includes information and control, which are typically controlled by technologies such as artificial intelligence, the Internet of Things, digital twins, and blockchain (Wanasinghe et al., 2020). When these technologies are applied correctly in all these elements, synchronization can be achieved, resulting in a more productive operation (Gyamfi et al., 2021). Considering the complexity associated with the activities in this element, automation becomes an inevitable factor due to the vast amount of data stored regarding orders, time, and other details. By automating logistics operations, human errors can be eliminated, and the productivity of the operation can be further enhanced.

2.4. Literature summary

In the literature review, sustainability has been found to be crucial to the oil industry, as it improves agility and transparency. Through value mapping, logistics and value chains enable organisations to create value across all chains, leading to sustainable development in the oil industry. In the logistics and value chain processes, innovative technology has been identified as a useful tool for enhancing agility and resilience. However, research on this topic has been limited. Sustainable practices in the oil industry have been studied in relation to logistics and the environment. However, there is limited research analysing the logistics of the oil industry in relation to all three dimensions of sustainability, namely the environment, economy, and social factors. Although some studies have looked at the environmental impact or economic aspect separately, comprehensive research that integrates all three dimensions is lacking. The reason why we need to enhance our understanding of how the practices of logistics can contribute to the economic viability,

welfare of the people, and environmental issues of the oil industry is due to this gap. This study contributes to sustainability efforts and examines how technologies may contribute to enhanced efficiency of value chains and their resilience through a value chain analysis of the logistics in the oil industry. By bridging this gap, the oil industry will be given the opportunity to gain a great deal of insight into ways of writing more sustainable practices and policies.

3. Research methodology

Research methodology describes how a study was conducted, including the research design, the collection and analysis of data, as well as considerations concerning the validity and limitations of the study's findings. This section explained how data were collected and analysed, as well as the reliability and generalizability of the findings.

3.1. Research design

Using the research approach and research strategies, inductive analysis was done on the study of logistics in the oil industry's contributions to sustainability initiatives in the value chain. They created theories about value chains based on sustainability activities in the oil sector by looking at the details of various and applicable logistics. Logistics practices contribute to analysing the oil industry's value chain by making it easier for patterns to appear in the collected data. In an analysis of a value chain, these strategies help to sustain the company's activities. It adds more details to the way value chain logistics plays a role in being sustainable.

Qualitative data collection methods were analysed at important logistical and sustainability metrics within the oil industry. Analysis of the whole study was carried out through an action-based research strategy. Value logistics practitioners and environmental experts are commenting on subjective experiences and interpretations. As one of the aspects of the research strategy, it has been possible to evaluate the effectiveness of the sustainability initiatives over different regions and oil companies. To better understand how logistics practices and sustainability initiatives are connected, this all-encompassing research approach is meant to illustrate this connection. Fig. 3 depicts the overall research process.

3.2. Data collection and analysis

In an overall integrated way, a mixed-methods approach is utilised in exploring sustainability integration in the oil industry by combining qualitative and quantitative methods. A qualitative phase generates

rich, contextualised insights from those who are key stakeholders, and a quantitative phase assigns the prioritisation of integration activities pertaining to sustainability integration using a multi-criteria decision analysis (MCDA) method. This research integrates a data-driven review of integration strategies and in-depth opinions on the challenges of sustainability.

In the qualitative phase, it includes a thematic analysis of primary and secondary sources of data. The secondary data were gathered from academic databases (such as PubMed and Scopus), industry reports, government documents and other relevant web sources. Sustainability efforts in the value chain logistics were described in those sources in a general way. In the course of primary data collection, interviews were carried out with experts from three industries, which included a logistics specialist and an environmental expert who shared valuable insight on the complex nature of sustainable logistics. This process aimed to have a better understanding of the integration of sustainability in the oil industry. The collected data were then systematically coded and categorised through thematic analysis.

Quantitative analysis was conducted using the Best-Worst Method (BWM), developed by Rezaei (2015), to prioritise sustainability integration activities. BWM is one of the most efficient multi-criteria decision-analysis techniques (Darvazeh et al., 2022). This method provided a structured approach to evaluate and rank various sustainability activities. The BWM methodology involved the following steps: Defining the activities to be prioritised.

1. Identifying the best and worst activities.
2. Assessing the degree of preference of the best activity over the other activities.
3. Assessing the degree of preference of the other activities over the worst activity.
4. Calculating the final weight of the activities. To determine the optimal weights of the activities, for every couple of w_B/w_j and w_j/w_W should be satisfied $w_B/w_j = a_{Bj}$ and $w_j/w_W = a_{jW}$ for all j . Therefore, a solution should be found where the maximum absolute value differences $\left| \frac{w_B}{w_j} - a_{Bj} \right|$ and $\left| \frac{w_j}{w_W} - a_{jW} \right|$ minimise for all j . Due to the non-negative weight of each activities ($\sum_{j=1}^n w_j \geq 0$) and the constraint that satisfies the sum of weights ($\sum_{j=1}^n w_j = 1$), the optimisation model is formulated as Eq. (1). By solving this model, the optimal weights of all activities ($w_1^*, w_2^*, \dots, w_n^*$) and value ξ^L were obtained.

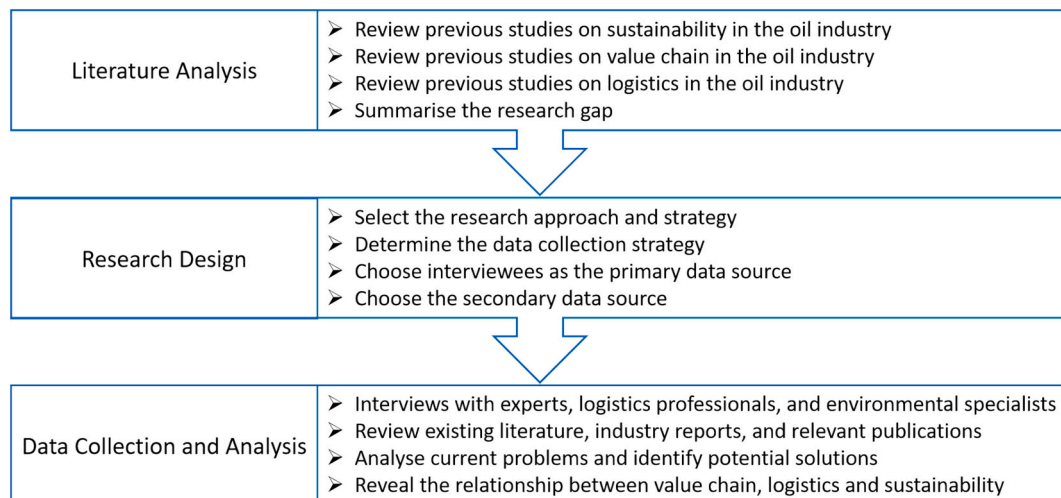


Fig. 3. Research process.

$$\begin{aligned} \min_{\xi^L} \quad & \\ \text{s.t.} \quad & |w_B - a_{Bj}w_j| \leq \xi^L, \text{ for all } j \\ & |w_j - a_{jW}w_W| \leq \xi^L, \text{ for all } j \\ & \sum_j w_j = 1 \\ & w_j \geq 0, \text{ for all } j \end{aligned} \quad (1)$$

Where w_B denotes the weight of the most important activity, w_W denotes the weight of the least important activity, w_j represents the weight of j , a_{Bj} denotes the degree of preference of the most important activity over the activity j , and a_{jW} represents the degree of preference of activity j over the least important activity. Calculating Inconsistency Ratio (IR).

To calculate the inconsistency ratio, the value of ξ^{L*} obtained in the previous step, along with the consistency index (CI) reported for different values of a_{BW} (as shown in Table 2 and according to Eq. (2)), are used.

$$IR = \frac{\xi^{L*}}{CI} \quad (2)$$

3.3. Reliability and validity of the study

The study considers content validity by conducting a thorough literature review and consulting with subject matter experts. These experts include logistics professionals and environmental specialists. As part of this study, experts were crucial in identifying the relevant concepts, variables, or themes to be included in the value mapping based on the research objectives. Experts are important in ensuring that concepts, variables, or themes are clear, relevant, and appropriate by refining their wording. A Kappa Kohn analysis was conducted to ensure the reliability of qualitative data. As a statistical index for qualitative research reliability and consistency among experts throughout different stages of coding, the Kappa coefficient is widely used (Gisev, Bell, & Chen, 2013). The research applied the consistency ratio to the quantitative phase to confirm its reliability. Multi-criteria decision analysis relies heavily on evaluating the consistency rate to ensure that decision-makers' judgments are logically coherent, resulting in dependable decisions (Pant et al., 2022).

Several potential limitations should be acknowledged and discussed when analysing the logistics in the oil industry as a contributor to sustainability initiatives. Firstly, the study focused on specific segments or regions in the oil industry, which could limit its generalisability. Additionally, the study was conducted within a limited timeframe, which might not have captured long-term trends or changes in sustainability practices. This study has, however, identified the main important logistics process activities that can be used to determine performance improvement opportunities.

4. Analysis of results and discussions

The section elucidates data collected through the interviews to provide clearer insights into logistics operations in the oil industry. Primary findings and analyses can help in incorporating real-time information into the research. As a result, this study can become more data-driven and factual. Secondary qualitative findings will be incorporated by analysis of the peer-reviewed journals relevant to the research. The discussion section compares and contrasts data with the literature review to show the points of differences and similarities. This helps in interpreting the results more comprehensive and organised.

Table 2
Consistency index (CI) of BWM.

9	8	7	6	5	4	3	2	1	a_{BW}
5.23	4.47	3.73	3.00	2.30	1.63	1.00	0.44	0.00	CI

4.1. Analysis and discussion of primary data

As illustrated in Fig. 4, the logistics process in the oil industry is mapped based on the primary analysis. The logistics process consists of a number of key activities upstream, midstream, and downstream. As a result of these activities, synthesis is maintained in the operational space, followed by increasing value.

4.1.1. Upstream activities

In the upstream activity, including exploration, development, and production, the role of research and development (R&D) is very important to accelerate operational efficiency, technological innovation, and sustainability at large. According to the experts, it is a process that systematically investigates and experiments to discover new technologies, improve the procedures and treatment of problems experienced in the upstream activity, exploration, development and production of oil and gas resources.

R&D activities are key to bringing technological innovation into exploration. There have been new developments in R&D in regard to the new technology of seismic imaging, drilling methods (directional drilling, extended reach drilling), and models of reservoir construction, to increase the rates of exploration success. R&D is useful in the creation of more effective and affordable exploration techniques. Such as the application of machine learning algorithms for lecturers' interpretation of the seismic data or the implementation of remote sensing technologies for their definition of possible hydrocarbon reserves.

R&D aims to come up with better ways of characterising reservoirs and better plans for developing reservoirs by learning about sub-surface formations. In this field, there is the application of methods such as fluid flow modelling, well spacing optimisation and enhanced oil recovery (EOR). Developing drilling and completion technologies can make drilling more effective, reduce the ecological footprint and improve the well integrity. One of the most important functions performed by the R&D is planning out the methods of enhanced oil recovery (EOR) such as steam flooding, chemical injection, and gas injection to restore the mature fields at the production activity's service. Over the course of R&D, better systems of asset management and tools of predictive analytics emerge that optimise production processes, minimise downtime, and lower the cost involved.

The experts are of the view that R&D activities are necessary for overcoming the challenges posed by the industries, maximising the utilisation of resources, and increasing upstream competitiveness and sustainability. Some of the initiatives and partnerships include cooperation movements and industry partnerships such as cleaner methods of production, low emission of greenhouse gases, and the reduction of an environmental footprint. With time and more research and technology, the company will be able to find a balance between meeting the global energy demand and advancing towards a more environmentally friendly future. It is a frequent case when natural gas is produced simultaneously with crude oil inside the reservoirs. The associated gas has hydrocarbons which can be processed and used. Gas processing facilities are used for the processing of gas during upstream operations. Oil fields send crude natural gas streams to these plants where it is separated to valuable products such as methane, ethane, propane, butane, and liquefied natural gas (LNG). To liquefy natural gas, it has to be processed and purified. LNG liquefaction is the process of cooling the purified natural gas through extremely low temperatures (-160°C to -162°C) to change its state from gas into a liquid state for simpler storage and transportation. Containerisation is greatly utilised in the transportation of gas. LNG occupies approximately 1/600th volume of natural gas in gaseous form,

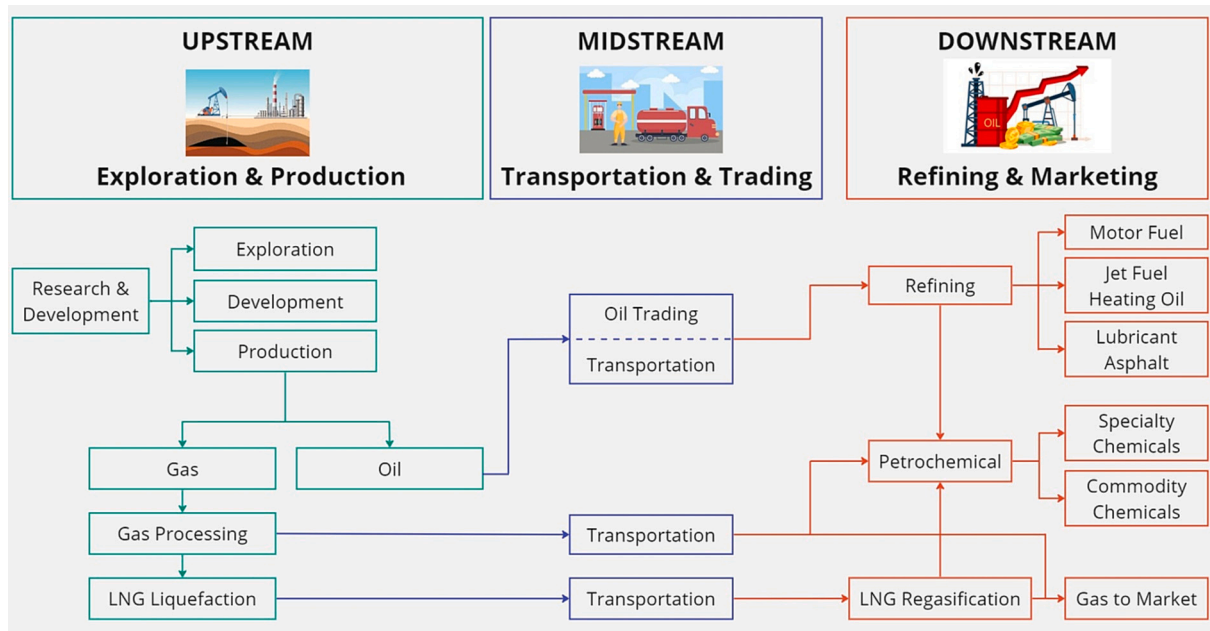


Fig. 4. A Complete logistics process in the oil industry (adapted from E&M Combustion (2018) and expert review).

and therefore easier to transport by sea in vessels. In areas that have no access to domestic gas, LNG allows countries that have an excess gas supply for export in order to supply natural gas. When regions move from coal or attempt to decrease carbon emissions, LNG helps to diversify the energy mix.

For the oil industry to contribute to its broader sustainability initiatives, embedding sustainability in downstream activities is crucial. However, sustainability is not always implemented optimally. There are several strategies that can be applied to improve the quality of the products and the performance in the environment, integrate cleaner greener technologies, implement waste reduction and recycling programs, promote health, safety and well-being, implement Environmental Management Systems (EMS), collaborate and engage with the stakeholders, invest in research and innovation, set and measure sustainability goals, and develop oil downstream activities play a crucial role in ensuring sustainability, lowering the level of environmental impact, and improving corporate responsibility by embracing the listed strategies. Sustainability not only brings risks into business but unleashes opportunities to innovate, cut down costs and deliver long-term value.

For the sustainability practice to be incorporated into downstream operations in the oil industry, there is a need to have cleaner, greener technologies. The carbon emission due to energy consumption can be minimised by directly investing in investment in renewable energy, as is the case with solar or wind power to power the downstream operations, and measures of energy efficiency should be carried out. To minimise environmental impact and enhance operational sustainability, energy-saving technologies are being applied to modernise the equipment, to improve the insulation, and to use energy better. Through the implementation of such strategies, downstream activities in the oil industry can play a major role in sustainability drives, ensuring the efficiency of resources and conservation of the environment.

The oil industry has to work to encourage sustainable packaging and low-carbon fuels in order to enhance product quality and environmental performance downstream. Low-carbon fuels or renewable fuels such as biofuels, hydrogen, or synthetic fuels can be used to drastically reduce the amount of greenhouse gases emitted, compared to conventional fossil fuels. The use of recyclable or biodegradable materials for product packaging helps to minimise wastage and the impact on the environment in the lifecycle of a product. Due to such initiatives, the

downstream operations become more sustainable and fit in wider objectives of sustainability, with the whole oil industry promoting such programs.

The experts were keen to note the necessity of enforcing credible waste reduction and recycling programs. For instance, by-products that build up in refining and distribution processes can be recycled and reused. Ecosystems and public health equally depend on the recovery of valuable resources through recycling, curbing waste and minimising impacts on the environment. In addition, proper disposal of hazardous waste will protect ecosystems and the public. Apart from complying with environmental regulations, hazardous wastes ought to be treated and disposed according to the environment. These waste reduction and recycling practices support a more sustainable and responsible attitude in downstream activities, where environmental conservation and resource efficiency are concerned in the oil industry.

Another possible measure is to focus on health, safety, and well-being initiatives. This starts with ensuring the safety of the workers by training them thoroughly, providing them with the required personal protective equipment (PPE) and observing rules on the standards of occupational health carefully. By ensuring that the welfare of workers is prioritised, downstream operations can not only make the workplace safer but also more productive whilst putting workplace dangers at bay. Interaction with local communities is important in enhancing a positive relationship and taking care of environmental matters. Contributing to activities that promote health and education among the local residents around the areas of operation through corporate responsibility is a way of creating greater well-being for the citizens. By engaging in frontline health, safety, and community service advocacies, the downstream side of the oil industry can foster larger issues concerning sustainability and develop trust with stakeholders.

The strength of EMS in the oil industry is important. This entails employing internationally recognised standards of the environment, such as ISO 14001 in order to define the objectives, measure the performance, and what should be done to make continuous improvements in the environment. By following these standards, downstream operations can be able to handle environmental risks effectively as well as minimise the ecological footprint. Another initiative is to carry out periodic environmental audits are critical in performance appraisal and compliance with regulatory requirements. Environmental audits can help point out the areas for improvement, correct non-conformities, and

make environmental reporting more transparent. With the integration of environmental management systems and regular audits, the oil business's downstream activities can improve sustainability performance and reduce environmental impact, while demonstrating responsible practice with regard to stewardship of the environment.

Another initiative in contributing towards sustainability initiatives can be undertaken through collaborations with non-governmental organisations (NGOs), government agencies (in sharing knowledge, experience and contributing towards sustainability initiatives). Partnering with external stakeholders makes it possible to use expertise, resources to address the challenges of sustainability effectively. Besides, close interaction with customers and suppliers is important to spread sustainable activities along the supply chain. Collaborating with stakeholders can enable downstream operations to adopt fresh solutions, promote transparency, and respond to changing sustainability expectations. This collaborative effort enhances interconnection, esteem, and collective efforts towards sustainability objectives in the oil industry.

Sustainability objectives setting and monitoring are important to contribute to the sustainability initiatives. The next step is to create objectives that can be measured for energy efficiency, lowering emissions, cutting down on waste, and being involved in the community. With set targets, downstream companies can focus on the main sustainability areas and check their progress towards the objectives. By frequently checking sustainability performance and reporting results, it becomes easy to prove one's accountability and transparency to stakeholders. When sharing data about reductions in carbon or info about impact on the community, downstream actors can illustrate that they care about doing the right thing. By having and following sustainability goals, the oil industry becomes more accountable and turns towards lasting environmental and social improvements.

It is important to promote a sustainability culture in the activities that happen after oil is extracted, as it is key to starting change and lasting activities. The employees require proper training and education on how to act sustainably. Increasing employee understanding and involvement enables them to actively contribute to sustainability initiatives and integrate sustainable practices into daily operations. Recognising sustainability achievements is important for reinforcing positive behaviour among the employees and motivating continued progress. When employees' efforts and success in furthering the sustainability goals are recognised, a culture of constant improvement and creativity is established. This creates motivation, commitment and collective responsibility as regards sustainability in the organisation to promote positive impact and instil a sustainable mindset in downstream operations.

4.1.2. Midstream activities

In the midstream oil industry, logistics in terms of transport and trading is a key ingredient in moving crude oil, refined products, and natural gas from where they are produced to where they will be refined or consumed. The movement of crude oil and refined products through the midstream segment of the oil industry is a complex process using many logistics methods to ensure the oil moves efficiently from production to turnover. Pipelines are the dominant transport mode because pipelines move a lot of oil from point A, where it is produced, and point B, where it is ultimately refined, and thus, at an economically viable and environmentally friendly capacity, over distances. The second largest logistics mode of transport is by railcar, especially when rail is the only option available to move products where a pipeline does not exist, but more importantly, railcar can fill the gap in remote locations to move oil to the final mile within a particular market. Tanker ships, while not frequently associated with logistics specifically, serve as logistics transport modes for crude oil and petroleum products across oceans and waterways to connect production areas to refineries and global markets. Trucks are the key component of logistics, as they transport crude oil and petroleum products to refineries, distribution channels, or consumers. There are a wide variety of modes of logistics in transport that

demonstrate how broad supply chains can be, and likewise, the distribution of oil and gas products works well within the midstream of the oil industry.

There are many reasons why cost-effective and efficient logistics are important to the midstream operations of the oil industry: first, the logistics cost savings contribute to overall supply chain efficiency, which creates opportunities for cost savings in transportation. Effective logistics operations that are reliable provide value to an oil company by ensuring crude oil and refined products move domestically and internationally as planned, and this gives oil companies their plans for revenue, profitability, and sustainability in the markets they operate in. Effective logistics provide a sustainable transport and minimise the impact on the environment as oil companies strive to minimise emissions throughout the movement of oil and gas products while maintaining the safety standards.

Well-managed logistics contribute to delivering security by maintaining adequate inventory levels and ensuring continuity of product deliveries, thereby meeting market demands and enhancing overall operational resilience. By prioritising efficient logistics in midstream activities, oil companies can achieve cost savings, market competitiveness, environmental stewardship, and supply chain reliability.

Based on the analysis, it can be stated that in the transportation stage, sustainability has been applied. However, there are still other areas that require sustainable practices. In this context, the primary analysis sheds light on the management, resources, and technological strategies that are needed to ensure the successful application of sustainability. The experts mentioned that embedding sustainability into midstream activities, specifically oil transportation and trading, is essential for advancing broader sustainability initiatives within the oil industry. One key strategy is to optimise transportation efficiency by maximising the use of pipeline infrastructure for transporting crude oil and refined products over long distances. Pipelines are recognised for their energy efficiency and lower carbon footprint compared to alternative transportation modes like trucks or ships. Promoting shifts towards more sustainable transportation modes, such as railcar and marine shipping, can further reduce reliance on road transportation and minimise emissions. Implementing energy-efficient practices across transportation operations, including the adoption of technologies to optimise fuel efficiency, contributes to reducing environmental impact.

As part of lowering the impact on the environment, midstream operations may opt for electric or hybrid cars for local movement and change over to cleaner fuels. The company should take strong measures to prevent and respond to spills so that any environmental effects can be reduced if an accident happens. Considering the use of solar or wind energy to fuel transportation and trade can make companies less dependent on fossil fuels and help reduce their impact on the environment.

Besides focusing on the environment, having sustainable trading practices is vital for midstream work. It is necessary to promote the use of crude oil and petroleum produced ethically, to ensure that suppliers do not engage in cutting down forests, harming people, or other practices that are not environmentally sound. Taking part in carbon offsetting programmes helps balance the climate impact caused by transportation and trading activities. Using technologies such as blockchain makes it possible to follow the supply chain closely, ensuring that ethical practices are used for sourcing and trading.

It is important to partner with NGOs, authorities, governments, customers, and suppliers to implement ethical business practices and ensure sustainability in the supply chain. Developing new ideas and making improvements in sustainable technologies for delivery and trading activities, along with reducing waste and maximising how we use resources, are vital for promoting sustainability in the midstream sector. Setting specific targets for emissions, energy usage, wastage, and engagement with local communities, and frequently checking progress and reporting helps midstream companies show responsibility and support broader oil industry sustainability initiatives.

4.1.3. Upstream activities

Adding sustainability to the start of the oil process, especially in refining and marketing, is vital to contributing to sustainability. To accomplish this, refining operations can improve equipment and processes, use heat recovery, and manage energy more efficiently to lower their use of energy and cut their greenhouse gas emissions. Producing fuels with less sulfur and more biofuels can mitigate pollution and encourage the use of cleaner methods in transportation. Putting stricter control in place and managing waste properly adds to how sustainable the food manufacturing sector is.

Refineries have the opportunity to use the supply chain more efficiently to decrease the miles needed for product delivery and related emissions. Using different types of transport, for example, railcar, marine, or pipeline, has a smaller adverse effect on the environment than using conventional road transport. Incorporating recyclable materials in packaging and ethical methods of advertising contribute to being environmentally friendly and clear with the public.

It is important for a business to reach out to the community and cooperate with customers, suppliers, and others in charge of regulations to solve concerns, develop local projects, and achieve environmental goals as a group. Placing efforts on new technologies and circular economy solutions is a main strategy for greening activities upstream. Setting and adhering to easy-to-understand sustainability goals in energy, the environment, waste, and the community, and reporting on how well the company is reaching them, is a clear sign of commitment to sustainability. These methods help make the oil industry stronger and more sustainable, and improve key environmental and social factors.

Carbon emission maps prove to be beneficial for determining the average carbon emissions. As a result, the industry manages to remain resilient and accurate in its logistics practices. It is intended to bring more value to the logistics process by uniting operations which happen at various parts of the value chain. The main analysis highlights the concept of supply chain resilience and the main framework related to it, as this helps to control factors, including exogenous and endogenous.

Based on the study of the interview data, the role of sustainability is now more noticeable in how the oil industry handles logistics. In addition, sustainability has contributed to the oil industry moving logistics with more agility, flexibility, and speed. It helps reduce waste in the oil industry, which can enhance how the supply chain processes are organised. Basile et al. (2021) believe that applying the reuse-refurbish-recycle loop is an important step that can streamline the way logistics are managed by an organisation.

The adoption of advanced technology can significantly increase the agility and transparency in the logistics processes of the oil industry. Conducting the comprehensive environmental analysis of upstream and downstream operations advancing organisations to effectively incorporate sustainability into their logistics strategies. Thus, implementation of the environmental standards and education of employees on practical sustainability practices could have substantial beneficial effects on the oil industry's logistics operations.

Interview insights align with existing literature, indicating that infrastructure remains a critical challenge in logistics operations, directly impacting the implementation of sustainability initiatives. Consequently, the oil industry must stick to the measures to maintain the supply chain continuity and mitigate infrastructure-related issues.

The literature further emphasises the adoption of value chain mapping in supply chain management, as it fosters transparency and efficiency within the logistics systems. Chofreh et al. (2019) ensured that value mapping is a critical strategic point for ensuring operational transparency and viability. By designing an effective value chain framework, organisations can identify the multidimensional aspects of supply, ensuring value retention across all the process stages of logistics operations. There are primary key actors in the oil industry that enable organisations to sustain the logistics process. These actors include oil producers and extractors, midstream companies, refineries, logistics and transportation providers, oil traders and marketers, regulatory agencies

and governments, technology providers, and industry associations and collaborative initiatives. To keep the logistics process in the oil industry working well, these key actors cooperate, focus on the efficient movement of oil and petroleum goods from extraction to use, stick to the set rules, and use advanced technology for both better operations and less impact on the environment. For resilience to last throughout the logistics process, parties must work as a team to make it happen. Table 3 shows the main role of each group involved and their impact on sustainability.

4.2. Analysis and discussion of secondary data

Sustainability encourages companies to achieve an advantage over rivals in the market. It has been stated by Langshaw et al. (2020) that conducting an environmental and economic analysis makes it possible for oil businesses to quickly switch from diesel to other alternatives, such as LPG. Thus, the companies in the oil industry are able to implement sustainable logistics and continue to improve their value chain as a whole. Analysing the economy and environment related to LPG makes it possible to identify weak spots in sustainability within the logistics process. It is useful in outlining dangers in the supply chain, which plays a role in setting the total value offered by the oil market. If sustainability is followed throughout the oil industry's value chain, this could significantly decrease the possibility of harming the environment and cutting down on carbon emissions.

Before designing an efficient sustainable formulation, it is critical to grasp the key mechanisms for adopting sustainability. Adopting a sustainable loop could foster a business model that enhances the value chain process within the oil industry. Alkaraan et al. (2022) found that transforming the business operations can further facilitate such sustainable practices significantly. Incorporating technology not only streamlines business processes but could decrease the potential errors, thereby optimising supply chain operations through increased agility and flexibility.

The integration of technology can be least complex by the implementation of sustainability initiatives, particularly in value chain mapping within logistics. Brand et al. (2020) focused on achieving net-zero targets that required a comprehensive sustainable framework, encompassing upstream, downstream and midstream processes. Designing a robust supply chain framework can enhance resilience and efficiency, which will further promote sustainable practices across the industrial environment.

However, adopting advanced technology necessitates a shift from traditional infrastructure to more manageable systems. Upadhyay et al. (2021) found infrastructure deficiencies as major hurdles to effective logistics management in the oil industry. Since technology and infrastructure are interdependent, a lack of advanced infrastructure can hinder automation efforts and negatively impact overall financial performance. Thus, organisations must constitute a strong infrastructure to effectively implement technological advancements.

Conversely, Tambi et al. (2021) argued that inadequate training poses a significant challenge to operational efficiency in the oil industry. Insufficient training can impede employees' ability to utilise new tools effectively, undermining the successful integration of sustainability and technology initiatives. Consequently, organisations must prioritise training to mitigate these risks and facilitate smoother transitions to advanced operational models. It is argued that a lack of knowledge among employees makes it more complex to manage and successfully incorporate sustainability within a business. To mitigate these challenges, the business model must change, and the company must shift to a dynamic operational model of logistics. This can help logistics operations to gain more agility and momentum. Fig. 5 summarises the integration of sustainability strategies across upstream, midstream, and downstream activities within the oil industry based on the primary and secondary data analysis. The detailed activities are provided in Table 4.

Table 3

Key actors in the logistics process in the oil industry.

Actor	Role	Contribution to sustainability
Oil producers and extractors	The companies that are responsible for extracting crude oil from oil fields. They play a critical role in initiating the supply chain process by providing the raw material for downstream activities.	Oil producers have the opportunity to adopt sustainable practices in oil extraction, such as minimising environmental impact during drilling, reducing water usage, and implementing responsible land reclamation post-extraction. They can invest in renewable energy technologies to power their operations.
Midstream companies	Midstream companies are involved in transporting, storing, and distributing crude oil and petroleum products. They operate pipelines, terminals, tankers, and other infrastructure essential for the transportation of oil from production sites to refineries and markets.	Midstream companies can contribute to sustainability by optimising transportation routes to reduce carbon emissions, implementing leak detection systems to prevent spills, and investing in pipeline maintenance to ensure safe operations. They can prioritise eco-friendly practices in storage and distribution facilities.
Refineries	Refineries process crude oil into refined petroleum products such as gasoline, diesel, jet fuel, and various chemicals. They are key actors in the oil industry responsible for transforming raw crude oil into usable products.	Refineries play a crucial role in sustainability by focusing on energy efficiency during refining processes, reducing air and water pollutants, and exploring cleaner production methods such as biofuels and hydrogen production. They can promote circular economy practices by recycling and reusing waste materials.
Logistics and transportation providers	Companies specialising in logistics and transportation play a vital role in managing the movement of oil and petroleum products throughout the supply chain. This includes transportation by pipelines, railcars, ships, and trucks.	Logistics and transportation providers can adopt sustainable transportation practices, such as using energy-efficient vehicles, optimising delivery routes to minimise fuel consumption, and investing in alternative fuels. They play a key role in reducing the carbon footprint of oil and petroleum product transportation.
Oil traders and marketers	Oil trading companies facilitate the buying and selling of crude oil and refined products in domestic and international markets. They play a crucial role in optimising supply and demand, pricing, and market access.	Oil traders and marketers can promote sustainable sourcing by favouring suppliers with strong environmental and social commitments. They can engage in responsible trading practices that prioritise transparency and ethical considerations, contributing to sustainable supply chains.
Regulatory agencies and governments	Regulatory bodies and government agencies oversee and regulate various aspects of the oil industry, including safety standards, environmental regulations, and transportation permits. They ensure compliance and enforce rules to	Regulatory bodies and governments establish and enforce environmental regulations, safety standards, and emission limits for the oil industry. They play a crucial role in ensuring compliance with sustainability requirements and driving industry-wide

Table 3 (continued)

Actor	Role	Contribution to sustainability
Technology providers	Companies developing and providing technology solutions for the oil industry, such as software for supply chain management, asset tracking, and predictive maintenance, contribute to optimising logistics processes and enhancing efficiency.	initiatives to reduce environmental impact. Technology providers develop and offer innovative solutions that enable the oil industry to improve efficiency and reduce environmental impact. This includes technologies for emissions monitoring, energy management, and data analytics to optimise operations and support sustainability goals.
Industry associations and collaborative initiatives	Organisations such as trade associations, industry groups, and collaborative initiatives allow different parties in the oil industry to exchange best practices, solve the same issues, and focus on sustainability in logistics and supply chain management.	Members of industry associations and team-up efforts discuss new ideas, share information, determine new best practices, and collaborate on developing sustainable practices. It supports teamwork, new ideas, and practices that are environmentally responsible in the oil business.

4.3. Reliability analysis of the qualitative phase

To ensure the reliability of the qualitative phase of the research, a Kappa Kohn analysis was conducted. Two experts, each with over ten years of academic and industry experience and holding a doctoral degree, were invited to review the entire qualitative research process, focusing particularly on the extraction of codes and categorisation. The experts evaluated each phase of the research using a 5-point Likert scale (1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = very good). The degree of agreement between the two experts was calculated using the Kappa Kohn coefficient, and the results were analysed using SPSS software. As shown in Table 5, the Kappa Kohn coefficient is 0.655. Since the coefficient is above 0.6, it confirms the reliability of the qualitative phase.

4.4. Prioritising sustainability integration

After completing the qualitative phase of the research and identifying a comprehensive list of sustainability integration activities, the next step was to prioritise these activities. A survey was conducted with three experts experienced in both the oil industry and sustainability integration strategies. Using a pairwise comparison questionnaire, the experts assessed the importance of each activity. Following the steps outlined in Section 3.2, the importance of each activity was calculated. The results of this prioritisation provide valuable insights into the most critical sustainability actions, ensuring that limited resources are allocated effectively to improve sustainability. To demonstrate how to calculate the weights of sustainability integration activities using the BWM technique, the importance of the 10 downstream sustainability integration activities is calculated based on data gathered from Expert No. 1, as shown below.

1. Defining the activities to be prioritised: Fig. 6 presents the **hierarchical diagram** of sustainability integration strategies, outlining the **main activities** and their corresponding **sustainability integration measures**.
2. Identifying the best and worst activities: Determining the most important and least important criteria: According to Expert No. 1, the

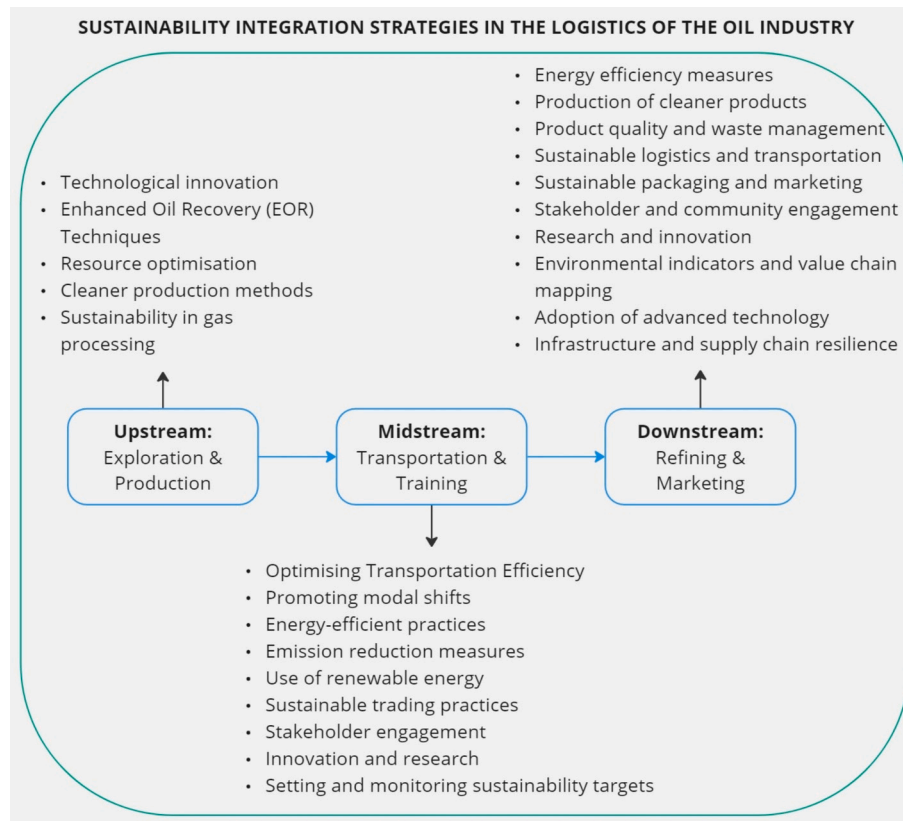


Fig. 5. Sustainability integration into the logistics of the oil industry.

most and least important downstream activities are the production of cleaner products (A32), and Sustainable packaging and marketing (A35).

3. Assessing the degree of preference of the best activity over the other activities: Table 6 shows the degree of preference of the most important downstream activity over the other activities according to Expert No. 1. As seen in Table 5, the degree of preference of the most important activity (A32) over the first activity (energy efficiency measures) is equal to 5 ($a_{B1} = 5$). It is obvious that the degree of preference for the most important activity over the second (the most important) activity is equal to 1 ($a_{B2} = a_{BB} = 1$). The degree of preference for the most important activity over the third activity (A33) is equal to 4 ($a_{B3} = 4$). The remaining values can be explained in a similar manner.
4. Assessing the degree of preference of the other activities over the worst activity: Table 7 shows the degree of preference of the other activities over the least important activity according to Expert No. 1. As seen in Table 6, the degree of preference for the first activity (A31) over the least important activity (A35) is equal to 4 ($a_{1W} = 4$). The degree of preference for the second activity over the least important activity is equal to 8 ($a_{B3} = a_{BW} = 8$). It is obvious that the degree of preference for the fifth activity over the least important activity is equal to 1 ($a_{5W} = a_{WW} = 1$). And the remaining values can be explained in a similar manner.
5. Calculating the final weight of the activities: Calculating the degree of importance for each activity requires modelling and solving the linear programming problem outlined in Eq. (1), based on the data presented in Tables 6 and 7. The details of this process are discussed in Table 8.

By solving the above linear programming model, the importance of

the 10 downstream activities is obtained according to Expert No. 1. As it is clear the inconsistency rate is equal to 0.0148 and is lower than 0.1 and it is acceptable. The importance of the other activities were calculated according to the opinion of the three experts. Finally, the final weight of the activities was obtained by calculating the geometric mean of the weights obtained from each of the experts. Due to the limited number of pages, the details of calculating the importance of other activities have been omitted. Table 9 shows the final weights of the sustainability integration activities calculated using the BWM technique. The inconsistency rate of all comparisons is less than 0.1 and close to zero, which confirms appropriate consistency and subsequently high reliability of the results.

As shown in Table 9, technological innovation, with a normalised weight of 0.331605, is considered the most important sustainability integration activity according to the experts' opinion. This highlights the significant role that technological advancements play in improving operational efficiency and reducing environmental impact in the oil industry. Therefore, it is recommended that oil industry decision-makers focus on investing in and implementing innovative technologies. This can enhance productivity, optimise logistics operations, and reduce energy consumption, contributing to both environmental and economic sustainability.

The next place is cleaner production methods, which have a normalised evaluation score of 0.094957. Minimising the impact on the environment during oil extraction, production, and refining depends largely on cleaner ways of working. They aim to reduce amounts of waste, save energy, and prevent pollution. Hence, industry leaders should pay closer attention to introducing cleaner production into all their operations. Using this approach can reduce emissions, help the environment, and conserve resources, all at the least cost. Sustainability in gas processing, given a normalised weight of 0.101721, falls at number three on the priority list. It is important to practise sustainability in gas processing to limit the oil industry's harm to the environment.

Table 4
Summary of sustainability integration activities.

Main activity	Sustainability integration activity	Detailed activity
Upstream activity	Technological innovation	The development of advanced technologies such as seismic imaging, directional drilling, and reservoir modelling enhances exploration efficiency while minimising environmental impact.
	Enhanced Oil Recovery (EOR) techniques	Developing and improving EOR methods like steam flooding, chemical injection, and gas injection, which increase hydrocarbon recovery from mature fields while reducing the environmental footprint.
	Resource optimisation	Contribute to better reservoir characterisation, fluid flow modelling, and well spacing optimisation, leading to more efficient resource use and minimising environmental degradation.
	Cleaner production methods	Support the adoption of environmentally friendly production techniques that reduce greenhouse gas emissions and minimise the overall environmental impact of upstream activities.
	Sustainability in gas processing	The processing of associated natural gas during oil production, including its liquefaction into LNG, supports the transition to cleaner energy sources and reduces the environmental impact of gas flaring.
Midstream activity	Optimising transportation efficiency	Maximising the use of pipelines for crude oil and refined product transportation to reduce carbon footprints and enhance energy efficiency.
	Promoting modal shifts	Encouraging the use of more sustainable transportation modes such as rail and marine shipping over road transport to minimise emissions.
	Energy-efficient practices	Implementing technologies and practices that optimise fuel efficiency in transportation operations to reduce environmental impact.
	Emission reduction measures	Utilising electric or hybrid vehicles for local transport, adopting cleaner fuels, and implementing robust spill prevention and response strategies.
	Use of renewable energy	Incorporating renewable energy sources, such as solar or wind power, to reduce reliance on fossil fuels in transportation and trading operations.
	Sustainable trading practices	Promoting ethical sourcing of crude oil and petroleum products, supporting carbon offsetting initiatives, and enhancing supply chain transparency through technologies like blockchain.
	Stakeholder engagement	Collaborating with NGOs, governments, and other stakeholders to promote sustainable practices and incorporate sustainability criteria into supply chain management.
	Innovation and research	Investing in the development of sustainable technologies and embracing circular economy practices to minimise waste and maximise resource utilisation.

Table 4 (continued)

Main activity	Sustainability integration activity	Detailed activity
Downstream activity	Setting and monitoring sustainability targets	Establishing clear sustainability goals related to emissions reduction, energy efficiency, and waste reduction, and regularly monitoring and reporting on progress to ensure accountability.
	Energy efficiency measures	Implementing energy-efficient equipment, optimising processes, and incorporating heat recovery systems in refineries to reduce energy consumption and greenhouse gas emissions.
	Production of cleaner products	Shifting towards low-carbon products such as low-sulfur fuels and biofuels to minimise environmental impact and promote cleaner alternatives in the transportation sector.
	Product quality and waste management	Enhancing product quality through stringent quality control and adopting effective waste management strategies to contribute to sustainability efforts.
	Sustainable logistics and transportation	Optimising logistics networks to reduce transportation distances and emissions, and exploring alternative transportation modes like rail, marine, or pipeline transport to minimise environmental impact.
	Sustainable packaging and marketing	Promoting the use of recyclable materials in product packaging and adopting ethical marketing practices to reduce waste and increase transparency.
	Stakeholder and community engagement	Engaging with stakeholders, including communities, customers, suppliers, and regulatory bodies, to address concerns, support community development, and advance collective sustainability goals.
	Research and innovation	Investing in the development and deployment of innovative technologies for cleaner refining processes, and exploring circular economy initiatives to minimise waste and maximise resource efficiency.
	Environmental indicators and value chain mapping	Incorporating environmental indicators like carbon emissions mapping to assess and manage the environmental impact, adding value and transparency to the value chain process across upstream, midstream, and downstream activities.
	Adoption of advanced technology	Utilising advanced technologies to add agility and transparency to the logistics process, ensuring successful integration of sustainability into operations.
	Infrastructure and supply chain resilience	Addressing infrastructure challenges to maintain supply chain momentum and resilience which is crucial for the successful application of sustainability in logistics operations.

Prioritising less waste and emission reduction in gas processing help make the industry more sustainable. Using energy-efficient technology and finding eco-friendly options to reduce emissions and trash should be a priority for those making decisions in gas processing plants.

Table 5
Experts' agreement coefficient.

		Value	Asymptotic Standard Error ^a	Approximate T ^b	Approximate Significance
Measure of Agreement	Kappa	0.655	0.187	2.583	0.010
N of Valid Cases		10			

^a Not assuming the null hypothesis.

^b Using the asymptotic standard error assuming the null hypothesis.

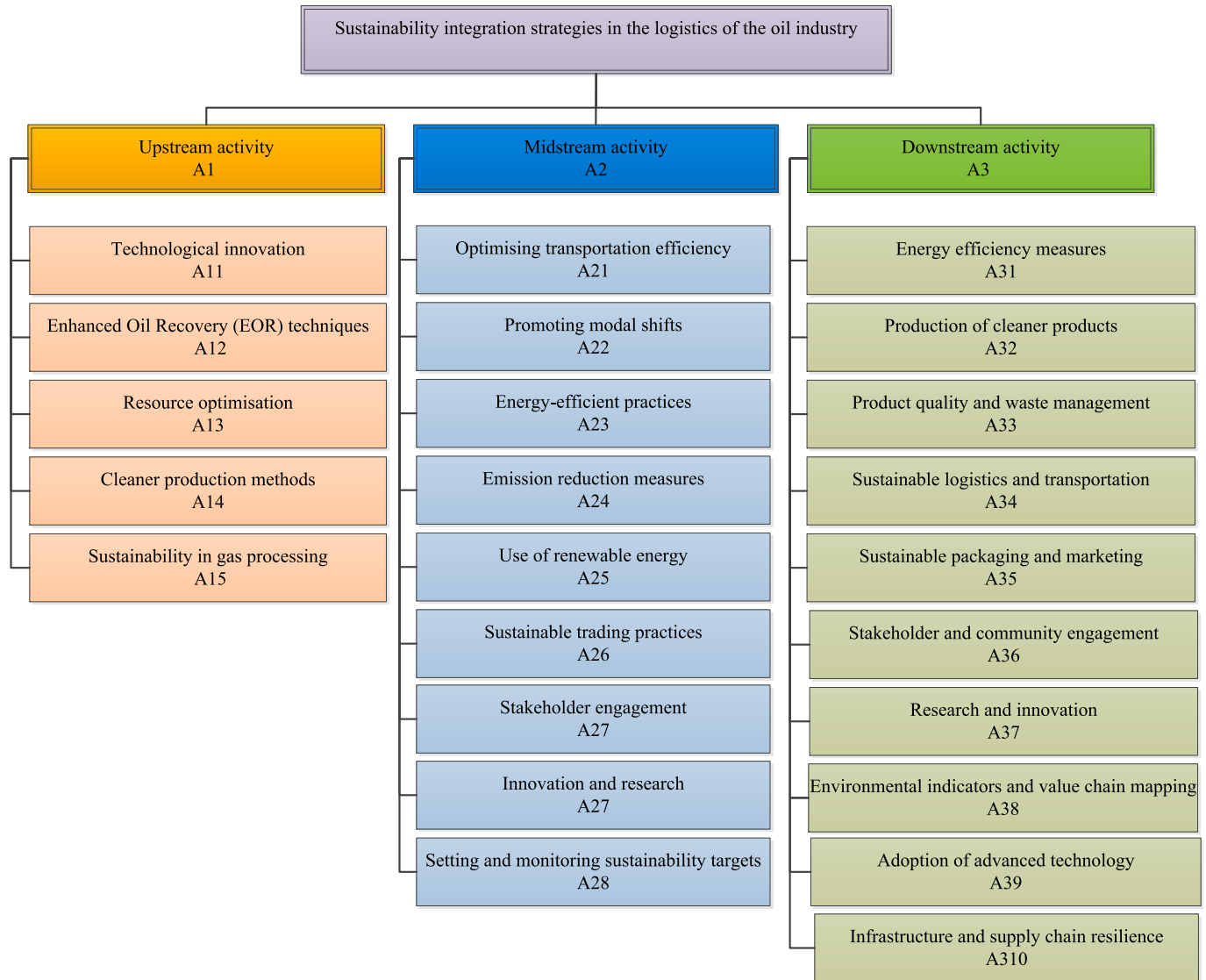


Fig. 6. Hierarchical diagram of sustainability integration strategies in the logistics of the oil industry

Table 6
Degree of preference of the most important strategy over the other- Downstream activities.

A310	A39	A38	A37	A36	A35	A34	A33	A32	A31	Downstream Activities
3	4	2	7	6	8	3	4	1	5	The most important activity: A32

5. Conclusions

The study focused on how logistics in the oil industry can be more sustainable, since it plays a key role in providing energy and encounters several obstacles related to the environment and its operations. With a mix-method approach, the study applied thematic analysis and multi-criteria decision-making to spotlight and list main actions to integrate

sustainability into business processes in oil industry. The qualitative phase involved interview with experts and review the literature, which helped to categorise 23 sustainability integration actions into three main groups: five different tasks take place in the upstream sector, eight in the midstream sector, and ten in the downstream sector.

The Best-Worst Method (BWM) was carried out in the quantitative phase to sort the activities according to experts' opinions. Technological

Table 7

Degree of preference of the other strategies over the least important strategy-Downstream activities.

The least important activity: A35	Downstream activities
4	A31
8	A32
5	A33
6	A34
1	A35
3	A36
2	A37
7	A38
5	A39
6	A310

Table 8

BWM linear model and weights of downstream activities according to expert no. 1's opinion.

BWM linear model	Outputs
$\min \xi^L$	
S.t.	
$ w_2 - 5 w_1 \leq \xi^L$	
$ w_2 - 4 w_3 \leq \xi^L$	
$ w_2 - 3 w_4 \leq \xi^L$	$W1 = 0.0797$
$ w_2 - 8 w_5 \leq \xi^L$	$W2 = 0.3321$
$ w_2 - 6 w_6 \leq \xi^L$	$W3 = 0.0996$
$ w_2 - 7 w_7 \leq \xi^L$	$W4 = 0.1328$
$ w_2 - 2 w_8 \leq \xi^L$	$W5 = 0.0332$
$ w_2 - 4 w_9 \leq \xi^L$	$W6 = 0.0664$
$ w_2 - 3 w_{10} \leq \xi^L$	$W7 = 0.0569$
$ w_1 - 4 w_5 \leq \xi^L$	$W8 = 0.1992$
$ w_3 - 5 w_5 \leq \xi^L$	$W9 = 0.0996$
$ w_4 - 6 w_5 \leq \xi^L$	$W10 = 0.1328$
$ w_6 - 3 w_5 \leq \xi^L$	$\xi^{L*} = 0.06641$
$ w_7 - 2 w_5 \leq \xi^L$	
$ w_8 - 7 w_5 \leq \xi^L$	
$ w_9 - 5 w_5 \leq \xi^L$	$IR = \frac{\xi^{L*}}{CI} = \frac{0.06641}{4.47} = 0.0148 \leq 0.1 \Rightarrow \text{Consistent}$
$ w_{10} - 6 w_5 \leq \xi^L$	
$\sum_{j=1}^{10} w_j = 1$	
$w_j \geq 0$, for all j	

innovation (0.331605), cleaner ways of production (0.094957), and sustainability in gas processing (0.101721) top this list of highest priorities. They underline the importance for leaders in the oil industry to direct investments towards new technologies to run their businesses better and lessen impact on the environment. On top of this, promoting cleaner methods in industry can lead to less waste and fewer emissions, while making gas processing more sustainable will help use resources more effectively and lower the industry's emissions. Overcoming issues such as insufficient education, lack of resources, and problems with infrastructure is key to a successful implementation of sustainable practices. Applying a strategy for sustainability, the oil industry can ensure its financial and ecological achievements last for many years and play a role in global sustainability.

Based on the research, incorporating sustainability can help the oil industry improve and develop in a positive way. It points out that making a value chain map is vital in logistics, as it helps companies to become better organised, flexible, and transparent. According to research, value chain mapping helps the logistics system locate the areas in the supply chain that could be improved more. The use of value chain mapping can speed up a logistics system by giving each stage in the process added accessibility. Based on the analysis of the literature, it can be seen that exogenous and endogenous factors play a crucial role in

Table 9

Weights of sustainability integration activities.

Main Activity	Weight	Sustainability integration activity	Weight	Normalised weight
Upstream activity	0.5642	Technological innovation	0.276627	0.331605
		Enhanced Oil Recovery (EOR) techniques	0.049875	0.059787
		Resource optimisation	0.05721	0.06858
		Cleaner production methods	0.079214	0.094957
		Sustainability in gas processing	0.084856	0.101721
		Optimising transportation efficiency	0.020963	0.025129
		Promoting modal shifts	0.008347	0.010006
		Energy-efficient practices	0.016646	0.019954
		Emission reduction measures	0.018788	0.022522
		Use of renewable energy	0.014039	0.016829
Midstream activity	0.1599	Sustainable trading practices	0.011545	0.01384
		Stakeholder engagement	0.010969	0.013149
		Innovation and research	0.043173	0.051753
		Setting and monitoring sustainability targets	0.020963	0.025129
		Energy efficiency measures	0.010612	0.012721
		Production of cleaner products	0.017447	0.020914
		Product quality and waste management	0.012586	0.015087
		Sustainable logistics and transportation	0.013852	0.016605
		Sustainable packaging and marketing	0.005011	0.006007
		Stakeholder and community engagement	0.009121	0.010934
Downstream activity	0.1073	Research and innovation	0.010912	0.013081
		Environmental indicators and value chain mapping	0.014722	0.017648
		Adoption of advanced technology	0.009807	0.011756
		Infrastructure and supply chain resilience	0.016921	0.020284

designing supply chain operations in the oil industry, which involve technological innovation, sustainability standards, employee training, and so on.

This work significantly advances the oil industry by forcing the integration of sustainability within the value chain processes of the operations. It presents remarkable insights from industry experts, highlighting the current market requirements and demands. The research examines the role of value chain logistics, offering a comprehensive understanding of critical factors such as value chain mapping. It addresses the challenges associated with implementing sustainability in operations, which could adversely impact the oil industry. To counter these challenges, the study explores technological prospects capable of enhancing logistics operations and adding new dimensions to the value chain process.

The study exhibits both primary and secondary methodologies to define logistics operations within the oil industry. The qualitative approach efficiently captures the contextual and conceptual insights into the integration of sustainability in the logistics processes. However, the study is limited by the absence of quantitative data, which resists the

objective analysis and impacts the interpretation of the key results. In conclusion, the study lacks a data-driven perspective, emphasizing the need for future research to incorporate numerical justification for more robust conclusions.

This study examines the evolution of the value chain in the oil industry's logistics operations, speculating on the role of sustainability in the progress of overall operational efficiency. It gives a valuable comparison for identifying alternative solutions to achieving zero-waste logistics operations. The primary data responses offer insights that can guide future research in expanding the scope of the subject through the experimental methods aimed at identifying optimal strategies for making the value chain operations more agile and resilient. This study serves as a primary reference for exploring value mapping in the oil industry, motivating future research to delve deeper into numerous sites of the value chain that contribute significantly to operational achievement.

Note: The current study employed AI tools for passage checking and grammatical revision. We guarantee the validity of the content, and its accuracy has been verified through human expertise.

CRedit authorship contribution statement

Abdoulmohammad Gholamzadeh Chofreh: Writing – review & editing, Supervision, Project administration, Investigation, Formal analysis, Validation, Resources, Methodology, Funding acquisition, Conceptualization. **Feybi Ariani Goni:** Validation, Investigation, Data curation, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Zhipeng Yu:** Writing – original draft, Writing – review & editing, Methodology, Formal analysis, Validation, Investigation. **Bohong Wang:** Writing – review & editing, Methodology, Formal analysis, Investigation, Conceptualization. **Mohd Afzal:** Conceptualization, Formal analysis, Data curation. **Saeed Sadeghi Darvazeh:** Conceptualization, Formal analysis, Writing – review & editing, Data curation, Writing – original draft. **Mostafa Hajiaghahi-Keshteli:** Supervision, Writing – review & editing, Project administration, Formal analysis.

Declaration of competing interest

None.

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