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CHALLENGES AND SOLUTIONS IN SUPPLY CHAIN RISK MANAGEMENT IN THE PETROLEUM INDUSTRY – A REVIEW

Abstract

This paper aims to analyze the key challenges and risks affecting supply chains in the petroleum industry. Through a systematic review of numerous scientific studies, including the state-of-the-art studies, the main factors that may disrupt the stability of supply chains have been identified. The study summarizes existing risks, such as geopolitical, environmental, climatic, market, economic, and technological factors. Additionally, the paper aims to propose potential solutions to mitigate the negative impact of these risks on the petroleum industry supply chains. Considering the increasing complexity of global energy markets and the growing emphasis on sustainability, enhancing the resilience of supply chains is essential for maintaining operational efficiency and long-term competitiveness in the industry. The originality of this review is that it brings geopolitical, environmental, economic, technological, and reputational risks into a single framework and supports the analysis with comparative tables of mitigation strategies, offering a more integrated view of petroleum supply chain risks.

Key words: *SC, petroleum industry, risk, SCM*

JEL classification: *L0*

ИЗАЗОВИ И РЕШЕЊА У УПРАВЉАЊУ РИЗИЦИМА У ЛАНЦИМА СНАБДЕВАЊА У НАФТНОЈ ИНДУСТРИЈИ – ЛИТЕРАТУРНИ ПРЕГЛЕД

Апстракт

Овај рад има за циљ да анализира кључне изазове и ризике који утичу на ланце снабдевања у нафтној индустрији. Кроз систематски преглед бројних научних студија, укључујући и најновија истраживања, идентификовани су главни фактори који могу нарушити стабилност ланаца снабдевања.

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Студија сумира постојеће ризике, као што су: геополитички, еколошки, климатски, тржишни, економски и технолошки ризици. Поред тога, рад има за циљ да предложи потенцијална решења за ублажавање негативног утицаја ових ризика на ланце снабдевања у нафтној индустрији. С обзиром на све већу сложеност глобалних енергетских тржишта и растући значај одрживости, јачање отпорности ланаца снабдевања кључно је за одржавање оперативне ефикасности и дугорочне конкурентности у овој индустрији. Оригиналност овог рада огледа се у томе што сагледава геополитичке, еколошке, економске, технолошке и репутационе ризике у оквиру једне целине и употпуњује анализу прегледним табелама, пружајући јаснији и целовитији увид у ризике у ланцима снабдевања у нафтној индустрији.

Кључне речи: *Ланци снабдевања, нафтна индустрија, ризик, менаџмент у ланцима снабдевања*

Introduction

One of the most important raw materials in the world is oil. It has been one of the leading energy sources in the period of the last seven decades, and it also significantly affects the growth of other industries (Lisitsa et al., 2019). Besides oil, gas represents one of the most important drivers of industrial processes. According to (Gardas et al., 2019) supply chains of the oil and gas industry are very long. In all sectors of the petroleum industry, upstream, midstream, and downstream, supply chains can be considered as the backbone but also the bottlenecks. Numerous service companies have to work together in order to achieve the final tasks of all three sectors. Moreover, these sectors need to be connected and work together to accomplish the main task of the petroleum industry: distribution of the final product to the end users. Assuming everything said, the oil and gas industry has to have a great collaboration among different sectors' supply chains. (Piya et al., 2022; Raut et al., 2017).

A variety of risks that might negatively affect various operations in the petroleum industry can be identified. The risks that range from logistical disruptions, across geopolitical threats and environmental incidents, to market instability, have the potential to disrupt business continuity, increase costs, and threaten the viability of the industry. Supply chain risks can be classified as one of the most notable risks in the petroleum industry because supply chains can be considered as very fragile. For instance, supply chain disruptions in the petroleum industry can be provoked by political instability in certain countries that are among the leading ones in the world in terms of oil and gas distribution to end users, which is happening nowadays. Moreover, global crises can affect supply chains as well. The COVID-19 crisis has affected the supply chains of almost every industry, including the petroleum industry. (Milenković & Milovanović, 2024; Piya et al., 2022). Additionally, modern environmental legislations have to be implemented in traditional supply chains that need to balance economic and operational efficiency and environmental standards (Ahmad et al., 2017).

Moreover, the development of digital technologies, such as the Internet of Things (IoT), artificial intelligence (AI) and blockchain, has opened up new opportunities for

improving risk management in supply chains (Shahzadi et al., 2024). IoT sensors enable monitoring of critical points in real time, artificial intelligence supports predictive analysis to identify potential risks, while blockchain contributes to transparency and security in procurement and delivery processes. However, despite these technological advances, dealing with risks in supply chains requires a comprehensive and integrated approach, which combines traditional risk management strategies with innovative technological solutions.

Supply chain risk management (SCRM) defines, evaluates and reduces potential risks in supply chains in order to minimize risks of possible hazards, thus enhancing resilience. The petroleum industry is a high-investment industry, which means that financial risks are common, so the need for prediction and mitigation of potential risks is high (Fazli et al., 2015). This systematic approach addresses risks specific to the petroleum industry, including supply-side disruptions, logistical inefficiencies, and operational hazards. As already said, the COVID-19 pandemic reshaped the industry sectors drastically (Szczygielski et al., 2022), so it emphasized the importance of improving powerful mechanisms to manage all the challenges, expected and unexpected ones. Moreover, complex supply chains, such the ones in the petroleum industry, are more vulnerable that the simpler ones (Fazli et al., 2015; Miner et al., 2024).

The supply chains of the petroleum industry require a thorough approach that considers evolving standards and technologies to be able to ensure adaptive resilience in the face of diverse challenges.

The aim of this paper is to investigate and analyse the key risks in the supply chains of the oil industry, identify opportunities for improving the management of those risks and analyse the potential of digital technologies in the optimization of supply chains. This paper provides a theoretical contribution to risk management research in the context of the petroleum industry. The analysis will include a literature review, a discussion of current challenges, and a proposal for strategies to improve the resilience and sustainability of supply chains. Research results can be useful both for the scientific community and for practitioners in industry, providing them with concrete guidelines for risk reduction and process optimization.

Accordingly, the central research question of this review paper is: How can the petroleum industry effectively identify and mitigate risks in supply chains in order to enhance resilience and sustainability in a rapidly changing global environment?

Methodology

Review Process

To conduct a comprehensive and adequate literature review, Google Schoolar, KoBSON and ResearchGate have been used. Moreover, some information were collected from the websites sucha as IEA and UN. The process of writting this paper began with searching and downloading the scientific articles related to supply chains (SC), supply chain management (SCM), supply chain risk management (SCRM), green supply chain management (GSCM), oil and gas (O&G) industry and sustainability. Duplicate papers were subsequently removed. A detailed reading of articles have been performed in order to identiy

studies that are relevant to the topic of this paper. This research is based on 59 references: 2 from 2015, 5 from 2016, 3 from 2017, 2 from 2018, 5 from 2019, 3 from 2020, 3 from 2021, 6 from 2022, 8 from 2023 and 22 from 2024. Taking into consideration the fact that more than 61% of the references used in this paper have been published in the previous 3 years, and more than 81% of it have been published in the last 6 years, it can be said that this paper represents a-state-of-the-art review paper. More than one-third of the primarily downloaded articles were found incompatible for this research and have been ignored.

Literature Eligibility Criteria

Inclusion criteria were: studies published in peer-reviewed journals or conference proceedings, written in English, and focusing on supply chain risks in the petroleum industry, particularly those published in the last 5–6 years. Exclusion criteria included papers outside the energy sector, studies without clear methodological grounding, non-scientific sources (reports, news articles), and papers older than 10 years unless considered seminal works.

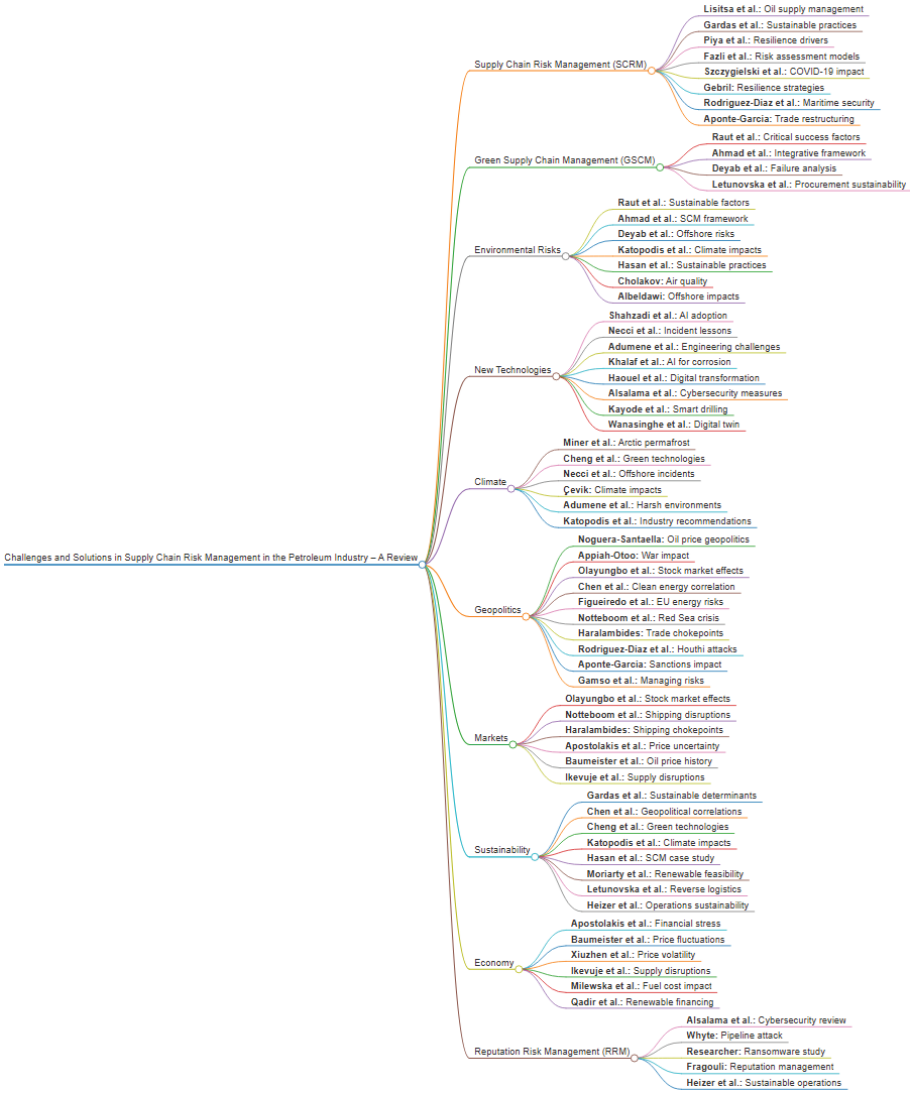
The mind map (Figure 1) illustrates the thematic structure of the paper "*Challenges and Solutions in Supply Chain Risk Management in the Petroleum Industry – A Review*" by organizing references under key thematic areas.

The central topic is the **Challenges and Solutions in Supply Chain Risk Management in the Petroleum Industry**, branching into ten key thematic areas:

1. **Supply Chain Risk Management (SCRM)**: Focuses on strategies, resilience drivers, and risk assessment models.
2. **Green Supply Chain Management (GSCM)**: Highlights sustainable practices and procurement frameworks.
3. **Environmental Risks**: Covers impacts from climate change, offshore operations, and air quality.
4. **New Technologies**: Includes advancements like AI, digital twins, and cybersecurity.
5. **Climate**: Discusses climate change effects, Arctic permafrost, and extreme weather challenges.
6. **Geopolitics**: Analyzes impacts from oil price wars, conflicts, and chokepoints like the Red Sea.
7. **Markets**: Examines oil price fluctuations, shipping disruptions, and stock market effects.
8. **Sustainability**: Addresses green technologies, reverse logistics, and renewable energy impacts.
9. **Economy**: Reviews financial stress, fuel costs, and renewable energy transitions.
10. **Reputation Risk Management (RRM)**: Focuses on cybersecurity, ransomware incidents, and reputation management.

Each branch includes references summarized with concise keywords that highlight their contribution to the topic. The structure clearly visualizes how different risk dimensions contribute to supply chain vulnerabilities in the petroleum industry.

Figure 1. The mind map.



The "References" section below contains the list of references for particular literary sources.

Review Results

This section presents a synthesis of literature findings on key categories of supply chain risks in the petroleum industry, while their broader implications and possible mitigation strategies are described and analysed in the Discussion section.

The petroleum industry represents one of the main factors in the world economy system because the demand and supply of petroleum products are vital for determining the state of the world economy, which means that changes in oil price will affect other markets (Abd El Ghany Gebril, 2024; Appiah-Otoo, 2023; Noguera-Santaella, 2016; Olayungbo et al., 2024). As already said, supply chains in the petroleum industry are complex systems that include many sectors that are tightly connected. Due to the nature of the petroleum industry, which relies on global operations and complex infrastructure networks, these chains are particularly vulnerable to various types of risks. The key risk factors in the petroleum industry will be analysed and discussed in this chapter.

Table 1: Categories of Supply Chain Risks in the Petroleum Industry

Risk category	Key authors	Main insights
Geopolitical risks	Figueiredo et al. (2022); Gamso et al. (2024); Heizer et al. (2020)	Wars, sanctions, market instability; diversification and exit strategies as mitigation
Climate & environmental risks	Çevik (2024); Katopodis & Sfetsos (2019); Miner et al. (2024); Necci et al. (2019)	Arctic challenges, extreme weather, logistics and safety issues
Market & economic risks	Baumeister & Kilian (2016); Olayungbo et al. (2024); Attia et al. (2019)	Oil price volatility, inflation, investment risks
Technological risks	Alsalama & Alzahrani (2024); Haouel & Nemeslaki (2023)	Cybersecurity vulnerabilities, AI and IoT adoption challenges
Reputational & social risks	Fragouli (2016); Arora & Lodhia (2017); Ahmad et al. (2023)	ESG standards, loss of community trust, brand damage

Geopolithical Risks

According to (Chen et al., 2024), international political events can have a great influence on the economy and global market, so it can be concluded that geopolitical risks are one of the key factors that can disrupt smooth business operations in the petroleum industry. These risks can influence petroleum exploration, production, transportation, refining and pricing mechanisms, and can be provoked by political, economic and social instabilities which can lead to international tensions (Figueiredo et al., 2022). According to (Cheng et al., 2023), detailed understanding of these types of risks is crutial in order to develop strategies that will minimize their potential negative consequenses.

Political instability in oil- or gas-producing regions, or in the regions that serve as a transit for hydrocarbons transportation, can affect SC in many different ways: conflicts, civil and political unrest, regime changes etc. Due to the political instabilities and military conflicts, such as the ones in Ukraine and Gaza, which have affected the logistics and shipping dynamics on one of the main routes for oil and gas transportation (Notteboom et al., 2024). For instance, the Red Sea crisis that started in October 2023 had a huge impact on maritime logistics and SC of many industries, including the petroleum industry (Haralambides, 2024). The Red Sea and the Gulf of Aden represent one of the most important interoceanic passages, with 8.8 million barrels of oil per day, which

represents 8.7% of daily global demand (Notteboom et al., 2024). The Bab al-Mandab Strait represents one of the keypoints for international trading of hydrocarbons because it is one of the two marine entrances to the Red Sea that is fairly important for importing of Persian Gulf oil to Europe (Haralambides, 2024). The hydrocarbon supply chain in the region of the Gulf of Aden and Bab al-Mandab Strait is highly vulnerable because of its location. The Gulf of Aden constantly faces issues such as piracy and smuggling, which is bad for the stability of secured trading (Haralambides, 2024; Notteboom et al., 2024). Moreover, the entire region of the Red Sea, including the Suez Canal, is the chokepoint for the traders because of the Houthi attacks, which led to a drastic decrease in shipping activities in this region because of the security issues (Rodriguez-Diaz et al., 2024).

Geopolitical rivalries can lead to economic sanctions. Previously mentioned, the Russia-Ukraine conflict can serve as a great example of geopolitical instability, destabilizing not only hydrocarbon supply chains in Europe but also in the world. As a response to the sanctions, Russian Federation has changed its policy for hydrocarbon commerce by transferring exports to non-sanctioning countries (Aponte-Garcia, 2024). It is well known that Russia is one of the greatest hydrocarbon producers in the world, and it is responsible for about 12% of the world's oil supplies. The military conflict that started in February 2022 had a huge impact on the oil price. Before the conflict, in January 2022, the oil price was around 74.17 USD per barrel, while in March of the same year, the price rose by around 73%, which equals 129.02 USD per barrel (Https:// Tradingeconomics.Com/Commodity/Crude-Oil, n.d.; Olayungbo et al., 2024). This increase directly disrupted the oil supply from the Russian Federation to the world's market, which affected global supply chains (Olayungbo et al., 2024).

Climate and Environmental Risks

Global warming, climate change and natural environmental hazards can have a dramatic influence on the petroleum supply chains, especially in upstream and midstream sectors (Çevik, 2024; Deyab et al., 2018; Necci et al., 2019). A great amount of petroleum reservoir rocks is located in coastal and offshore regions, as well as areas that are vulnerable to extreme weather conditions such as hurricanes, floods, droughts, high winds, low temperatures etc. (Adumene et al., 2023; Katopodis & Sfetsos, 2019).

Due to global warming, the icemelting is happening, making the Arctic and Sub-Arctic hydrocarbon reserves more and more accessible to the oil and gas companies. But the processes of exploration and extraction of hydrocarbons in such extreme weather conditions require well-organized logistics systems (Necci et al., 2019). The transportation of special and sophisticated equipment represents a big challenge for petroleum industry supply chains and risk management. Moreover, extreme weather conditions can dramatically affect employees. Because of this, it is crucial to predict and prevent possible situations that can negatively affect the integrity of the equipment and the workers' health. Disruption in one part of a supply chain will cause delays and possibly halts in the entire supply chain, so SCRM has to deal with these problems that can provoke financial losses for a company (Çevik, 2024). All the possible vulnerabilities have to be predicted and adequately treated to decrease any possibility of fatal accidents in terms of safety and financial losses in the extreme weather conditions. High winds, low

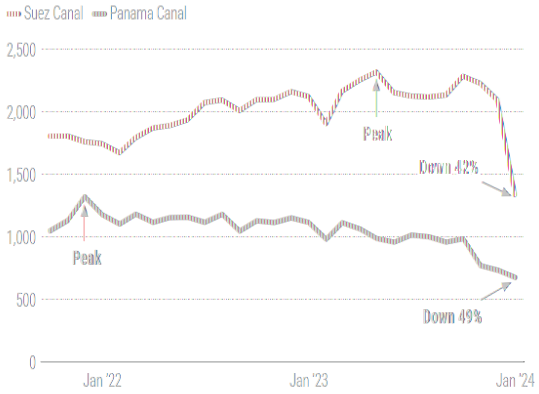
temperatures and storms are not the only challenges that supply chain risk management system has to deal with. Limited visibility and darkness, moreover presence of sea ice are also the challenges that need to be taken into consideration (Miner et al., 2024; Necci et al., 2019).

According to (Necci et al., 2019), the climate in the far northern parts of our planet is getting worse in terms of the strength of storms due to the climate change, which represents new environments for the upstream operations that SCRM has to deal with. This is confirmed by the statement of the authors (Deyab et al., 2018), who claim that equipment failure risk is directly related to the extreme weather conditions of the working environment, so the special risk management measures have to be implemented to stop or reduce hazardous events in the extreme weather conditions.

Moreover, global trend of rising temperatures can significantly impact oil and gas business in permafrost areas where melting of permafrost is happening which can lead to damage of exploitation and transportation infrastructure that have been build upon the permafrost (Miner et al., 2024).

When talking about climate effects, the Panama Canal is facing the problem of a decrease in the freshwater levels, especially in 2023 and 2024, which can dramatically affect SC of all the industries worldwide, including the petroleum industry. This issue can negatively affect the companies that want to ship their products all around the globe. Wait times are prolonged and tolls are higher, which represents another challenge to SCM of the petroleum industry (Notteboom et al., 2024).

Figure 2. This figure highlights how maritime chokepoints concentrate global petroleum flows, meaning that disruptions in only a few locations can create cascading effects worldwide. For the petroleum industry, this underlines the vulnerability of long supply chains to both geopolitical tensions and environmental shocks.



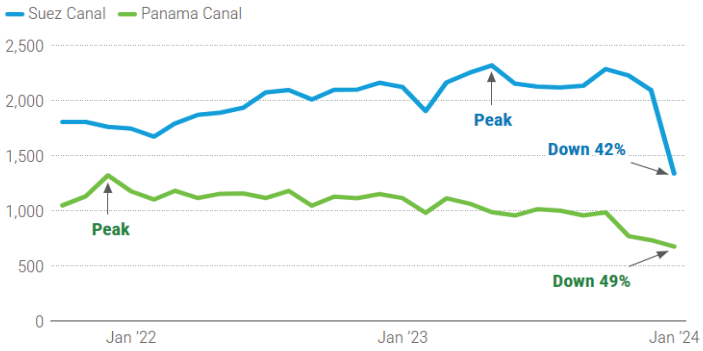
(Source: https://Periscopeglobal.Substack.Com/p/Revenge-of-Geography-Maritime-Chokepoints, n.d.)

It can clearly be seen from Figure 2 that the Panama Canal, Suez Canal and Bab el Mandab Strait are some of the key points for the shipping of petroleum products.

Drought in the Panama Canal and the Red Sea crisis, combined together, represent the event that gives the SCRM of the petroleum industry serious challenges that need to be solved while keeping financial losses as low as possible. This is the situation when multiple factors (geopolitical and climate) can affect SC in the same way.

Transits in the Panama and Suez canals in January 2024 have decreased by about 40% from their highest points since October 2021. While transits via the Panama Canal have been down for the past few years, the Suez Canal has seen a significant reduction as well (Figure 3) (https://Unctad.Org/Publication/Navigating-Troubled-Waters-Impact-Global-Trade-Disruption-Shipping-Routes-Red-Sea-Black?Utm_source=chatgpt.Com, n.d.).

Figure 3. The decline of transits through the Panama and Suez canals directly illustrates the impact of combined climate and geopolitical risks on petroleum supply chains. Reduced capacity in these routes leads to higher shipping costs, delivery delays, and ultimately market instability, showing how infrastructure bottlenecks translate into global supply chain risks. (October 2021 - January 2024)



(Source: https://Unctad.Org/Publication/Navigating-Troubled-Waters-Impact-Global-Trade-Disruption-Shipping-Routes-Red-Sea-Black?Utm_source=chatgpt.Com, n.d.)

Besides all the climate challenges that SCRM of the petroleum industry faces each day, it has to deal with environmental legislations such as the Kyoto Protocol and the Paris Agreement that require companies to adopt more sustainable and greener practices. The oil and gas industry has always been known as one of the biggest polluting industries in the world (Gardas et al., 2019). Compliance with new environmental protection measures usually requires significant investments in the operational procedures and technology, adding complexity and extra cost to SCM (Hasan et al., 2024).

Market and Economic Risks

All the risks discussed earlier, that can affect SC of the petroleum industry, can lead to market and economic instabilities that can provoke disruption in oil and gas industry supply chains. If market and economic instabilities, due to various occasions, are at high levels, it can potentially lead to financial loss that SCM needs to deal with. Situations like oil price volatility, demand-supply imbalances, inflation and geopolitics can provoke

market and economic instabilities, so the risks (Apostolakis et al., 2021). The global petroleum market, represented by a very complex structure can provoke instabilities in value chains, so the SCRM has to be at a very high level (Gardas et al., 2019).

Oil price fluctuations, which are usually very difficult to predict (Baumeister & Kilian, 2016), can be considered as one of the biggest issues that SCRM needs to deal with (Gunasekaran et al., 2015). This critical risk factor (price volatility) can be provoked by multiple events, such as global demand and supply imbalances, geopolitical events, global crises etc (Baumeister & Kilian, 2016; Xiuzhen et al., 2022). We have witnessed the global crisis that happened due to the COVID-19 pandemic, which drastically affected the oil market and the oil price (Apostolakis et al., 2021). Such declines in oil prices can reshape all three sectors of petroleum industry (upstream, midstream and downstream) in terms of investment in exploration and exploitation activities, profitability, transport costs and revenues (Attia et al., 2019; Augusta Heavens Ikevuje et al., 2024; Gunasekaran et al., 2015). On the other hand, price spikes that can happen due to supply disruptions can be presented as a new challenge for SCM of petroleum industry. High prices can put the pressure especially on downstream operations and simultaneously elevate costs across the value chain. The oil price spikes can have a very positive effect on the profits of the oil-exporting countries, thus the income overcomes the production costs, while for the oil-importing countries it can have the opposite effect (Apostolakis et al., 2021).

Inflation is one of the main economic factors that can be considered as a high-risk for the petroleum SC and it can be provoked by oil price shock (Apostolakis et al., 2021). Inflation can significantly impact the costs in upstream, midstream and downstream operations by raising labor wages, higher material and equipment costs, increasing transportation and working machinery rental expenses etc. All these issues can lead to higher exploration, production, transportation and distribution costs. Logistic expenses due to inflation can rise sharply, contesting the financial sustainability of industrial processes (Milewska & Milewski, 2022). SCRM of the oil and gas companies has to mitigate the effects of inflation by implementing strategies such as cost optimization and supplier diversification.

Renewable energy could be considered a long-term economic risk for oil and gas companies. According to (Moriarty & Honnery, 2020) renewable energy is getting more and more present in everyday life accounting for 14% of global produced energy, while on the other hand, according to IEA (Https://Www.Iea.Org/Reports/World-Energy-Balances-Overview/World, n.d.), we still need combustion of the fossil fuels due to the fact that we get more than 81% of globally produced energy from fossil fuels (Cholakov, 2016). The global economies are heading towards more sustainable future, but the process of transition to 'cleaner energy' requires significant investments (Çevik, 2024; Hussein Khalaf et al., 2024; Letunovska et al., 2023; Necci et al., 2019; Qadir et al., 2021). Additionally, market players have to balance these investments with the continuous demand for conventional fuels, which presents both financial and strategic difficulties (Qadir et al., 2021). This problem can be overcome by implementing sustainable supply chain management (SSCM) practices. SSCM represents the integration of environmental legislations and policies in supply chains, which can be done by implementing green practices, such as reverse logistics (Gardas et al., 2019; Letunovska et al., 2023). According to (Gardas et al., 2019) the implementation of SSCM measures increases profits, reputation, and customer loyalty of the company while positively affecting the environment by reducing oil spills, flaring, and disasters caused by humans.

Technological Risks

Technological advancements are constantly transforming the oil and gas industry, enabling more efficient operations and bigger production capabilities. However, all the advancements have also introduced a range of risks, such as system and cybersecurity vulnerabilities. In this section, a comprehensive discussion of the key technological risks in the oil and gas industry has been reviewed.

As the complexity of new technologies increases, the likelihood of system failures increases as well. Modern technologies implemented in oil and gas sector, such as drilling automation, corrosion monitoring systems, robotics, etc. are crucial to oil and gas operations nowadays in terms of increasing hydrocarbon recovery and equipment maintenance (Haouel & Nemeslaki, 2023; Hussein Khalaf et al., 2024).

Continued investment is needed to keep up with technological advancements, which can be one of the challenges for the petroleum industry. Moreover, management of the companies that want a high level of digitalization has to find a way to introduce new technologies to employees but also to hire highly qualified experts that can lead future projects and manage future risks (Haouel & Nemeslaki, 2023). The oil and gas industry is vulnerable to cyberattacks because it operates with very sensitive data about new projects, petroleum reserves, production capacities, financials, etc. (Alsalama & Alzahrani, 2024). In some way, all the companies, including petroleum ones, are forced to implement state-of-the-art machine learning (ML) and artificial intelligence (AI) technologies to mitigate the effect of new developing cyberattack technologies, which are, according to (Alsalama & Alzahrani, 2024) one of the main threats that can ruin smooth business operations. This is very important step in the process of digitalization in terms of infrastructure; moreover, supply chains could be disrupted by cyberattacks if a company does not have professionals and well-developed defense mechanisms (Haouel & Nemeslaki, 2023). The Colonial Pipeline ransomware attack that happened in 2021 is one of the examples of the importance of cybersecurity. The Colonial Pipeline is one of the main suppliers in the USA, contributing 45% of the East Coast's fuel supplies. The system integrates 37 facilities for storage that are capable of storing 7.7 million barrels. The attack that happened in 2021 dramatically affected supply chains across 13 states (Researcher, 2024; Whyte, 2024).

According to (Researcher, 2024), the operational shutdown that lasted for 6 days had a huge impact on supply chains of the East Coast, directly affecting more than 50 000 000 consumers and the financial damage exceeded 2.1 billion USD (Researcher, 2024). Such cyberattacks can have a negative impact on company's reputation as well (Alsalama & Alzahrani, 2024; Researcher, 2024; Whyte, 2024).

Reputation and Social Risks

The reputation of the company is a very important thing when it comes to collaboration with other companies. Bad reputation and lack of collaboration in the petroleum industry can negatively affect supply chains of the oil and gas company. Because of that, it is highly important for a company to have a good reputation, which will strengthen the bonds with other companies; without which, usually, a single company

cannot survive the modern and challenging market environment. Fruitful collaboration between different petroleum companies positively affects the supply chains.

Environmental incidents and ethical violations can seriously damage the reputation of a company (Fragouli, 2016). Negative media reports on environmental incidents, which are such a big risk in the petroleum industry due to the fact that the oil and gas industry has always been in the top three polluting industries (Gardas et al., 2019), can negatively affect investor relations, market value and supply chains. In order to maintain competitiveness on the market and supply chain stability, reputation management has become one of the most crucial parts for international petroleum companies (Fragouli, 2016).

As already said, reputational and social risks in the petroleum industry are strongly intertwined with supply chain resilience (Feria-Domínguez et al., 2016). For example, suppliers and contractors may distance themselves from companies that suffer reputational crises, leading to supply chain disruptions provoked by delays and cost overruns. This is particularly visible in global supply chains where international partners must comply with strict ESG (Environmental, Social, and Governance) standards, and any association with reputationally damaged companies can harm their own businesses (Ahmad et al., 2023).

A well-known case is the BP Deepwater Horizon disaster in 2010, which not only caused severe environmental damage, but also reputational damage for the company. According to (Arora and Lodhia, 2017) relied heavily on social and environmental disclosures on its website to manage reputation risk during the crisis. Instead of focusing on concrete remedial actions, BP emphasized its world-class facilities, management strategies and plans to resolve the accident employing a corrective and bolstering strategy to divert attention from the massive environmental damage. This approach emphasizes the importance of prioritizing the reputation of the company even in the most challenging situations in order to preserve partnerships and partners' trust (Feria-Domínguez et al., 2016).

Such cases illustrate that reputational damage could directly affect supply chain risk management by weakening the trust of the local communities (Ukhurebor et al., 2023), increasing regulatory scrutiny and potentially discourage collaboration with new partners.

Taking into consideration everything mentioned in this chapter, supply chain risk management strategies must include reputational and social risk assessments as integral components. Building the reputation of a company help maintain supply chain stability and can reduce vulnerability to crises that periodically occur.

Discussion

Building upon the review results, this section provides a critical discussion of their significance and explores potential strategies for risk mitigation and supply chain resilience.

Addressing the diverse risks associated with supply chains in the petroleum industry requires a very detailed strategic approach. The complexity of modern SCM systems is underscored in previous chapters in which geopolitical uncertainties, environmental

and climate-related risks, market volatility, technological advancements, reputational risks and social pressures have been analysed. To give the possible solutions to these risks, effective mitigation strategies that integrate proactive planning and innovation and collaboration across stakeholders have to be implemented to ensure adaptability and resilience.

Potential solutions for each identified risk category have been presented in this section, emphasizing the importance of a systematic literature review approach. By leveraging advanced technologies, fostering sustainable practices and engaging with local and global communities, companies can navigate these challenges while enhancing operational efficiency and maintaining stakeholder trust. These potential solutions aim to provide practical frameworks for managing unstabilities and to ensure long-term success in a challenging industrial environment.

Most authors agree that geopolitical and climate risks are the main factors that disrupt supply chains in the petroleum industry (Çevik, 2024; Chen et al., 2024). On the other hand, fewer studies deal with technological risks and cybersecurity (Alsalama and Alzahrani, 2024), which shows that digital threats are still underestimated in the literature. Many papers examine oil price volatility and market instability (Baumeister and Kilian, 2016; Olayungbo et al., 2024), but they usually look at these risks separately. There are not enough studies that analyse how financial, technological, and reputational risks are connected and how they can occur at the same time. Also, a large number of papers are based on case studies of specific regions, such as the Russia–Ukraine war or the Red Sea crisis. This limits the possibility to make general conclusions for the whole industry. Finally, many studies focus only on one part of the supply chain (upstream, midstream, or downstream), while there are fewer works that show how risks spread through the entire chain (Attia et al., 2019; Miner et al., 2024). Because of that, the literature still lacks an integrated approach that includes all categories of risks together in one framework.

Table 2: Critical Review of the Literature – Coverage and Gaps

Area	What is well covered	What is missing (gap)
Geopolitical risks	Many studies on wars/conflicts	Few long-term, cross-regional analyses
Climate risks	Arctic & extreme weather well studied	Weak links with other risk categories
Market risks	Oil price volatility deeply analysed	Few works integrate financial + technological + reputational risks
Technological risks	Cybersecurity issues identified	Mostly conceptual, few empirical validations
Reputational risks	ESG, case studies (e.g. BP)	No systematic frameworks connecting reputation & SC resilience

Potential Solutions to the Geopolytical Risks

As already said, many geopolitical risks threaten to disrups SC of petroleum industries; they also have a powerful influence on shaping the future of energy markets (Figueiredo et al., 2022). To fight and mitigate the impact of these risks, SCMS have to act wisely by implementing different strategies.

Table 3: Risk Categories and Mitigation Strategies

Risk category	Mitigation strategies	Key authors
Geopolitical	Diversification, exit strategy, ownership separation	Gamso et al. (2024); Heizer et al. (2020)
Climate	Contingency plans, specialized equipment, weather forecasting	Necci et al. (2019); Çevik (2024)
Market	SSCM, supplier diversification, cost optimization	Gardas et al. (2019); Qadir et al. (2021)
Technological	AI, IoT, predictive maintenance, cybersecurity	Alsalama & Alzahrani (2024); Haouel & Nemeslaki (2023)
Reputational	ESG compliance, transparent communication	Arora & Lodhia (2017); Ahmad et al. (2023)

According to (Gamso et al., 2024), risk diversification and proactive positioning could be the strategies to mitigate the potential negative consequences of geopolitical risks. For example, the identification and exploitation of new opportunities, such as spreading investments and resources and entering more stable markets can enhance business stability. Moreover, SCM has to consider the strategy of consciously preparing an exit plan in the event of a bad geopolitical situation. One more strategy that can be fruitfully implemented is separating ownership control from operational management (Gamso et al., 2024). This strategy enables owners to keep ownership and profits while transferring operational duties to managers who are more equipped to handle external risks such as political instability. Because operational choices can be made more quickly by individuals with experience in handling such difficulties, this technique helps to lessen the influence of geopolitical concerns and ensures economic stability even in unpredictable times (Heizer et al., 2020). These strategies enable petroleum companies to reduce vulnerability to geopolitical turbulence and can ensure long-term profitability if implemented wisely.

Potential Solutions to the Climate and Environmental Risks

To mitigate the risks associated with climate change and natural environmental hazards impacting petroleum SC, particularly in the upstream and midstream sectors, several strategic measures are recommended by the authors (Çevik, 2024; Https://Unctad.Org/Publication/Navigating-Troubled-Waters-Impact-Global-Trade-Disruption-Shipping-Routes-Red-Sea-Black?Utm_source=chatgpt.Com, n.d.; Katopodis & Sfetsos, 2019; Miner et al., 2024; Necci et al., 2019). Special attention should be given to transportation, equipment handling and worker's health, as challenges posed by high winds, low temperatures, storms, and sea ice in regions like the Arctic and Sub-Arctic are significant (Necci et al., 2019). Establishing contingency plans that account for these

risks, along with specialized equipment for operating in harsh climates, is essential for minimizing operational disruptions. Advances in technology, such as weather forecasting, remote monitoring and early-warning systems, can provide early warnings and enable companies to adjust their operations proactively, which lowers the risk of accidents and equipment failure (Çevik, 2024; Katopodis & Sfetsos, 2019).

A better understanding of risks is crucial for diminishing climate change and environmental effects on the oil working facility. It's also critical to invest in infrastructure that can survive severe weather conditions. Permafrost melting threatens transportation and extraction infrastructure; hence, specific building methods that take into account ground stability and the possibility of changing topography as a result of thawing permafrost have to be used (Katopodis & Sfetsos, 2019; Miner et al., 2024).

Addressing the combined effects of geopolitical and climate-related risks requires a coordinated response. As already said, essential chokepoints for the global petroleum industry are the Suez Canal, Bab al-Mandab Strait, and Panama Canal. In order to maintain the flow of goods and minimize financial losses, disruptions in these areas brought on by political unrest or climate change must be managed through diversified supply routes and improved international cooperation (Https://Unctad.Org/Publication/Navigating-Troubled-Waters-Impact-Global-Trade-Disruption-Shipping-Routes-Red-Sea-Black?Utm_source=chatgpt.Com, n.d.).

When talking about environmental regulations, according to (Hasan et al., 2024), petroleum companies have to implement GSCM measures. Moreover, oil and gas companies are investing in renewable energy sources and diversifying their business models in order to become a more environmentally friendly industry and to meet modern environmental standards (Wang et al., 2022).

Through the implementation of a comprehensive strategy that integrates cutting-edge risk management techniques, infrastructure modification, and technological advancement, the petroleum sector can more effectively lessen the influence of environmental and geopolitical hazards on its supply chains.

Potential Solutions to the Technological Risks

By incorporating cutting-edge technologies like ML and AI, operations in the oil and gas sector can be optimized by enhancing efficiency and precision (Oladiran Kayode Olajiga et al., 2024). Automated drilling systems and digital twins also improve safety and efficiency in oil and gas operations (Wanasinghe et al., 2020). Although technological developments have increased oil and gas industry efficiency, they have also brought about risks such as cybersecurity vulnerabilities and system failures. To manage these difficulties and maintain operational stability, significant investments, knowledgeable workers, and effective cybersecurity measures are needed. According to (Https://Www.Api.Org/-/Media/Files/Policy/Cybersecurity/2018/Defense-in-Depth-Cybersecurity-in-the-Natural-Gas-and-Oil-Industry.Pdf, n.d.), petroleum companies should invest in cutting-edge technologies and put in place thorough cybersecurity measures to reduce technological risks in the oil and gas sector. Moreover, the same author claims that enhancing resilience against cyber threats can be achieved by implementing a defense-in-depth strategy, which consists of several layers of security controls.

Potential Solution to the Reputational Risks

As already said, environmental incidents and ethical violations followed by negative media reports can dramatically damage a company's reputation, leading to disruptions in SC and financial losses. In order to increase or maintain a high reputation, risk and reputation management of the companies has to implement comprehensive strategies that prioritize environmental responsibility, ethical practices, and transparent communication with stakeholders (Albeldawi, 2023). Moreover, the same authors emphasize the importance of controlling and managing polluting emissions and discharges in order to minimize negative impacts of the companies' operations, which can lead to building trust in the company that implements these measures (Fragouli, 2016).

Conclusions

Addressing the diverse risks associated with SC in the petroleum industry requires a comprehensive and proactive approach. This paper has identified and analysed the major risk factors, including geopolitical, environmental, climatic, market, economic, technological, and reputational risks, each of which poses significant challenges to the stability and efficiency of petroleum supply chains. By systematically reviewing the literature and examining various mitigation strategies, this study has highlighted the importance of integrating risk management practices, technological advancements, and strategic planning to enhance supply chain resilience.

To mitigate geopolitical risks, companies must diversify investments, establish contingency plans, and separate ownership control from operational management to ensure stability in volatile regions. Addressing environmental and climate-related risks demands advanced monitoring technologies, infrastructure adaptation, and compliance with evolving regulatory frameworks to reduce operational disruptions. Technological risks, particularly cybersecurity threats, require substantial investments in AI, ML, and robust security frameworks to ensure operational continuity. Furthermore, reputational risks can be minimized through ethical business practices, environmental responsibility, and transparent communication with stakeholders.

The findings emphasize that a multi-layered risk management approach, combining innovation, strategic partnerships, and sustainability initiatives, is crucial for securing long-term profitability and competitiveness in the petroleum industry. Future research could explore the dynamic interdependencies of these risks and the effectiveness of emerging technologies in mitigating their impacts. By implementing an integrated and forward-looking strategy, petroleum companies can navigate uncertainties in SC, optimize SC performance, and contribute to a more resilient and sustainable energy sector.

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