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Sustainable performance and disaster management in the oil and gas industry: An intellectual capital perspective

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ABSTRACT

In the post-COVID era and amidst the ongoing Ukraine conflict, the natural resource extraction sector, particularly oil and gas, faces unprecedented challenges in maintaining its sustainability. Disasters in this sector, ranging from environmental catastrophes to operational disruptions, further exacerbate these challenges, eroding environmental integrity and aggravating social issues. These events underscore the urgency of strengthening disaster management capabilities in the oil and gas sector to safeguard against future uncertainties and sustain its operational viability. Against this context, this study aims to examine two critical facets of disaster management in the oil and gas sector. The first objective is to assess the role of intangible resources, particularly intellectual capital, in improving an organization's disaster management capabilities. Intellectual capital, encompassing human, relational, and structural capital, is posited as a key driver in managing complex and unpredictable challenges. The second objective is to investigate the role of supply chain risk management in mediating the impact of intellectual capital on disaster management. Data for this study were collected from firms in the oil and gas sector of Pakistan through a structured questionnaire Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed for data analysis. The results reveal a significant impact of intellectual capital on improving both the responsiveness and alertness aspects of disaster management. Further, supply chain risk management emerges as a crucial factor in channeling the influence of intellectual capital on disaster management effectiveness. Findings of the study not only contributes to the theoretical understanding of disaster management in the natural resource sector but also offers practical insights for industry practitioners. The novelty of this study lies in its empirical examination of the interplay between intellectual capital, supply chain risk management, and disaster management capabilities, win the context of the oil and gas sector.

1. Introduction

The exploration and exploitation of natural resources, particularly in the oil and gas sector, has become increasingly complex and fraught with risks, leading to an urgent need for effective disaster management strategies. This need is especially pronounced in countries, where the oil and gas sector are not only a significant contributor to the national economy but also a field susceptible to various supply chain-related disasters (Daghigh and Pishvaee, 2021; Liu and Chen, 2022; Mubarik et al., 2023). These disasters, ranging from environmental catastrophes to operational disruptions, pose a significant threat to the sustainability and resilience of this sector (Marchese et al., 2018; Pinto et al., 2019; Ajami, 2020; Mubarik et al., 2023). A major example of this can be seen in the aftermath of oil spills or gas leakages, where the long-term ecological and economic impacts often extend far beyond the immediate vicinity of the incident, highlighting the critical need for robust disaster management approaches (Zhang et al., 2019; Nazir and Yu, 2023).

Extensive research has been conducted to identify effective strategies for managing disasters in the natural resource sector (Ahmad et al., 2020; Khan et al., 2020; Zeng et al., 2022). These studies have largely focused on conventional risk management, technological solutions, and

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regulatory frameworks. However, there remains a significant gap in understanding the role of specific organizational capabilities, particularly intellectual capital (IC) and supply chain risk management (SCRM), in enhancing disaster management effectiveness. Intellectual capital (IC), *comprising human, relational, and structural capital*, is increasingly recognized as a vital component for fostering organizational resilience and adaptability (Mahmood and Mubarik, 2020; Ali et al., 2021; Khan et al., 2022; Kusi-Sarpong et al., 2022). In the context of the oil and gas sector, the IC of a firm is not just a repository of knowledge and skills but also a catalyst for innovation and strategic thinking, essential for managing complex supply chain challenges. Furthermore, anecdotal evidence suggests that a strong base of intellectual capital can significantly enhance a SCRM capabilities, which in turn can lead to more effective disaster management. However, the empirical exploration of these relationships is still in its nascent stage, particularly in terms of their generalizability and the magnitude of their impact. Therefore, this study aims to fill this gap by empirically examining how IC, both in its overall form and through its individual components, can influence supply chain disaster management (SCDM). Additionally, it seeks to understand the role of SCRM as an intermediary in the relationship between IC and disaster management effectiveness.

The oil and gas sector of Pakistan presents a unique and important context for this study. As a key player in the country's economy, the performance of this sector and sustainability has far-reaching implications. The challenges faced by this sector, characterized by its complex supply chains and high-risk operations, provide a fertile ground for examining how IC and SCRM can contribute to more effective disaster management (Ali et al., 2023; Junaid et al., 2023; Nazir et al., 2023b). This examination is crucial not only for the theoretical advancement in the fields of disaster management and supply chain resilience but also for providing practical insights to policymakers and industry practitioners in Pakistan and similar contexts.

The contributions of this study are manifold. Firstly, it seeks to unveil the impact of IC on SCDM, thus providing a more in-depth understanding of how organizational knowledge resources can be leveraged for managing complex and unpredictable disruptions. Secondly, by exploring the role of SCRM in the nexus between IC and SCDM, this study contributes to the literature by elucidating the mechanisms through which intellectual capital can be effectively translated into disaster management capabilities. Furthermore, this study contributes to the broader literature on sustainability and resilience in the natural resource sector, particularly in emerging economies like Pakistan, by highlighting the pivotal role of organizational capabilities in navigating the challenges of supply chain disruptions and environmental risks.

2. Literature review

2.1. Definitions and dimensions

2.1.1. Twin blades of SC disaster management

Despite advancements in technology, effectively disasters management remains a significant challenge (Sinha et al., 2019; Khan et al., 2020). Disasters, defined as events causing widespread harm to people, damaging infrastructure, or resulting in loss of life and property, necessitate comprehensive management strategies (Van Wassenhove, 2006; Farahani et al., 2020). These strategies, collectively known as disaster management, involve deploying resources to address such adverse situations (Demiroz and Haase, 2020). The United Nations Office for Disaster Risk Reduction (UNISDR) reports an increase in natural disasters in recent years, attributed to climate change, including droughts, cyclones, floods, typhoons, hurricanes, and landslides (UNISDR, 2018). In response, nations develop diverse supply chain strategies for managing disasters, addressing both the preparatory and recovery stages (Botchie et al., 2019). The economic impact of these disasters is profound and often destabilizing economies (Botzen et al., 2019).

According to prior studies such as Panwar and Sen (2018), Botchie et al. (2019), Tang et al. (2019) and Nazir et al. (2023a) indicates that disasters have significantly hindered economic growth globally. Between 2016 and 2020, the world incurred an estimated US$894 billion in economic losses, with 99,244 fatalities (EM-DAT, 2021). Developing countries, particularly in Asia, bore the brunt of these losses, with deaths in Asia being twice as many as in Europe, America, and Oceania combined during this period (EM-DAT, 2021). Fig. 1-A and 1-B illustrate the disproportionate impact of natural disasters in Asia, largely due to inadequate disaster relief planning, such as the unavailability of relief items and delayed casualty evacuation (Botchie et al., 2019; Altay et al., 2018; Altay and Green, 2006). This underscores the need to focus on disaster impacts in developing countries and to design resilient supply chain networks to improve relief operations.

In this study, we operationalize disaster management through two primary indicators: *supply chain responsiveness and supply chain alertness*. Supply chain responsiveness is the capacity of an organization to react swiftly to supply chain disruptions, while supply chain recovery focuses on the organization's ability to recuperate post-disaster. These elements aid organizations in mitigating negative impacts, enhancing traditional risk management strategies, and managing supply chain risks effectively (Pettit et al., 2013). Developing a responsive supply chain network is crucial in reducing risks from unforeseen disturbances (Hanna et al., 2010; Gupta et al., 2022) minimizing losses and damages (Scholten and Fynes, 2016) and implementing emerging strategies that facilitate the restoration of operations following a disaster (Azmat et al., 2019; Tsadikovich et al., 2020; Schwarz et al., 2023).

2.1.2. Intellectual capital

Intellectual capital, an intangible knowledge asset within an organization, is crucial for sustained competitive advantage. It encompasses not only the knowledge embedded within the structure, processes, and culture of an organization but also its people and routines (Mahmood and Mubarik, 2020; Mubarik and Bontis, 2022; Nazir et al., 2023b). This multifaceted asset is composed of three primary components: human capital, structural capital, and relational capital, each playing a distinct role in organizational resilience and disaster management. Human capital (HC) refers to the collective knowledge, skills, experiences, and capabilities of employees, along with their loyalty, commitment, and motivation towards the organization (Dost et al., 2016; Ahmed et al., 2020; Mubarik and Naghavi, 2020). It is a critical element in enhancing individual and organizational capacity to withstand and recover from disasters. Furthermore, Khan et al. (2022), emphasizes that human capital encompasses the skills and experiences that enable individuals to effectively address and recuperate from disaster situations. Likewise, structural capital (SC), the second component of intellectual capital, represents the knowledge and information ingrained in an organization's databases, structures, routine operations, patents, processes, and procedures (Youndt et al., 2004; Mahmood and Mubarik, 2020; Mahmood et al., 2021). This element is essential for efficient operations both before and after a disaster strikes. Mubarik et al. (2021) highlights that structural capital also includes the organizational structure and business processes, serving as a vital tool for knowledge acquisition and integration. Similarly, the third component, relational capital (RC), is pivotal in creating value and pertains to the firm's relationships with its internal and external stakeholders (Subramaniam and Youndt, 2005; Mubarik et al., 2018; Ahangama et al., 2021). This aspect covers the organization's connections with employees, suppliers, customers, and other stakeholders (Ali et al., 2021). Additionally, the relational capital facilitates the acquisition of valuable information and supports innovation in supply chain performance through effective information integration with suppliers and customers (Han and Li, 2015; Mubarik et al., 2021). This interconnectedness is crucial for enhancing the organization's overall disaster resilience and response capabilities.

The present study operationalizes IC by taking its above discussed three major constituents: human capital, relational capital, and

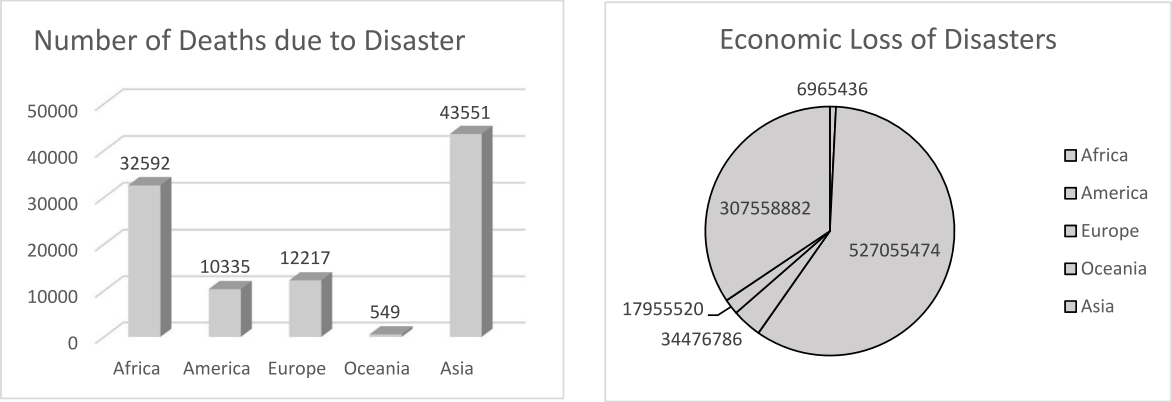

Fig. 1. Impacts of natural disasters in Asia.

structural capital. Drawing on Mubarik et al. (2018), the above literature explains human capital as the knowledge, skills, abilities, attitudes, attributes, and stabilities of employees of an organization. Further, Nazir et al. (2023b) rationalizes the relational capital as an organizational relationship with its both upstream supply chain partners and downstream partners such as suppliers, employees, customers, and other related stakeholders, that include but not limited to governments, and institutions. Likewise, this research operationalizes the structural capital (Mubarik and Bontis, 2022) as an organization's unique processes, databases, practices and repositories through which that organization perform its business.

2.1.3. Supply chain risk management

The concept of risk in the context of supply chains has been extensively explored in literature, offering a multitude of definitions and dimensions (Fan and Stevenson, 2018; Vilko and Lättilä, 2018; Vilko et al., 2019). At its core, risk can be defined as the presence of unpredictable events that have the potential to result in both favorable and unfavorable consequences (Baryannis et al., 2018). The comprehensive concept of risk is exemplified in the studies conducted by Scholten and Fynes (2016), Azmat et al. (2019), Katsaliaki et al. (2021) who discusses the inherent uncertainty and its consequences. Supply chain risks in extraction industries such as mining, oil, and gas extraction are inherently complex and have several dimensions. These risks stem from a variety of factors, including social, environmental, geopolitical, operational, and market-based challenges (Frederiksen, 2018; Liaropoulos et al., 2019).

Environmental risks are the most prominent, as the extraction of natural resources often involves significant disruption of ecosystems and can lead to issues such as pollution, habitat destruction, and water contamination (Johnston et al., 2019; Brown et al., 2020). These environmental impacts not only pose a risk to the surrounding environment but also to the companies involved, as they can lead to regulatory fines, cleanup costs, and reputational damage (Kusi-Sarpong et al., 2022). Furthermore, social risk in supply chain is an additional significant concern that is progressively acknowledged as a pivotal determinant affecting the viability and sustainability of natural resource extraction operations. These risks arise from the interaction between the extraction activities and the social fabric of the communities and regions where these activities occur (Piprani et al., 2022). One of the key social risks is its adverse impact on local communities (Miemczyk and Luzzini, 2019). Oil and gas extraction often take place in remote or underdeveloped areas, where the local population may depend heavily on the natural environment for their livelihoods. The disruption caused by extraction activities, such as land use changes, land erosion, and increased traffic, can have significant social implications, including displacement of communities, and negative impacts on health due to pollution. This can also lead to the potential for conflict with local communities (Ayompe et al., 2021). This can arise from issues such as land rights, environmental degradation, and perceived inequality in the distribution of the benefits of resource extraction. In some cases, this can lead to protests, legal challenges, and even violence, which can disrupt operations and lead to costly delays and reputational damage. Likewise, labor issues also pose a significant social risk (Yawar and Seuring, 2015). The oil and gas industry are often linked with harsh working conditions, risks of accidents and injuries, and issues related to fair labor practices. Poor labor conditions can lead to worker unrest, strikes, and challenges in recruiting and retaining skilled workers (Orazalin and Mahmood, 2018). Further, operational risks in resource extraction are related to the technical and logistical challenges of extracting and transporting raw materials. These include the risks of accidents, equipment failures, and labor disputes, which can halt production and lead to significant financial losses. Similarly, the reliance on specialized equipment and skilled labor means that any disruption can have a prolonged impact on the supply chain (Abduljabbar and Breesam, 2022).

Keeping in view the dire, and detrimental effects of these risks, the necessity for robust risk management practices increases manifold:

Identification: This requires identification of risk, its types and magnitudes. The identification process involves not only recognizing these risks but also understanding their sources and the ways in which they could affect the supply chain (Alashhab, 2020).

Assessment: In this step the assessment of the risk, in term of its probability, nature and impact magnitude is done. This requires both qualitative and quantitative analysis of assessment. The goal is to prioritize the risks, focusing on those that are most likely to occur and have the greatest potential impact (Junaid et al., 2023).

Mitigation: Based on the assessment, strategies are developed to mitigate the identified risks. This might include diversifying suppliers to reduce dependency on a single source, investing in more resilient infrastructure, implementing better safety and quality controls, or developing contingency plans for rapid response to disruptions. Risk mitigation is about finding the right balance between reducing the probability or impact of risks and the costs or efforts involved in these mitigation strategies (Van Thuyet et al., 2019).

Control: this step involves monitoring and review of the risk management strategies. Due to the dynamic nature of SC, this step is of critical importance as new risks can emerge. Continuous monitoring allows for the detection of changes in the risk landscape, while regular reviews ensure that the risk management strategies remain effective and are updated as necessary (Smith and Merritt, 2020; Mubarik et al., 2021).

Drawing from the literature, we define SCRM as the systematic process of identifying, assessing, and mitigating risks in the SC to ensure continuity and efficiency of SC operations, by proactively addressing both external and internal factors that can disrupt the flow of goods and services from supplier to customer.

2.2. Theoretical exposition

The study takes its theoretical roots from the IC-based view of the firm, Dynamic Capabilities Theories (Teece et al., 1997) and Stake holders' theory (Parmar et al., 2010). According to the IC-based view of the firm, intellectual capital comprises one of the strategic intangible resources of an organization that can uplift an organization's performance and competitiveness (Ali et al., 2023). It is argued that supply chain alertness and supply chain responsiveness are two major organizational capabilities and any intangible resource that affects the performance may also impact these two organizational capabilities. Furthermore, it is argued that IC in terms of human capital provides the resilient, skilled, and apt human resources to prepare and respond to unforeseen disruptive events (Mubarik and Naghavi, 2020). Moreover, relational capital, an important cord of IC, helps an organization to build a greater understanding of the key stakeholders in its upstream and downstream supply chain (Mahmood and Mubarik, 2020) further helping to effectively respond to disruptions. Likewise, for the organizational processes, efficient structural capital development helps to prevent any unforeseen situation and offer systematical mitigation to it. Putting together, IC, which encompasses human capital, relational capital, and structural capital, can be viewed as a key resource, which develops robust disaster management capabilities by providing the necessary knowledge, skills, and relationships to effectively manage and mitigate disasters.

The Dynamic Capabilities Theory complements IC based vies by focusing on an organization's ability to build, integrate, and reconfigure internal and external competencies for addressing rapidly changing environments. In the context of oil and gas sector, firms must develop dynamic capabilities to manage risks and respond to disasters effectively. SCRM capability, a form of dynamic capability, helps firms to identify, assess, and respond, to disruptions, thereby enhancing their disaster management capabilities, and improving sustainability. The mediating role of SCRM, routing the impact of IC on disaster management, can be conceptualized in this framework, suggesting that IC contributes to the development of dynamic capabilities in SCRM, which in turn improves SC disaster management. Similarly, Stakeholder Theory further broadens the perspective by emphasizing the importance of considering the interests of all stakeholders in a firm's operations. In the context of disaster management in the oil and gas sector, this theory highlights the need for firms to manage risks and respond to disasters in a way that accounts for the expectations and needs of stakeholders, including employees, communities, investors, and regulatory bodies. Effective disaster management capability is thus seen not only as a means of protecting the firm's resources but also as a crucial aspect of maintaining trust and relationships with stakeholders, thereby contributing to sustainable performance.

Based on the above theoretical underpinnings, below theoretical framework of the study is drawn.

2.3. Hypotheses development

2.3.1. IC and SC disaster management

As discussed in the literature, SCs of natural resource extraction sectors are no longer confined to single countries; instead, they encompass a web of interconnected processes including procurement, manufacturing, and distribution across multiple global locations. This expansion and complexity inherently bring about a multitude of challenges for organizations. They now face an increasing array of unpredictable events ranging from natural disasters like earthquakes and floods, to pandemics, and geopolitical disturbances (Chen et al., 2013; Tukamuhabwa et al., 2015; Mandal and Saravanan, 2019). In response, there is a growing emphasis on building effective SC disaster management capabilities, through responsive and alert supply chains (RES-ALT SC)[1], capable of withstanding and quickly recovering from these disruptions (Khan et al., 2020; Demiroz and Haase, 2020; Munir et al., 2022). RES-ALT supply chains have the ability to prepare for, withstand, and recover from unforeseen events, maintaining continuous operations. It is an integral influencer of SCRM, as posited by various studies (Li et al., 2008; Alzoubi et al., 2022; Munir et al., 2022). The significance of such RES-ALT is highlighted by the fact that over eighty percent of organizations express concerns about the responsiveness, and alertness of their supply. Academic and practical discourses increasingly focus on developing RES-ALT supply chains as a means to rapidly recover from disruptions (Murino et al., 2011; Brandon-Jones et al., 2014; Alzoubi et al., 2022). Furthermore, the role of supply chains extends beyond mere operational recovery; they are pivotal in aiding communities and individuals to rebound from disastrous events to a state of normalcy (Ayoub and Abdallah, 2019). Crafting an effective disaster management strategy within supply chains necessitates a plethora of skills and capabilities to navigate uncertainties and gain a competitive edge. At the heart of this strategy lies Intellectual Capital (IC), an invaluable asset in fostering both alertness and responsiveness of a supply chain. The nexus between IC and RES-ALT highlights the critical importance of intellectual capital in improving supply chains' ability to withstand and recover from disasters. The organization's intellectual capital, which includes its workers, relationships, and robust processes, enhances its ability to effectively anticipate, address, and recover from crises. Against this context, the study proposes that.

H1. Intellectual capital improves the supply chain disaster management of a firm.

It is based on the idea that an organization's capacity to handle any disruptions in the supply chain is greatly enhanced by the knowledge, expertise, and relational networks that make up intellectual capital. Therefore, this study leads to the development of the following two hypothesis as a sub-hypotheses. These sub-hypotheses aim to test the pivotal role of IC in improving the disaster management capabilities of supply chains, with a particular focus on RES-ALT (responsiveness and alertness as key components of resilience) in the face of unforeseen challenges.

Hypothesis 1a. Intellectual capital improves the supply chain responsiveness of a firm.

Hypothesis 1b. Intellectual capital improves the supply chain alertness of a firm.

2.3.2. IC and SC disaster management: role of SC risk management

Before indulging into IC-disaster management paradox, it is important to reiterate that recently the world has witnessed a significant increase in disasters, both natural and man-made, leading to widespread disruptions affecting human lives, infrastructure, and the global economy. Various incidence reveals that conventional disaster management approaches, often reactive and short-term in nature, have proven inadequate, particularly in the context of SC continuity and resilience. This inadequacy underscores the need for more proactive and long-term strategies that integrate IC in disaster risk planning and management.

IC can be a critical asset in enhancing supply chain disaster management capability, acronymic as RES-ALT (responsive and alert supply chain). It provides the foundation for developing comprehensive SCRM strategies that can anticipate, prepare for, respond to, and recover from disruptive events. For example, human capital, a key component of IC, is

[1] The study takes SC responsiveness and SC alertness as two component of SC disaster management capability of a firm and uses acronym *RES-ALT SC* to represent 'SC *responsive and SC alertness"* together.

integral in developing and implementing effective SCRM strategies. It encompasses the knowledge, skills, and experience of the workforce, which are crucial in identifying potential risks and developing innovative solutions (Mubarik and Naghavi, 2020). As argued by scholars like Cuervo et al. (2017), a knowledgeable and skilled workforce can better anticipate and respond to disruptions, thereby enhancing the resilience of the supply chain. Moreover, HC contributes to a culture of risk awareness and proactive management, as suggested by Barney (1991), who emphasized the role of unique organizational capabilities in achieving competitive advantage. Similarly, Relational capital (RC), another dimension of IC, pertains to the relationships and networks a company maintains with external entities like suppliers, customers, and partners. These relationships are instrumental in risk management, as they facilitate information sharing and collaboration, which are essential in identifying and mitigating risks across the supply chain. Uzzi (1997) highlighted the importance of social relationships in facilitating adaptive behaviors in organizations, while Dyer and Singh (1998) pointed out the role of relational capital in creating relational rents and competitive advantage. In the context of SC risk management, strong relationships can lead to better coordination and cooperation, enabling quicker and more effective responses to disruptions, thereby enhancing resilience. Further, Structural capital, which includes the systems, procedures, databases, and organizational structures, serves as the backbone of SC risk management. It allows for the efficient organization and dissemination of information, ensuring that risk management processes are implemented effectively and consistently. According to Teece et al. (1997), the SC is a key component of dynamic capabilities of a firm, enabling it to adapt to changing environments. In the realm of SC risk management, well-designed systems and processes ensure that risk assessment and mitigation strategies are integrated into the daily operations of the supply chain, fostering resilience.

The mediating role of SCRM emerges as it translates the strengths of IC into actionable strategies to manage and mitigate risks. This translation is critical because, as Kähkönen et al. (2023) noted, the ability of a SC to bounce back from disruptions depends not only on the inherent capabilities but also on how these capabilities are operationalized in the face of risk. SCRM serves as the mechanism through which the relationships, and structures offered by IC are leveraged to enhance the resilience of the supply chain (Mahmood et al., 2021). For example, the knowledge and expertise of employees (human capital) can be utilized to develop predictive models and risk assessment tools (Junaid et al., 2023), while the relationships with suppliers and customers (relational capital) can be leveraged for collaborative risk management (Mubarik et al., 2018) and contingency planning (Cheng et al., 2023). Similarly, the organizational processes and systems (structural capital) ensure that risk management practices are consistently applied and integrated into the SC operations (Mubarik and Bontis, 2022).

Furthermore, the mediating role of SC risk management is underscored in the literature that explores the concept of responsiveness and alertness in supply chains. As Christopher and Peck (2004), Pettit et al. (2013), Mubarik et al. (2021), Mubarik and Bontis (2022) have noted, resilience in supply chains is not just about the ability to recover from disruptions but also about the capacity to anticipate, prepare for, and adapt to these disruptions. This proactive aspect of resilience is where SC risk management plays a pivotal role, bridging the gap between the capabilities provided by IC and the actual resilient outcomes in the supply chain. The above discussion leads us to draw the following hypothesis.

Hypothesis 2. SC risk management mediates the relationship between IC and SC Disaster Management of a firm.

In order to test the above major hypothesis, followings are two sub-hypotheses namely (H2a,b).

Hypothesis 2a. SC risk management mediates the relationship between IC and SC alertness of a firm.

Hypothesis 2b. SC risk management mediates the relationship between IC and SC responsiveness of a firm.

3. Methodology

3.1. Population and sampling

The focus of the study is Oil and Gas sector of Pakistan. The Oil and Gas sector, broadly termed as the energy sector, consists of two major streams of the supply chain i.e. upstream and downstream presented in Table 1. The first upstream supply chain is related to the "Exploration and Production (E&P)". A total of 24 firms (national and international) are operating in E&P. According to the Ministry of Energy Report (2020, p.12), "*37 exploratory wells and 67 appraisal/development wells were spudded in 2019.*" The downstream supply chain is divided into two sectors oil and gas downstream. The oil downstream sector is further categorized into oil refining and oil marketing. The oil downstream sector has six major ORC (Oil Refining Companies) and 30 OMC (Oil Marketing Companies) both from the public and private sectors. The sector has also 03 OPLC (oil pipeline companies). Primarily the storage of the oil is taken by the OMCs. In the gas downstream SSGCL and SNGPL are two utilities SOEs– NGPL provides gas to most of the country, whereas a small transmission network exists that is owned and operated by gas producers or bulk consumers for direct supplies. According to the Ministry of Energy Report (2020, p.13), "*OGDCL remains the largest exploration and production company in the country, with a 45.3 % & 29.2% share of the total annual oil and gas production in the country. MOL is the largest private and second-largest oil-producing company in the country with a production share of 24%. PPL – a pioneer of exploration and production in Pakistan is the second-highest gas-producing company in the country with a 19.3% production share. Other major companies include Eni, MOL, MPCL, and UEP.*"

Data were collected using a close-ended questionnaire adopted from the previous studies. There is a total of 62 firms in Oil and Gas sector of Pakistan and all were targeted for the data collection as presented in Table 2. It was decided to have at least 05 questionnaires from each firm to have a more robust and comprehensive response. A total of 36 organizations responded and we received 180 filled questionnaires. After initial screening 04 questionnaires were removed because of highly unengaged responses.

4. Data analysis and results

PLS-SEM was employed in order to analyze the hypothesized relationships. As this technique is considered as an appropriate rigorous method for both theory development and examination (Hair et al., 2011). PLS-SEM was applied in two major steps. First, the reliability and validity of the measurement model/constructs were ascertained through confirmatory factor analysis (CFA). In the second stage, hypotheses testing was performed through structural model. This approach is preferred over covariance-based SEM because of its ability to handle non-normal data.

4.1. Measurement model

At the first step, assessment of measurement models was performed.

Table 1
Population of oil and gas sector.

Stream	Activities	*n*
Upstream Supply Chain	Exploration and Production (E&P)	24
Down Stream	Oil Refineries Companies (ORC)	06
	Oil Marketing Companies (OMC)	30
	Gas Utility Companies (GUC)	02
Total		***62***

Table 2
Population of oil and gas sector.

	Firms targeted	Firms responded	Responses[a]
Exploration and Production	24	11	55
Oil Refineries	06	5	25
Oil Marketing Companies	30	18	90
Gas Utilities	02	02	10
Total	62	36	180

[a] 05 questionnaires from each organization.

Table 3 presents the results of this assessment for the reliability and validity of the constructs. These results help to determine the robustness of the constructs employed in this study as shown in Fig. 3.

4.1.1. Reliability of the scales

The reliability was tested using the values of Cronbach's alpha and composite reliability (CR), which must be greater than 0.70. The results (Table 3) show that all the values of Cronbach's alpha and CR are greater than 0.70 thus confirming the reliability of the constructs.

4.1.2. Construct validity

Both convergent validity and discriminant validity have been used to check the construct validity of the constructs used in this study. Convergent validity was ascertained using the average variance extracted (AVE) value, which should be greater than 0.50. Heterotrait-monotrait (HTMT) analysis was used to check the discriminant validity of the constructs. The AVE values of all the constructs are greater than 0.50 as exhibited in Table 3, whereas the HTMT values are lower than 0.90 (Hameed et al., 2020; Majid et al., 2023; Faiz et al., 2024). Both the values confirm the convergent validity and discriminant validity of the constructs.

4.2. Structural model

At the second step, the analysis of structural model was performed to test the hypotheses. Table 4 presents the results of structural model and Fig. 2 presents the estimated conceptual framework. The findings support the significant positive impact of IC on SC responsiveness ($\beta = 0.394$, $p < 0.005$) and on SC alertness ($\beta = 0.527$, $p < 0.05$). Likewise, the results also exhibit a significant impact of IC on supply chain risk planning ($\beta = 0.442$, $p < 0.05$). The high coefficient value reflects the large effect of IC on SC risk planning. Furthermore, SC risk planning has a positive impact on both cords of disaster management (SC alertness $\beta = 0.631$, $p < 0.05$; SC responsiveness $\beta = 0.283$, $p < 0.05$).

In order to get an in-depth picture, we also exhibit the findings on the indirect effect. The results show that human capital and relational capital influence SC alertness and SC responsiveness. However, structural capital has a positive influence only on SC alertness ($\beta = 0.442$, $p < 0.05$) but not on SC responsiveness ($\beta = 0.11$, $p > 0.05$). Its indirect impact on SC responsiveness through SC risk planning is also not substantiated ($\beta = 0.051$, $p > 0.05$). The results do not support both the direct and indirect impact of relational capital ($\beta = 0.14$, $p > 0.05$) on the SC responsiveness of a firm.

Putting together, the results show a strong direct and indirect impact (through supply chain planning) of IC on SC alertness and SC responsiveness. Likewise, the results also confirm the effect of human capital, and relational capital, directly and through supply chain risk planning on both dimensions of disaster management. Further R square value shows a considerable variation (59% approx.) in disaster management is explained by intellectual capital and supply chain risk planning. The value of blindfolding i.e. Q-square 0.43 reflects the high predictive relevance of the model.

5. Discussion

The study aims to investigate the relationships among the components of IC, supply chain risk planning, and disaster management (i.e., supply chain alertness and responsiveness) by taking the case of the oil and gas sector in Pakistan. The aforementioned results presented in Table 5 demonstrates the significance of intellectual capital and its

Table 3
Reliability and validity statistics.

Construct	Items	Loadings	CB α	CR	HTMT	AVE	AVE
Human Capital	HC1	0.810	0.76	0.870	0.89	0.6	0.76
	HC2	0.830					
	HC3	0.760					
	HC4	0.703					
	HC5	0.690					
Relational Capital	RC1	0.890	0.99	0.890	0.85	0.9	0.94
	RC2	0.708					
	RC3	0.795					
	RC4	0.738					
	RC5	0.799					
Structural Capital	SC1	0.822	0.880	0.9	0.87	0.9	0.95
	SC2	0.630					
	SC3	0.771					
	SC4	0.859					
	SC5	0.912					
Supply Chain Alertness	SA1	0.818	0.850	0.93	0.84	0.9	0.96
Supply chain Responsiveness	SA2	0.764					
	SA3	0.786					
	SA4	0.830					
	SA5	0.811					
	SR1	0.838					
	SR2	0.810					
	SR3	0.743					
	SR4	0.821					
	SR5	0.809					
Supply Chain Risk Planning	SCR1	0.836	0.820	0.88	0.83	0.9	0.94
	SCR2	0.670					
	SCR3	0.730					
	SCR4	0.760					
	SCR5	0.790					
	SCR6	0.680					

Table 4
Path analysis.

Paths	β	Std. D	t-value	Acc/ Reject
Intellectual Capital → SC Alertness	0.527	0.04	13.18	Acc
Intellectual Capital → SC Responsiveness	0.394	0.11	3.58	Acc
Intellectual Capital →Supply Chain Risk Planning	0.442	0.09	4.91	Acc
Supply Chain Risk Planning → SC Alertness	0.631	0.13	4.82	Acc
Supply Chain Risk Planning → SC Responsiveness	0.283	0.07	4.04	Acc
Human Capital →SC Alertness	0.194	0.02	9.70	Acc
Human Capital →SC Responsiveness	0.15	0.05	2.78	Acc
Human Capital → Supply Chain Risk Planning	0.25	0.02	12.50	Acc
Relational Capital → SC Alertness	0.09	0.02	4.50	Acc
Relational Capital → SC Responsiveness	0.14	0.09	1.56	Rej
Relational Capital →Supply Chain Risk Planning	0.181	0.01	18.10	Acc
Structural Capital → SC Alertness	0.44	0.02	22.00	Acc
Structural Capital → SC responsiveness	0.11	0.09	1.24	Rej
Structural Capital → Supply Chain Risk Planning	0.306	0.02	15.30	Acc
Mediating role				
Intellectual Capital → SCR Planning → SC Alertness	0.279	0.05	5.58	Acc
Intellectual Capital → SCR Planning → SC Responsiveness	0.125	0.02	6.25	Acc
Human Capital → SCR Planning → SC Alertness	0.158	0.01	15.78	Acc
Human Capital → SCR Planning → SC Responsiveness	0.071	0.05	1.42	Rej
Relational Capital → SCR Planning → SC Alertness	0.114	0.07	1.56	Rej
Relational Capital → SCR Planning → SC Responsiveness	0.051	0.04	1.25	Rej
Structural Capital → SCR Planning → SC Alertness	0.193	0.09	2.05	Acc
Structural Capital → SCR Planning → SC Responsiveness	0.087	0.06	1.44	Rej
R square 0.591				
Q square 0.43				
F-square 0.39				

***Acc* entails the acceptance of the relationship modeled.**
***Rej* represents the rejection of relationships modeled**

positive impact on the firms' SC response to unforeseen events and the rapid action plan to be dealt with (H1a, b). This shows that IC which is widely recognized as a primary driver of corporate performance also plays an essential role in supply chain responsiveness and alertness. The findings suggest that component IC plays a critical role in the development of a supply chain that is responsive to any unforeseen circumstances and better prepared to overcome the challenges associated with it through efficient use of human, relational and structural capital. These findings are in line with the earlier work of Zhang and Lv (2015), Wang and Huo (2018), Shou et al. (2018), Mubarik et al. (2021), which highlights the critical role of the components of IC. Such as, Human Capital comprises the expertise and knowledge gained through the collaboration between employees and supply chain partners which develop a unique competitive advantage (Xu et al., 2019; Sumbal et al., 2021), while Mubarik et al. (2021) finds that employee knowledge, skills, satisfaction, and motivation are all tied to human capital. Which in turn leads to improved competencies and better collaboration (Shou et al., 2018; Wang et al., 2019). Similarly, by incorporating relational capital, organizations can generate more innovative ideas by learning from other people's experiences, as well as by sharing knowledge and information with the supply chain partners including suppliers (Duodu and Rowlinson, 2019). The relationship with suppliers could be further improved by information sharing, collaboration, treating them as partners, focusing on value not price, treating them fairly, fostering trust and ensuring mutual interest. It is possible to improve the connections between internal members, contribute to information sharing and transformation while external relational capital can also give firms a new opportunity for discovering and incorporating information into their existing internal resources (Xu et al., 2019; Mubarik et al., 2021). Structural Capital includes the organizational structures, processes, and culture and it is the knowledge that an organization owns after employees leave (Xu et al., 2019). It also creates the foundation for human capital to generate values in the firm through employees learning and development. Furthermore, it enables businesses to improve the quality of both their products and their processes while incurring the least amount of expense, resulting in increased profitability and better responsiveness (Zhang and Lv, 2015).

Further analysis of H2a and H2b demonstrates the significant positive direct impact of IC on a firm's responsiveness and alertness while indirect significant impact via supply chain risk planning. Nevertheless, previous research has established the linkages between human, relational and structural capital and has highlighted the fact that IC components improve competitive advantages by interacting and collaborating (Shou et al., 2018; Dogan and Kevser, 2020; Nguyen and Doan, 2020). However, the findings indicate that human capital and structural capital positively affects supply chain alertness directly and indirectly via supply chain risk planning but not affecting the supply chain responsiveness significantly. Furthermore, relational capital, on the other hand has direct significant impact on SCRP but it has no substantial impact on supply chain alertness nor on supply chain responsiveness with the mediating role of supply chain risk planning. This could be due to hierarchical decisions in many organizations as previously no work has been done on this change. Therefore, its indirect effect on Supply Chain responsiveness via Supply chain risk management is not significant. Similarly, the data indicates that the IC has a large impact on supply chain risk planning. The high coefficient value

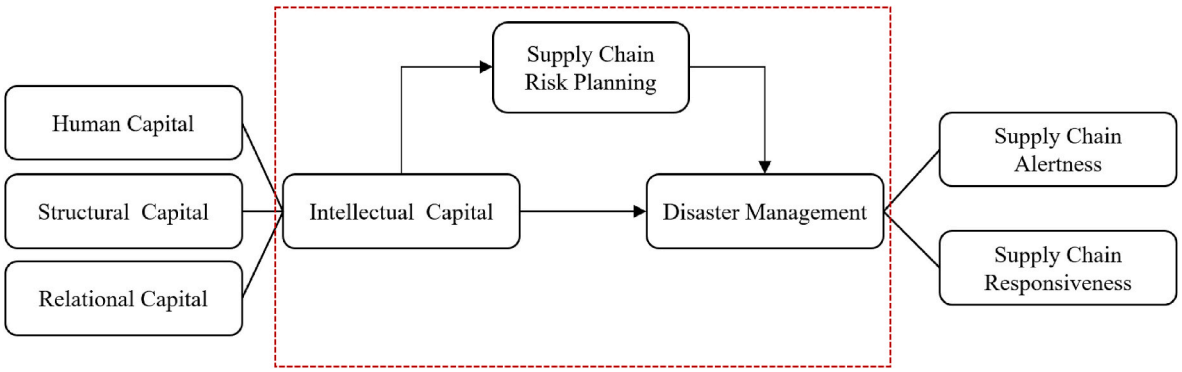

Fig. 2. Theoretical framework.

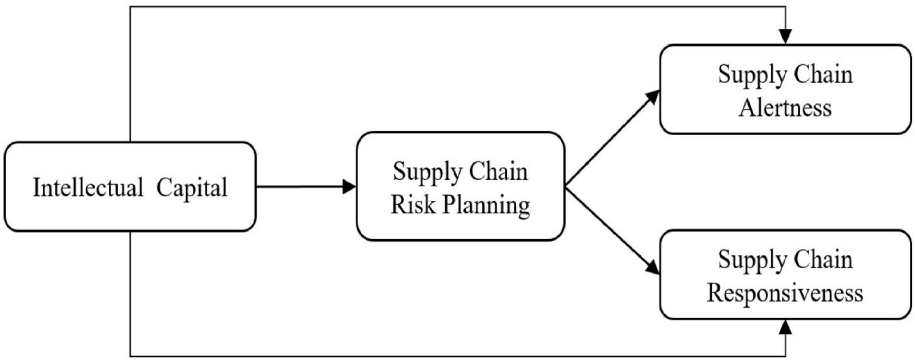

Fig. 3. Expanded conceptual framework.

Table 5
Hypothesis testing.

Hypotheses	Decision
Implementing IC has a positive influence on SC alertness	Supported
Implementing IC has a positive influence on SC responsiveness	Supported
Supply Chain Risk Planning mediates the relationship between IC and SC alertness of a firm	Supported
Supply Chain Risk Planning mediates the relationship between IC and SC responsiveness of a firm	Supported

represents that IC has a large effect on SC risk planning. Additionally, SC risk management has a beneficial effect on both sides of disaster management (SC alertness and a firm's disaster management response plan) which are all statistically significant and supporting the (H2a, b).

6. Conclusion, implications and limitations

The overarching aim of the present study was to test the influence of IC on SC responsiveness and SC alertness of a firm. The study also explores the role of SC risk planning in the association between IC and SC responsiveness and alertness. The data was collected from Pakistan's Oil and Gas sector using a close-ended questionnaire. The findings of the study support the direct and indirect impact of IC on the SC responsiveness and SC alertness of a firm. Nevertheless, the by-dimensional analysis reveals that relational capital and structural capital do not directly influence the SC responsiveness of a firm. The findings also rejected the indirect influence of relational capital on SC alertness and responsiveness of a firm. Likewise, the indirect impact of structural capital was also not supported by the findings of the study. Taken together, overall IC has a strong direct and indirect impact on the SC responsiveness and alertness of a firm and could be used as an organizational strategy for disaster management. We propose incorporating the elements of intellectual to build an alert and responsive supply chain capable of responding to disasters through better preparation. Based on our findings, we also suggest that such an alert and responsive supply chain would enable supply chain managers to propagate an environment of collaboration, innovation, and information sharing between entities involved in planning or managing disaster relief efforts. To measure the IC-driven SC performance over time, we suggest that SC performance should be closely observed before and after the implementation of IC in the supply chain, each element of IC should be treated and measured individually such as employees learning, and development should be measured against how employees dealt with the unforeseen event and impact of disruption. It should also be measured that if the SC performance is improving overtime or decreasing while firm incorporates IC in its functioning.

The study has some profound implications. First of all, managers must understand that the inherent complexity and intertwined relationship of present-day supply chains make them susceptible to supply chain disruption, which can have far-reaching effects. In order to overcome this complexity, intellectual capital can play a very effective role as illustrated by the findings of this study. We suggest managers develop a threefold strategy for each dimension of IC namely human capital, relational capital, and structural capital. For human capital, managers may adopt specific training programs aimed at harnessing the planning, relationship management, and risk management skills of human resources. Likewise, these skills could also be made an integral part of the organization's recruitment and selection criteria to increase the right stock of human capital. Further, the organizations also need to recognize the importance of relationship management, relational capital and must devote strategy to manage the right relationship with the right supply chain partner. Further, we also suggest that the organizations relook at the current business processes and ensure their alignment with the SC risk management, SC alertness, and responsiveness needs. The realignment would greatly help an organization to have seamless, well-integrated, and uninterrupted business processes contributing to the SC alertness and responsiveness. Moreover, it is important that to attain IC-led supply chain alertness and responsiveness, policies must be focused on specific objectives and implementation strategies.

This study is subject to some limitations. It studies the oil and gas industry in Pakistan; therefore, findings should be applied with caution in any other industry and developed countries. Future research can include studying a number of developing countries and drawing generalizations from the findings. Also, a comparative study between developing and developed countries with respect to disaster alertness and responsiveness could be another source of future research.

Ethical approval

Researchers have adhered to ethical standards while doing this research study.

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Consent to participate

All authors consent to participate as per the above structure.

Appendix: questionnaire

1. Intellectual Capital	
A. Human Capital	
HC1	Employees in our company are highly skilled in their respective jobs.
HC2	Employees in our company are considered among the best people in our industry
HC3	Employees in our company are experts in their particular jobs and functions
HC4	Our employees can find simple solutions for more complex problems.

(*continued on next page*)

(*continued*)

1. Intellectual Capital	
HC5	Our employees are well-educated compared with their peers in the industry
B. Relational Capital	
RC1	Employees from different departments feel comfortable while calling each other
RC2	Our employees apply the knowledge leaned from one area of the company to the other area when they face any problem.
RC3	Our company is keen on developing long-term relationships with its suppliers and customers.
RC4	We collaborate extensively with external parties (e.g., customers and suppliers) to develop new solutions
RC5	Customer feedback guides our company activities
C. Structural Capital	
SC1	Much of our company's knowledge is contained in manuals, archives, and databases.
SC2	We usually follow the sequence of written rules and procedures
SC3	Our company embeds much of its knowledge and information in structures, systems and processes
SC4	Our company uses intellectual property rights (patents/registered software, and copyrights) as a way to store knowledge
SC5	Our company protects knowledge and key information to avoid loss of key people left the company
2. (Supply Chain) Disaster Management	
A. Supply Chain Alertness	
SA1	Identify technologies for supply chain management that increase supply chain visibility.
SA2	Track structural changes (i.e. structural shifts in the market caused by economic progress, political and social changes, demographic trends and technological advances)
SA3	We detect threats to supply networks
SA4	We detect sudden changes in demand
SA5	We detect unexpected changes in the physical flows throughout the supply chain.
B. Supply Chain Responsiveness	
SR1	We reconfigure supply chain resources to respond to the sudden changes in supply/demand.
SR2	We adapt supply chain processes to reduce lead time
SR3	We adjust supply chain processes to increase (the ratio of) in time delivery.
SR4	We streamline supply chain processes to reduce non-value-added activities.
SR5	We effectively respond to changes in market demand and adjusts the supply chain processes accordingly.
3. Supply Chain Risk Management	
SCR1	Our firm has a comprehensive risk management plan in place that specifically addresses various potential supply chain disruptions."
SCR2	We regularly conduct risk assessments to identify and mitigate potential supply chain vulnerabilities.
SCR3	Our supply chain risk management strategies are well-integrated with our overall business continuity plans.
SCR4	We have established strong relationships with multiple suppliers to ensure supply chain resilience in case of disruptions.
SCR5	Our firm invests in advanced technologies and systems to enhance visibility and control over our supply chain risks.
SCR6	Our firm actively trains and educates our staff on supply chain risk management practices and procedures.

CRediT authorship contribution statement

Sajid Nazir: Writing – review & editing, Writing – original draft, Resources, Project administration, Investigation, Data curation, Conceptualization. **Mahmood Ali:** Writing – review & editing, Project administration, Investigation. **Munazza Saeed:** Validation, Software, Investigation, Data curation. **Muhammad Shahzad Mubarik:** Visualization, Validation, Investigation, Data curation. **Qasim Jalil:** Visualization, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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