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GREEN HYDROGEN SUPPLY CHAIN PRACTICES' IMPACT ON OIL AND GAS COMPANIES' PERFORMANCE

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Abstract

The study assesses the organizational performance of oil and gas companies in the MENA region in relation to the impact of green supply chain practices, specifically waste management and regulatory compliance. The research examines the potential of green hydrogen supply chain practices to improve operational efficiency and performance, with a particular emphasis on the moderating effects of technological and managerial barriers, using the Natural Resource-Based View (NRBV) theory. The research employs a mixed-methods approach, utilizing a cross-sectional survey to gather quantitative data and in-depth interviews to gain qualitative insights. The results suggest that organizations' performance is considerably enhanced by the implementation of effective waste management and legislations and regulations. Nevertheless, these outcomes are adversely affected by managerial barriers and technological barriers. In spite of these obstacles, the implementation of green hydrogen supply chains indicates potential for enhancing performance and sustainability. The strategic value of integrating environmental considerations into core business operations is underscored by these insights, which provide practical guidance for industry practitioners and policymakers who are striving to promote green supply chains and sustainability in the oil and gas sector of the MENA region.

Keywords: Green hydrogen supply chains, green hydrogen supply chain practices, green hydrogen, organizational performance, NRBV theory, MENA

1 Introduction

The availability of environmentally sustainable, secure, and dependable energy sources is crucial for maintaining societal development and improving quality of life, particularly considering the limitations imposed by social, environmental, political, and economic considerations on energy supply (Ishaq et al., 2022). The increasing global population and the fast economic growth rate have led to a significant rise in energy demand, negatively impacting fossil fuel reserves (Hermesmann & Müller, 2022). Although fossil fuels still meet a substantial part of this increasing demand, multiple issues are linked, such as the exhaustion of natural resources and increased greenhouse gas (GHG) emissions (Ishaq et al., 2022). Mitigating these challenges necessitates a unified worldwide transition from conventional fossil fuels to sustainable energy sources (Hosseini & Wahid, 2019). Among these options, researchers (Kazi et al., 2021; Seck et al., 2022) have indicated that hydrogen is a highly promising fuel with prospective uses beyond its traditional uses (Acar & Dincer, 2019). Hydrogen surpasses synthetic carbon-based fuels in its capacity to achieve carbon neutrality or even carbon negativity across its entire life cycle, providing substantial environmental advantages. Hydrogen production can be classified into blue, green, and gray hydrogen categories (Dowell et al., 2021), each characterized by distinct manufacturing methods and environmental consequences.

Green hydrogen, generated from sustainable energy sources, is significant as it can reduce carbon emissions and facilitate the shift towards a low-carbon economy (Agaton et al., 2022). Green hydrogen is expected to make up over 85% of the overall hydrogen generation by 2050, with an estimated yearly range of 500 to 800 million tons (Energy Transitions Commission, 2023). Additionally, from a production cost perspective, green hydrogen has the capacity to eventually surpass its alternatives in terms of economic feasibility (Manna et al., 2021). Despite the current lower production costs of blue hydrogen, estimated at around $2 per kilogram, and the even more cost-efficient gray hydrogen at around $1.5 per kilogram, the costs of green hydrogen production, currently estimated to be between $3 and $5 per kilogram, are projected to show a significant reduction in the future (Energy Transitions Commission, 2023). The prospect of achieving cost reductions in the production of green hydrogen and its inherent environmental benefits has resulted in heightened worldwide attention towards its advancement.

The current research focuses on the Middle East and North Africa (MENA) region due to its abundant oil and gas deposits and the region's increasing focus on sustainable energy. The MENA region also prioritizes green hydrogen to broaden its energy sources and enhance sustainability. Nations such as Oman, the United Arab Emirates (UAE), and Egypt have initiated extensive green hydrogen initiatives to position themselves as frontrunners in renewable energy (Abdelshafy, 2024; Martin, 2023; Martin & Parkes, 2023). Through 2022, the MENA region received over 63 proposals for green and low-carbon hydrogen projects, with Egypt and the UAE taking the lead (Connecting Hydrogen MENA, 2023). The increasing emphasis on green hydrogen production in the MENA area corresponds to its strategic objective of mitigating the negative impacts of climate change and decreasing its reliance on fossil fuels (IRENA, 2021; McKinsey & Company, 2021).

However, it is important to acknowledge that even though green hydrogen is important for the oil and gas industry, some challenges are linked to its manufacturing and distribution networks. Challenges related to implementing green hydrogen supply chain (GHSC) practices include insufficient infrastructure, financial burdens, and regulatory barriers (Brandon & Kurban, 2017; Grubel et al., 2020). Furthermore, the successful implementation of these practices may be impeded by managerial resistance to change and poor strategic vision (Ahmad et al., 2016; Raut et al., 2017). According to Bhandari and Shah (2021) and Reuß et al. (2019), the implementation of green hydrogen supply chains (GHSCs), which prioritize the production and transportation of green hydrogen, has the capacity to improve operational efficiency, environmental sustainability, and competitive advantage of oil and gas companies in the MENA region. Nevertheless, it is necessary to conduct an empirical study in order to evaluate the influence of GHSC practices on the performance of organizations within this particular setting in the context of MENA's oil and gas industry. The study also focuses on evaluating the moderating role of technological and managerial barriers on the relationship between GHSC practices and organizational performance. Furthermore, it expands on the Natural Resource-Based View (NRBV) theory to emphasize the ways in which firms can improve their performance by including environmental sustainability in their fundamental activities (Olajide et al., 2019; Tseng et al., 2019).

2 Literature Review

2.1 Theoretical Framework – NRBV Theory

The NRBV theory, proposed by Stuart Hart in 1995, provides a crucial foundation for comprehending how firms might use environmental sustainability to gain a competitive edge (Olajide et al., 2019). In contrast to conventional business strategies that mainly prioritize economic growth, the NRBV emphasizes the role of natural resources and environmental factors in facilitating sustained organizational performance (Miemczyk et al., 2016). Hart (1995) outlines three essential elements that contribute to this competitive advantage such as pollution prevention, product stewardship, and sustainable development. Pollution prevention is the proactive reduction of waste and emissions throughout the manufacturing process, resulting in financial savings and enhanced operational effectiveness. The concept of product stewardship goes beyond the manufacturing stage and promotes the consideration of the whole lifespan of items, encompassing design, production, and disposal. Ultimately, sustainable development emphasizes the enduring consequences of corporate operations, guaranteeing that firms participate in endeavors that are both financially and environmentally sustainable (Hart, 1995).

Researchers have used the NRBV theory in various contexts. For instance, the results of McDougall et al. (2019) and Olajide et al. (2019) demonstrate that the NRBV theory guided in measuring organizational performance in relation to aspects such as operational efficiency, environmental sustainability, and financial performance. The underpinning of the NRBV theory also determines the competitive advantage based on ensuring regulatory obligations, lowering operational expenses, and enhancing overall market competitiveness. Furthermore, the incorporation of environmental factors into supply chain operations, as emphasized by Li et al. (2016), can enhance a company's capacity to maximize performance without compromising financial results.

Within the framework of GHSCs, the NRBV theory emphasizes the need of sustainable resource management and its capacity to stimulate innovation and enhance performance. Organizations that implement GHSC practices in line with the NRBV can experience advantages such as decreased waste, reduced emissions, and enhanced organizational performance. These factors all contribute to their long-term competitive advantage (Miemczyk et al., 2016).

2.2 Organizational Performance

Miller et al. (2013) have indicated that exploring organizational performance is a prevalent area of interest in the field of organizational management research. Taticchi (2010) offers a critical analysis of current definitions of performance. Combs et al. (2005) and Zhu et al. (2016) observed that financial performance is considered a primary aspect of overall organizational performance as they outlined that financial indicators determine optimal performance.

Nevertheless, Storey et al. (2016) and Taticchi (2010) contend that the existing theoretical framework for organizational performance is still constrained. Combs et al. (2005) propose that operational performance, as precisely described by Venkatraman and Ramanujam (1986), should be regarded as a precursor to overall performance. Prominent scholars such as Hubbard (2009) provide a comprehensive perspective that incorporates operational, social, and environmental performance as interrelated components. In the context of social and environmental outcomes, the optimization of operational processes has the potential to enhance resource efficiency and reduce waste (Zailani et al., 2012). According to Kumar et al. (2019), the incorporation of sustainable practices into operations can have a beneficial effect by improving both organizational performance and business reputation. Continuous improvement, stakeholder engagement, and the integration of sustainability concepts throughout the organization are integral components of performance. Organizations that demonstrate exceptional performance in all three metrics, such as environmental, social, and financial are more aptly positioned for sustained success, generating value for stakeholders, distinguishing themselves in the market, and making a positive contribution to sustainability.

2.3 Green Supply Chain Practices and Organizational Performance

In the field of green supply chain management (GSCM), researchers have indicated various practices, such as eco-design, regulations, green purchasing, and waste management among others (Zhu et al., 2007). The focus of the current research is waste management and regulations as they are more in line with hydrogen supply chains.

Specifically, Chung and Wee (2011) observed that government initiatives frequently result in the establishment of efficient regulatory frameworks and incentive programs that encourage sustainability in different industries. Legislations and regulations play a crucial role in promoting sustainable supply chains, as highlighted by Chen and Sheu (2009), who contend that effectively executed rules are vital in guaranteeing long-term sustainability. Lu et al. (2007) and Hitchcock (2012) emphasize that regulations frequently motivate firms to embrace environmentally sustainable practices. Zailani et al. (2012) have observed that proactive measures to tackle environmental concerns are being progressively pursued in preparation for changing regulatory obligations. Through strict adherence to these statutes, corporations not only guarantee conformity but also make a valuable contribution towards mitigating pollution and improving the general sustainability of their activities (Bahou, 2023). In addition, implementing regulations and legislations can improve the organizational performance of oil and gas firms involved in the production and distribution of green hydrogen and its supply chains (Moradpoor et al., 2023). Fiscal incentives, including tax exemptions, subsidies, and grants, can be offered by governments to facilitate the establishment of green hydrogen infrastructure, encompassing the processes of production, delivery, and storage (Ballo et al., 2022). Moreover, governments have the ability to allocate funds towards research and development activities that target the progress of green hydrogen technologies. They can provide grants to enterprises involved in pioneering advancements in this field (Ballo et al., 2022; Fúnez Guerra et al., 2020). The establishment of well-defined rules pertaining to the production, transportation, and use of green hydrogen can foster a stable and predictable business climate, therefore augmenting organizational performance for these enterprises (IRENA, 2022). Furthermore, governments have the potential to establish rigorous environmental criteria for the generation of green hydrogen, therefore guaranteeing that enterprises fully achieve their sustainability objectives. By complying with these criteria, oil and gas businesses can decrease carbon emissions, enhance environmental performance, and bolster their corporate image (Aung, 2017). Furthermore, regulations enable the incorporation of green hydrogen into current energy networks by implementing grid codes and technological standards that guarantee smooth links with electricity and natural gas infrastructures (Alturki, 2022). Governments should facilitate long-term offtake agreements between producers of green hydrogen and end-users, such as businesses and utilities, to establish a stable market and incentivize firms to expand their infrastructure investments (Nurdiawati & Urban, 2022). The establishment of renewable energy targets and the integration of green hydrogen into energy transition plans by governments generate a conducive investment climate for oil and gas companies, hence enhancing organizational performance (Arent et al., 2022; Dong et al., 2022).

Another GHSC practice that can contribute to high organizational performance is waste management. Effective waste management focuses on reducing waste generation, encouraging recycling and reuse, and implementing proper disposal methods to minimize environmental harm and protect public health (Upadhyay & Chakma, 2022). Xin et al. (2022) utilized a multi-objective location-allocation model to analyze a solid waste management system that includes collection, transportation, incineration, composting, recycling, and disposal. Similarly, Fiorucci et al. (2003) developed a decision support system to evaluate waste collection policies and identify optimal sites for treatment and disposal plants. Various mathematical models have also been applied to waste management (Suksanguan et al., 2022). Gupta and Barua (2021) advocate for waste prevention over post-generation management. Recent literature also examines environmental management systems (EMS), life-cycle assessments, and challenges in reverse manufacturing (White et al., 2003). In the oil and gas industry, persistent drilling operations generate hazardous waste, leading to stringent environmental regulations (Morero et al., 2020). Similarly, effective incorporation of waste management strategies within the GHSC is crucial to mitigate adverse environmental effects. In the field of green hydrogen production, electrolysis is the predominant technique that employs renewable energy to partition water into hydrogen and oxygen (Laguipo et al., 2022). Although the ecological impact of green hydrogen production is minimal, it is imperative to implement waste management methodologies to effectively manage by-products such as brine (Upadhyay & Chakma, 2022). Effective management of waste containment, treatment, and disposal is essential to minimize environmental damage. Optimal approaches, such as the implementation of recycling and water reuse practices, effectively mitigate freshwater usage and foster sustainable operations (Weerasooriya et al., 2021). Achieving environmental sustainability requires the implementation of appropriate procedures for handling, storing, and transporting green hydrogen, together with the minimization of waste generated by packaging materials (Preston, 2022). It is imperative to manage hazardous waste produced throughout the supply chain in compliance with rules to avoid any damage to the environment and human health (Cao et al., 2020). Integrating waste management strategies showcases a dedication to sustainability, therefore increasing the company's reputation and garnering favorable interest from stakeholders, such as investors and customers. Implementing efficient waste management practices can enhance organizational performance through cost reduction and productivity increase. Through the optimization of operations and the minimization of downtime, oil and gas firms have the potential to enhance their entire performance.

The following null hypothesis is developed based on the discussion that adherence to legislative and regulatory frameworks and effective waste management measures in GHSCs have a beneficial impact on organizational performance of oil and gas firms.

$H1_a$: There is an effect of GHSC practices (legislations and regulations and waste management) on the organizational performance of oil and gas companies in the MENA region.

2.4 Relationship between Implementation of Green Hydrogen Supply Chains and Organizational Performance

The implementation of GHSCs is increasingly being recognized as a viable approach to address climate change and shift towards greater sustainability in energy systems. Green hydrogen, derived from sustainable energy sources, provides oil and gas firms with an opportunity to broaden their energy portfolios, therefore decreasing their dependence on finite resources (Al-Orabi et al., 2023; Chi & Yu, 2018). These diversification efforts function as a risk management tactic, reducing the effects of volatile energy prices, regulatory shifts, and growing environmental demands. The implementation of GHSCs has the potential to improve the positioning of oil and gas firms in the low-carbon economy, therefore improving their market position and long-term sustainability (Dawood et al., 2020; Dong et al., 2022; Mneimneh et al., 2023). Within industries such as transportation, electricity generation, and industrial operations, green hydrogen has the potential to supplant traditional fuels (Dawood et al., 2020; Dong et al., 2022). Furthermore, the integration of green hydrogen can effectively mitigate carbon emissions and advance the cause of environmental sustainability (Van de Graaf et al., 2020). However, implementation of these supply chains necessitates significant financial investment in infrastructure, including electrolysis equipment, storage facilities, and transportation networks (Gondal, 2019). The oil and gas companies in the MENA region have been primarily dealt with fossil fuels and can face challenges in meeting the financial requirements and overcoming technological barriers concerning efficiency and scalability (Mathieu & Jordana, 2022). It can be understood that the implementation of green hydrogen can improve the organizational performance of the oil and gas companies in the MENA region, which has led to the development of the following null hypothesis.

$H2_a$: There is an effect of the 'implementation of GHSCs' on the organizational performance of oil and gas companies in the MENA region.

2.5 Managerial Barriers

De Jesus et al. (2019) conducted research to identify the primary barriers that affect the adoption of green and sustainable technology and revealed that organizations' limited knowledge of the advantages of sustainable innovations, a scarcity of competent staff, low consumer receptiveness towards sustainable products, inadequate investment in associated research and development, and the view of sustainability as a financial burden rather than a long-term investment could have a negative effect. De Jesus et al. (2019) indicated that these aspects are linked to insufficient managerial abilities in the areas of planning, delegating, and coordination, which can affect sustainability and performance. Managers are frequently compelled to participate in ethical leadership due to robust environmental and ethical principles (Eweje & Bathurst, 2017). Nevertheless, traditional corporate demands can clash with individual principles, resulting in difficulties (Busse, 2016). Internal organizational elements, such as financial considerations, inadequate organizational structure, contradictory strategies, and unfavorable views of sustainability, add complexity to the incorporation of sustainability criteria into company choices. Notwithstanding these difficulties, Slawinski and Bansal (2015) propose that the dedication of an organization to sustainability and the active involvement of stakeholders might assist in alleviating some of these conflicts. A study conducted by Xiao et al. (2019) found that buying managers, notwithstanding their preference for sustainable items, may be discouraged by constraints imposed by suppliers and economic demands. Various barriers at the managerial level, including deficiencies in communication, bureaucratic structures, and reluctance to embrace change, have the potential to weaken the process of decision-making and strategic planning, which gives rise to inefficiencies, escalated expenses, and diminished productivity, ultimately affecting the performance of the organization. Based on the above discussion, the following null hypothesis is developed.

$H3_a$: There is an effect of managerial barriers on the organizational performance of oil and gas companies in the MENA region.

Furthermore, the impact of GHSCs, such as regulations and waste management, on organizational performance may depend on the handling of managerial barriers. For instance, if new legislation requires firms to implement prescribed environmental or safety measures, the presence of managerial barriers may hinder the organization's ability to comply with these requirements that can lead to a decline in the overall performance of the business in terms of complying with regulatory obligations, reducing financial penalties, or maintaining a positive public image (Combs et al., 2005). Furthermore, the relationship between waste management and organizational performance might be influenced by constraints imposed by management. Potential consequences of this phenomenon include inadequate waste reduction, improper trash disposal, or non-compliance with waste standards, which can lead to reduced organizational performance (Hoque & Rahman, 2020). Such occurrences have the potential to lead to a decrease in the operational effectiveness of the business, shown by increased costs, negative environmental impacts, failure to comply with regulatory requirements, damage to reputation, and legal consequences. There is currently no empirical study that examines how managerial barriers moderate the relationship between GHSC practices and organizational performance, which led to the development of the following null hypothesis.

$H4_a$: There is a moderating effect of technological barriers on the relationship between GHSC practices and the organizational performance of oil and gas companies in the MENA region.

2.6 Technological Barriers

The incorporation of technology into production is becoming more crucial as a result of the expectations from policymakers, manufacturers, and industry stakeholders. Gupta and Barua (2018) emphasize the need to develop a strong innovation framework for effectively managing organizational activities. The adoption and implementation of innovations, particularly in the development of scalable operations, pose a multitude of barriers. Furthermore, numerous businesses encounter a deficiency of technical proficiency and human resources required for implementing sustainable innovations (Gupta & Barua, 2021). Notwithstanding substantial investments in eco-friendly products, enterprises frequently lack a comprehensive framework for efficiently integrating these technologies. Technological barriers encompass the transformation towards a zero-carbon economy, constraints in recycling technologies, and difficulties in integrating data and achieving eco-efficiency (Alzoubi, 2021). The significant upfront expenses associated with green hydrogen production and infrastructure, including electrolysis facilities and storage, present considerable challenges (Alzoubi, 2021). Insufficient financial resources may restrict the extent and pace of green hydrogen adoption, therefore adversely impacting the performance of the firm (Boulmrharj et al., 2023). Furthermore, the challenges related to the effectiveness and expandability of electrolysis technology, as well as the requirement for appropriate infrastructure for hydrogen storage and transportation, add complexity to the incorporation of this technology into current energy systems (IRENA, 2022). Based on the above discussion, the following null hypothesis is developed.

$H5_a$: There is an effect of technological barriers on the organizational performance of oil and gas companies in the MENA region.

The impact of legislations and regulations on organizational performance may be considerably moderated by technological barriers. Barriers pertaining to the adoption, deployment, and use of technology might hinder an organization's capacity to adhere to regulatory obligations (Ada et al., 2021). The absence of essential technology infrastructure or skills can pose challenges for firms in fulfilling legal requirements, therefore impacting their compliance and performance (Al-Orabi et al., 2023). Technological limitations exacerbate compliance efforts by introducing challenges related to data management and reporting, including integration deficiencies, accuracy issues, and data security (Ada et al., 2021). Financial constraints may also hinder organizations from allocating resources to or adopting the necessary technologies for efficient regulatory compliance. However, automated monitoring and reporting systems, in conjunction with sophisticated waste management technologies, have the potential to enhance efficiency, precision, and cost-effectiveness, therefore exerting a beneficial influence on organizational performance (Kamilaris et al., 2019). Technological barriers also can have an effect on the relationship between waste management practice and organizational performance. Inadequate integration and utilization of technology for waste management can impede an organization’s capacity to efficiently decrease, repurpose, or eliminate trash, resulting in higher expenses, environmental consequences, failure to comply with regulations, and harm to reputation (Ada et al., 2021). However, by surmounting these barriers and embracing appropriate technology for waste management, it is possible to optimize resource use, decrease expenses, and increase both the environmental footprint and the reputation of the firm (Cao et al., 2020). Factors such as the organization’s technological skills, available resources, industry norms, and dedication to good waste management determine the impact of technological barriers on the relationship between waste management and organizational performance. The dearth of extensive research in this field, namely in the oil and gas industry, emphasizes the need to investigate these relationships, resulting in the formulation of the following null hypothesis.

$H6_a$: There is a moderating effect of technological barriers on the relationship between GHSC practices and the organizational performance of oil and gas companies in the MENA region.

Based on the hypothesis developed in the above sections, the following conceptual framework is developed.

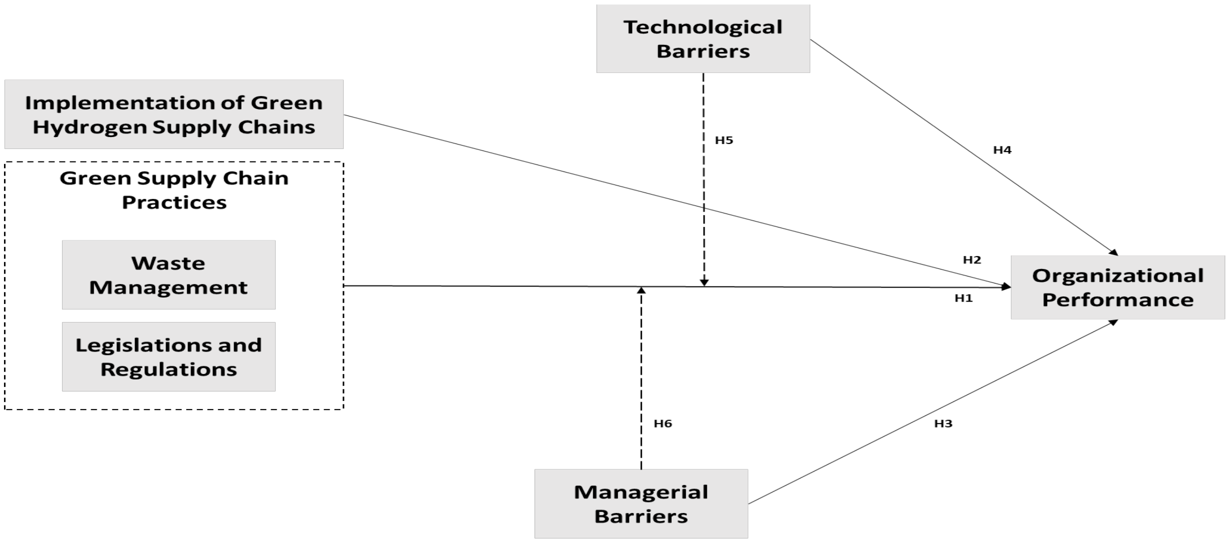

Figure 1: Conceptual Framework

(Source: Developed by the author)

3 Research Methodology

The research was underpinned by pragmatist research philosophy that considers both subjective and objective viewpoints in order to comprehend the intricate phenomena of establishing GHSCs. The study also adopted a deductive research approach that allowed the exploration of the empirical relationships among the variables indicated in the conceptual framework. The current research was conducted in two stages. The first was quantitative, and the findings of this stage were validated using qualitative method in the case study stage.

The first step of the study predominantly employs quantitative research as its approach, owing to its ability to generate objective and generalizable findings. A standardized questionnaire was developed using scales from the literature, as represented in the following table.

Table 1: Measures

Measure	Citation	Changes made to Measure	Reliability/Validity of Measure
Regulations & Legislations	Mohamad et al., 2012	New items were developed, and some were adopted from Zhu et al. (2007), Darnall (2006) and Carter and Carter (1998).	Reliability (Cronbach's alpha) - 0.705 Discriminant Validity was also not an issue, as the values were significant ($p<0.05$). Convergent Validity was also not an issues as the root mean squared error of approximation (RMSEA) was 0.048, confirmatory fit index (CFI), was 0.92 and incremental fit index (IFI) was 0.97, which indicated that the model fit was acceptable.
Waste Management	Scur & Barbosa, 2017	Items were adopted from Badurdeen et al. (2009) and Sarkis (2003)	Not outlined by the researchers
Organizational Performance	Lee, Kim, & Choi, 2012	Items were adopted from Zacharia et al. (2009)	Reliability (Cronbach's alpha) - 0.914 Discriminant Validity was also not an issue, as the values were significant ($p<0.05$).

Managerial Barriers	Baig et al., 2020	Items were developed from a scale by Giunipero et al. (2012)	Reliability (Cronbach's alpha) - 0.736 Discriminant Validity was also not an issue, as the values were significant (p<0.05).
Technological Barriers	Situmeang et al. (2022)	Items were developed from a critical review of the literature.	Subjective literature analysis was done.
Implementation of GHSCs	Bhandari & Shah, 2021	Items were developed from a critical review of the literature.	Subjective literature analysis was done.

The questions were measured with a 7-point Likert Scale, ranging from "Strongly Agree" to "Strongly Disagree,". A survey approach was used to collect data. Online administration of the questionnaire was conducted using Survey Monkey, which is available in English. The survey was specifically coded to be compatible with both laptops and mobile phones, and the hyperlink was kept operational for a duration of around 3 to 4 months to meet the schedules of the participants. In order to optimize the rate of response, the researcher circulated the survey link either through personal contacts within the oil and gas business or through HR managers in the MENA region, who then shared the survey with employees.

The population of the current research was employees of the oil and gas companies of the MENA region that were chosen using a purposive sampling strategy. Out of the 700 sample invites distributed, 515 responses were received, resulting in a response rate of 73.57%. According to Fincham (2008), a response rate above 60% is deemed acceptable, and this high rate improves the reliability and representativeness of the study. Post-data collection, the dataset underwent a cleaning process to remove any missing values and outliers. The final dataset of 510 valid responses was obtained by excluding five responses that had incomplete data. The use of this procedure guarantees the preservation and precision of the data utilized for the following analysis.

4 Results from Survey

4.1 Demographics Statistics

The demographic analysis of this study provides valuable insights into the composition of the sample population and reveals several key patterns relevant to understanding GHSCs within the oil and gas industry in the MENA region.

Table 2: Demographic Statistics

Age	Frequency	Percent
25-34 years	120	23.5
35-44 years	97	19.0
45-54 years	92	18.0
55-64 years	90	17.6
More than 65 years	111	21.8
Gender		
Female	242	47.5

Male	268	52.5
Experience in industry		
Less than 5 years	87	17.1
6 to 10 years	100	19.6
11 to 15 years	114	22.4
16 to 20 years	100	19.6
More than 20 years	109	21.4
Experience in the current position		
Less than 5 years	98	19.2
6 to 10 years	114	22.4
11 to 15 years	119	23.3
More than 20 years	101	19.8
Firm Size		
Less than 200 employees	70	13.7
200 to 2,000 employees	44	8.6
2001 to 5000 employees	42	8.2
5001 to 10000 employees	251	49.2
More than 10,000 employees	103	20.2
Firm Age		
Less than 10 years	129	25.3
11 to 20 years	134	26.3
21 – 30 years	123	24.1
More than 30 years	124	24.3
Firm Annual Sales		

Less than 10 billion USD	106	20.8
10 billion to 100 billion USD	50	9.8
More than 100 billion USD	354	69.4
Firm Type		
Private	168	32.9
Public	166	32.5
Semi-Private	176	34.5
Number of Suppliers in the Firm		
Less than 200 suppliers	118	23.1
200 to 2000 suppliers	130	25.5
2001 to 5000 suppliers	127	24.9
More than 5000 suppliers	135	26.5
Status of Implementation of GHSCs		
It is starting to think of using green hydrogen	109	21.4
It is midway in their journey of applying and using green hydrogen	354	69.4
It is advanced in using green hydrogen	47	9.2
Total	510	100.0

4.2 Testing Group Differences

One-way ANOVA was conducted to evaluate the differences in perceptions of participants regarding the variables of the study. The findings indicated that there was no statistically significant difference in perceptions of participants for all variables based on their age groups, industry experience, firm age, firm type, and firm suppliers. The findings also indicated there was no statistically significant difference in perceptions of participants for all variables, except managerial barriers based on their gender and working experience.

The findings also indicated there is a statistically significant difference in the means of organizational performance among participants working in organizations with different firm size ($F(4,505)=3662.652$, $p<0.01$). Similarly, for the other variables, differences in perceptions were found among participants perceptions regarding the implementation of GHSCs ($F(4,505)=264.815$,$p<0.01$), regulations and legislations ($F(4,505)=257.844$, $p<0.01$), waste management ($F(4,505)=141.939$, $p<0.01$), managerial barriers ($F(4,505)=114.461$, $p<0.01$), and technological barriers ($F(4,505)=175.962$, $p<0.01$) based on their firm size.

It was also found that there statistically significant difference in perceptions of participants for all variables based on their firm annual sales. It was found that there is a statistically significant difference in the means of organizational performance among participants working in organizations with different firm annual sales ($F(2,507)=1439.414$, $p<0.01$). Similarly, for the other variables, differences in perceptions were found among participants perceptions regarding the implementation of GHSCs ($F(2,507)=440.097$, $p<0.01$), regulations and legislations ($F(2,507)=469.132$, $p<0.01$), waste management ($F(2,507)=254.444$, $p<0.01$), managerial barriers ($F(2,507)=203.682$, $p<0.01$), technological barriers ($F(2,507)=317.563$, $p<0.01$) based on their firm annual sales.

There is statistically significant difference in perceptions of participants for all variables based on their implementation status of GHSCs of the firms. The results indicated that there is a statistically significant difference in the means of organizational performance among participants working in organizations with different implementation statuses ($F(2,507)=2009.690$, $p<0.01$). Similarly, for the other variables, differences in perceptions were found among participants perceptions regarding the implementation of GHSCs

(F(2,507)=503.717, p<0.01), regulations and legislations (F(2,507)=483.208, p<0.01), waste reduction management (F(2,507)=264.426, p<0.01), managerial barriers (F(2,507)=204.625, p<0.01), technological barriers (F(2,507)=353.077, p<0.01) based on their firms' implementation status of GHSCs.

4.3 Measurement Model

Covariance-based Structural Equation Modeling (CB-SEM) was used to conduct analysis for the research. IBM Amos was used to test the conceptual framework. The attainment of a good model fit is crucial when assessing the validity of the results obtained from a CB-SEM model. An appropriately fitted model precisely represents the fundamental data structure, which is essential for drawing dependable and significant inferences. One of the important indicators is that factor loadings of all items should be greater than 0.5, which was observed for all items of the variables of the current research as indicated in the following table.

Table 3: Factor Loadings

	OP	IGHSC	RL	WRM	MB	TB
OP1	0.8					
OP2	0.79					
OP3	0.77					
OP4	0.78					
IGHSC1		0.81				
IGHSC2		0.87				
IGHSC3		0.84				
IGHSC4		0.84				
RL1			0.74			
RL2			0.79			

RL3	0.76			
RL4	0.77			
RL5	0.81			
RL6	0.81			
WRM1		0.81		
WRM2		0.79		
WRM3		0.78		
WRM4		0.87		
WRM5		0.83		
MB1			0.75	
MB2			0.84	
MB3			0.85	
TB1				0.79
TB2				0.83
TB3				0.81
TB4				0.79
TB5				0.80
TB6				0.82

OP- Organizational Performance, IGHSC- Implementation of Green Hydrogen Supply Chains, RL- Regulations and Legislations, WRM- Waste Reduction and Management, MB- Managerial Barriers, TB- Technological Barriers

An evaluation of the model's efficacy is conducted using many fit indices that together measure the degree to which the model accurately reflects the data. The Chi-Square/df Ratio (CMIN/df) is a crucial metric employed to assess the congruence between the model and the observed data, taking into account the trade-off between model complexity and fit. An ideal model fit is indicated by a CMIN/df value below the threshold of 5. The CMIN/df score in this evaluation is 3.511, which falls below the established threshold, indicating a strong fit of the model to the data. The Goodness of Fit Index (GFI) measures the degree to which the model accurately represents the observed variance and covariance in the data. The scale spans from 0 to 1, where values above 0.90 typically suggest a reasonable level of fit. The goodness-of-fit index (GFI) for this study is 0.9, indicating a strong and accurate fit of the model to the data. Another metric is the Root Mean Square Error of Approximation (RMSEA), which quantifies the degree of fit of the model per degree of freedom. An RMSEA value of 0.08 is deemed satisfactory. The study presents an RMSEA estimation of 0.07, which falls below the established threshold and suggests a satisfactory degree of model fit. Furthermore, the Normed Fit Index (NFI), Relative Fit Index (RFI), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) are employed to evaluate the degree of fit between the proposed model and a null or independence model. The cutoff value for these indices is set at 0.9. The study findings indicate that the NFI ratio is 0.902, RFI is 0.92, TLI is 0.917, and CFI is 0.928. All of these values surpass the established threshold, therefore suggesting that the model exhibits a strong model fit. The confirmation of the model's good fit to the data serves to enhance the dependability of the findings and substantiate their generalizability.

Table 4: Model Fit Values

CMIN/DF	3.511 *(<5)*
GFI	0.90 *(≥0.9)*
RMSEA	0.07 *(<0.08)*
NFI	0.902 *(>0.9)*
RFI	0.92 *(>0.9)*

TLI	0.917 *(>0.9)*
CFI	0.928 *(>0.9)*

Note: Values in *Italics* are threshold values of the modification indices

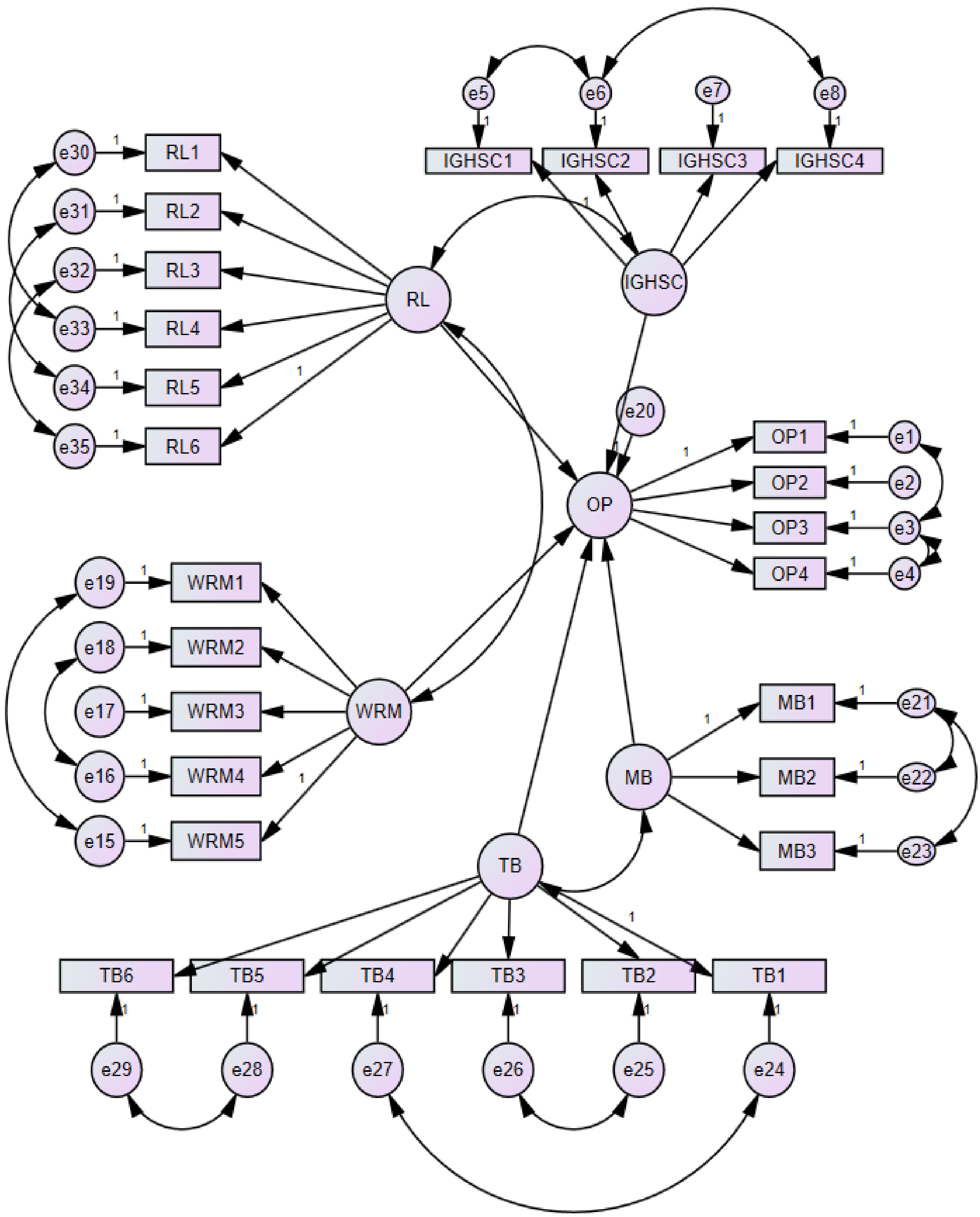

Figure 2: Measurement Model

(Source: Developed by the author)

4.4 Hypothesis Testing

The hypothesis $H1_a$, which suggested that the practices of the GHSC (including laws and regulations, as well as waste management) impact organizational performance, was accepted as the findings demonstrated that both GHSC practices have a significant effect on organizational performance. In particular, legislations and regulations had a significant effect on organizational performance ($B=0.279$, $p<0.01$). Therefore, it can be inferred that the implementation of stronger regulatory frameworks and proactive compliance measures results in better performance. Likewise, the implementation of waste management strategies had a favorable and statistically significant impact on performance ($B=0.127$, $p<0.01$). These practices are expected to have a beneficial effect since they promote greater environmental sustainability and corporate responsibility in the industry.

Furthermore, hypothesis $H2_a$ was accepted, which was the implementation of GHSCs impacts organizational performance. The findings demonstrated a statistically significant and beneficial impact ($B=0.262$, $p<0.01$), suggesting that the integration of green hydrogen into supply chains improves the performance of organizations. This can be ascribed to the capacity of green hydrogen to reduce carbon footprints, enhance operational efficiency, and conform to sustainability standards. As the industry shifts towards renewable energy sources, adopting green hydrogen practices provides organizations with a competitive advantage in the market, enticing investment and cultivating strategic partnerships.

$H3_a$, which posited that managerial barriers impact organizational performance, was accepted. The analysis revealed a statistically significant adverse impact ($B=-0.143$, $p<0.01$), suggesting that the presence of managerial obstacles, such as bureaucratic protocols and ineffective leadership, impedes the process of making decisions and implementing strategies, resulting in reduced efficiency and performance. The barriers faced by the oil and gas sector are particularly significant in the MENA area, where political instability and regulatory uncertainties greatly contribute to these barriers.

The findings partially supported Hypothesis $H4_a$, which suggested that there is a moderating effect of managerial barriers on the relationship between GHSC practices and organizational performance. The findings indicated that the influence of waste management on performance was not significantly moderated by managerial barriers ($B=0.013$, $p>0.01$), which indicated that the effect of waste management remains consistent irrespective of managerial barriers. However, the impact of regulations and legislations on organizational performance was strongly moderated by managerial barriers. The findings indicated that the efficacy of adhering to regulations in improving performance might be affected by restrictions imposed by management, which may reduce the beneficial effects of laws and legislations.

Research hypothesis $H5_a$, which posited that technological barriers had an impact on organizational performance, was accepted. The findings revealed a substantial negative effect ($B=-0.156$, $p<0.01$) of technological barriers, suggesting that technology limitations hinder the functioning of organizations. Technological progress is hindered by obstacles such as obsolete infrastructure and insufficient IT systems, which compromise operational efficiency and competitiveness. This is especially pertinent in the MENA region, where swift technical advancements have a substantial impact on the oil and gas industry.

Research findings supported Hypothesis $H6_a$, which suggested that technological barriers moderate the relationship between GHSC practices and organizational performance. A statistically significant moderating effect of technological barriers on the relationship between waste management and organizational performance was observed ($B=0.062$, $p<0.01$). This suggests that the influence of waste management is affected by technological challenges. The impact of regulations and legislations on organizational performance was shown to be considerably mitigated by technological barriers (B=0.037, $p<0.01$). This implies that the effectiveness of regulatory compliance is influenced by technological capabilities. Organizations facing substantial technological obstacles may encounter difficulties in managing waste and complying with regulations, which can greatly impact their overall performance.

Hypothesis	Structural Paths	Estimate	P	Label
$H1_a$	RL -> OP	0.279**	p<0.01	Accepted
	WRM -> OP	0.127**	p<0.01	Accepted
$H2_a$	IGHSC ->OP	0.262**	p<0.01	Accepted
$H3_a$	MB -> OP	-0.143**	p<0.01	Accepted
$H4_a$	MB*WRM -> OP	0.013	p>0.05	Rejected
	MB*RL -> OP	0.031*	p<0.05	Accepted
$H5_a$	TB -> OP	-0.156**	p<0.01	Accepted
$H6_a$	TB*WRM -> OP	0.062**	p<0.01	Accepted
	TB*RL -> OP	0.037*	p<0.05	Accepted

5 Case Study and Discussion

The findings of the quantitative stage of the research were validated with a case study by considering a case firm, Baker Hughes operating in the MENA region. It is a prominent energy firm globally and has taken the lead in establishing green hydrogen supply networks in the MENA region. Baker Hughes, with operations in more than 120 countries, has established itself as a leader in sustainability initiatives within the energy industry. The company has made substantial investments in clean energy technology, with a distinct focus on hydrogen. The researcher conducted interviews with 12 managerial-level personnel from several departments such as logistics, sustainability, operations, and technology.

The population of the study was managers as they understand the organization's strategic direction, policies, and the implementation of new initiatives such as Green Hydrogen Supply Chain practices and its related practices and implementation. However, it is important to consider that employees are also directly involved in the operational aspects of Green Hydrogen Supply Chain practices and could have offered a more practical perspective, emphasizing the practical challenges and barriers that arise during implementation. Their observations could identify operational challenges that managers may have overlooked, including inefficiencies in communication, resource allocation, or training. Furthermore, employees may express varying perspectives regarding the significance of green hydrogen initiatives, which could indicate that the organization has varying levels of awareness, or support. Conversely, managers are inclined to emphasize strategic, policy-driven elements, and more comprehensive organizational performance metrics. They also have a clearer view of the broader challenges, such as technological and managerial barriers, and are responsible for devising strategies to overcome these obstacles. By interviewing managers, the study can capture perspectives on how green hydrogen initiatives align with the company's strategic goals, regulatory compliance, and long-term sustainability objectives. By interviewing employees, adding more direct employees to the mix, the study could have captured more practical implementation challenges that may have affected the Thematic findings and positioning of the overall case study. The case study could be expanded upon and diversified through adding non-management employees' interviews.

The case study offers valuable insights into Baker Hughes' strategies and barriers in implementing green hydrogen technologies and practices. Thematic analysis was conducted for the collected qualitative data, which led to the development of the following themes and sub-themes presented in the following figure.

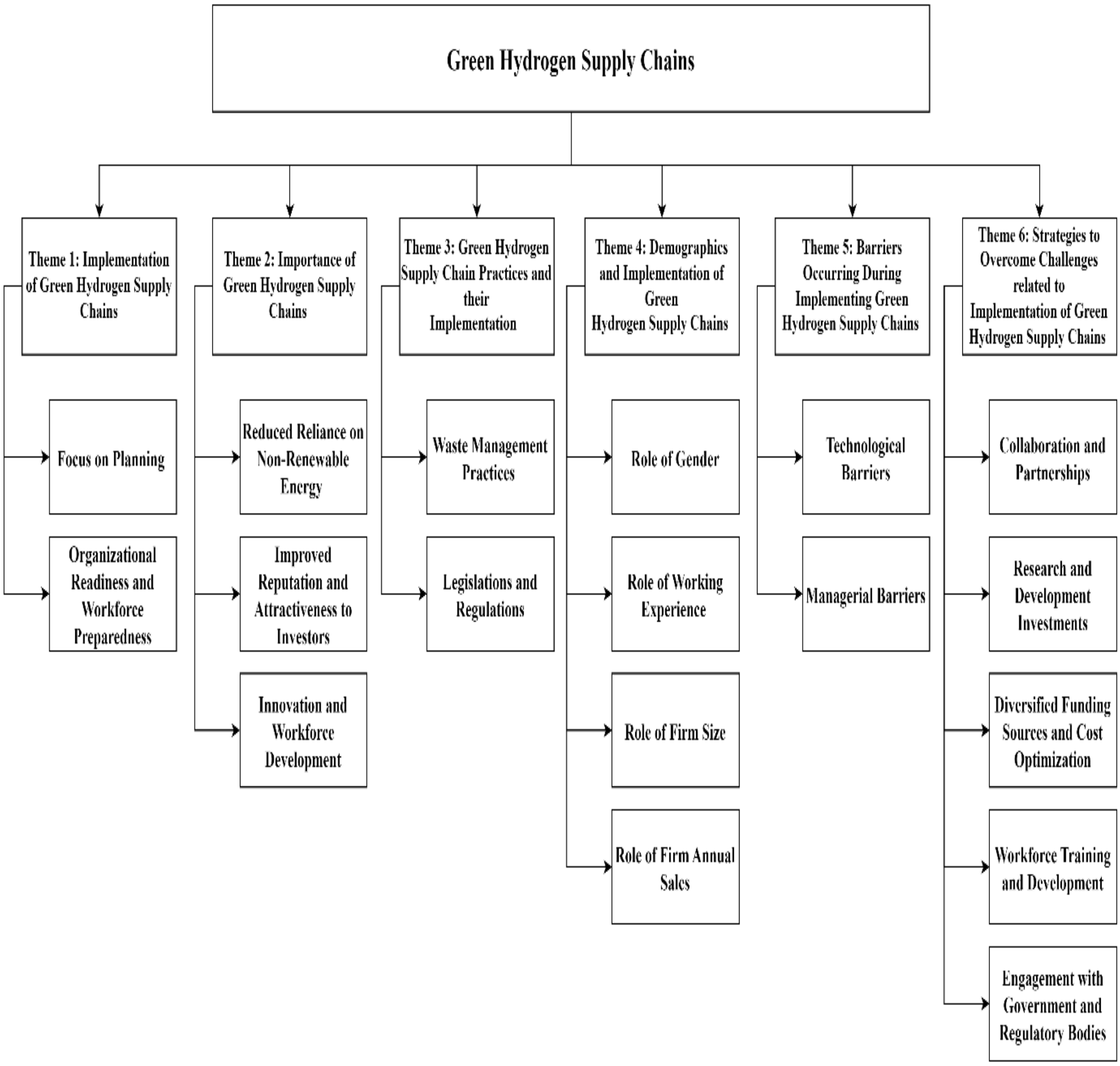

Figure 3: Thematic Analysis

(Source: Developed by the author)

The first theme and second theme, implementation and importance of GHSCs in Baker Hughes indicate the company's focus on planning, workforce development, reduced reliance on non-renewable energy source, increased reputation, and innovation. It was found that Baker Hughes placed importance on doing comprehensive feasibility studies and strategic planning prior to entering the green hydrogen industry, which entails participating in forums with senior executives and cooperating with engineers to develop customized solutions compatible with current technologies. Baker Hughes acknowledges the essentiality of workforce readiness in this shift, making substantial investments in employee training and development to guarantee that personnel at all hierarchical levels has the requisite knowledge and abilities to engage with green hydrogen methodologies.

The third theme 'GHSC practices and their implementation' indicated that Baker Hughes has adopted closed-loop systems for waste management in its GHSC operations. These systems are specifically designed to recover and recycle by-products that are produced during the chemical manufacture of hydrogen. Such a strategy is in accordance with sustainability principles and encourages the maximization of resource efficiency. Furthermore, the company focuses significant importance on complying with environmental legislation and waste management standards, which has been financially beneficial by preventing costly fines and legal consequences. Not only do these practices support the company's environmental objectives, but they also reduce the risks linked to possible pollution and the expenses incurred for cleanup.

At Baker Hughes, the significance of demographics in the execution of GHSCs has been a subject of keen interest that led to the discussion of fourth theme 'Demographics and Implementation of GHSCs'. While certain participants acknowledged possible variations in evaluations of managerial obstacles depending on gender, others held the belief that in the present age of comprehensive training, gender-based disparities are negligible. The corporation recognizes the longstanding male hegemony in the industry, especially in managerial roles in the Middle East, but underscores its dedication to policies that promote gender equality. Previous work experience was identified as a crucial determinant, as managers with more experience were seen to be more capable of addressing obstacles and offering creative approaches and answers. The successful adoption of GHSCs is significantly influenced by two key factors: company size and annual sales. Baker Hughes, being a major organization, encounters difficulties in efficiently disseminating technical knowledge and providing comprehensive training to its whole personnel about GHSC technologies. Nevertheless, its significant scale also confers benefits in terms of resources, technology, and investments, so enhancing overall efficiency and performance. Significant yearly sales of the corporation result in augmented financial resources, therefore strengthening its ability to embrace contemporary technology such as GHSCs and allocate funds towards essential infrastructure and human resource development.

The fifth theme 'Barriers' indicated that Baker Hughes encounters many technical and managerial obstacles in the implementation of GHSCs. The technological problems encompass enhancing the efficiency and cost-effectiveness of electrolyzers, incorporating novel technologies into current systems, guaranteeing the longevity of materials employed in electrolyzers, and establishing strong safety measures for hydrogen handling. The managerial obstacles encompass the need to synchronize technical and financial departments, provide thorough regulatory frameworks, handle uncertainties arising from advancing technology, and facilitate coordination among different departments engaged in the implementation process.

To surmount these obstacles, Baker Hughes has devised multiple strategies as per the identified theme 'Strategies to overcome challenges. The firm proactively pursues collaborations and partnerships with other companies and government agencies to exchange resources, expertise, and infrastructure. Considerable resources are dedicated to research and development in order to enhance the efficiency and cost-effectiveness of technology. Baker Hughes examines multiple funding options, such as government grants, private sector investments, and public-private partnerships, and integrates cost optimization strategies including bulk acquisition of technological components and optimizing operational processes.

The company’s connection with government and regulatory authorities is of paramount importance in its strategic approach. Baker Hughes actively engages in policy debates and lobbying efforts to exert influence on legislation that promote the establishment of green hydrogen supply networks. Employing this proactive strategy is especially crucial in the MENA region, where numerous major oil and gas corporations are subject to government regulation.

The adoption of GHSCs has yielded numerous beneficial effects on the organizational performance of Baker Hughes. By decreasing its dependence on non-renewable energy sources, the organization has achieved cost savings and enhanced operating efficiency. The company’s dedication to sustainability has bolstered its standing among clients, stakeholders, and partners, rendering it more appealing to investors who value environmentally conscious enterprises. Furthermore, the push towards green hydrogen has stimulated innovation within the organization and resulted in enhancements in personnel competencies and capacities.

In the study it was observed that the qualitative themes identified in the case study are substantially corroborated by the quantitative study's results, which offer a comprehension of the impact of GHSC practices on organizational performance. The insights from surveys with employees and interviews with managers indicate that an effect of implementation of GHSCs, green supply chain practices, and barriers influence organizational performance. Nevertheless, there was a discrepancy in the case of H4a. The hypothesis was partially supported by the quantitative results, which suggested that the relationship between waste management and performance was not influenced by managerial barriers. In contrast, the qualitative study discovered that participants believed that managerial barriers could have a detrimental effect on all variables, underscoring the perceived importance of managerial challenges in waste management. Such a difference highlights the importance of the qualitative perspective from managers, which can capture intricate organizational dynamics that surveys may fail to capture. The two methodologies indicated similar findings regarding all demographics, except for the impact of gender on perceptions of managerial barriers. The qualitative study revealed mixed views, implying that experiences of barriers may be more individualized, even though the quantitative analysis found differences based on gender.

Table 5: Comparison of case study results and quantitative study results

Findings	**Quantitative Stage Results**	**Results of Case Study**
Hypotheses Findings		
$H1_a$	Accepted	In agreement
$H2_a$	Accepted	In agreement
$H3_a$	Accepted	In agreement
$H4_a$	Partially Accepted as it was found that managerial barriers do not have any effect on the relationship between waste management and organizational performance	Not in agreement as participants indicated that managerial barriers can negatively affect all the variables

$H5_a$	Accepted	In agreement
$H6_a$	Accepted	In agreement
Additional Findings (t-test and ANOVA-based Findings)		
Employees have different perceptions of managerial barriers based on Gender.	In support	Mixed views of participants as some indicated that gender does not affect the perceptions of managerial barriers.
Employees have different perceptions of managerial barriers based on working experience.	In support	In agreement
Employees have different perceptions about implementation of GHSCs, its practices, and barriers based on firm size.	In support	In agreement
Employees have different perceptions about implementation of GHSCs, its practices, and barriers based on firm annual sales.	In support	In agreement

6 Conclusion

These results have significant ramifications for both theoretical understanding and practical application. The work enhances the NRBV theory by supporting it with actual evidence that demonstrates how sustainable practices can result in competitive advantages. This study also expands the use of NRBV to the particular environment of the oil and gas sector in the MENA region, therefore illustrating the theory's significance in many industrial and geographical contexts. In practical terms, the research provides useful direction for professionals in the industry, legislators, and leaders inside organizations. It underscores the significance of actively participating in legislative frameworks, implementing thorough waste management methods, and making investments in green hydrogen technology. Furthermore, the research emphasizes the need of surmounting managerial obstacles by means of leadership development and cultivating a culture of sustainability inside enterprises.

Notwithstanding these contributions, the study has constraints. Specificity to the MENA region may restrict the applicability of results to other geographic settings. Furthermore, the cross-sectional design of the study limits the capacity to track changes over time, which is especially important considering the dynamic character of green hydrogen technologies and practices. Potential future study should aim to overcome these constraints by undertaking longitudinal studies to capture temporal trends and comparative studies across various geographical areas and sectors. Furthermore, it is necessary to conduct a more thorough investigation of the particular obstacles related to management and technology that have been highlighted in this study. This might be achieved by innovating more advanced measurement instruments. Furthermore, future studies could explore the incorporation of nascent technologies like artificial intelligence (AI), Internet of Things (IoT), and blockchain into green hydrogen supply networks. An in-depth examination of the economic and financial dimensions of green hydrogen projects, encompassing cost-benefit evaluations and return on investment, would offer decision-makers substantial insights.

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