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Artificial Intelligence Implementations Towards Shaping the Future of Digital World

UNLOCKING THE FUTURE: HOW BLOCKCHAIN INFLUENCES SUSTAINABLE SUPPLY CHAIN PERFORMANCE: AN EMPIRICAL STUDY ON THE MARITIME INDUSTRY

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ABSTRACT:

Today, the digital world is seeing great technological advancements. Although block chain appears to be an emerging trend, it is still in its early stages in Egypt, particularly in the maritime supply chain. The purpose of this study is to investigate the adoption of block chain as a disruptive technology in sustainable supply chain performance by taking sustainable development goals (SDGs) as a moderator and sustainable competitive advantage as a mediator. An online survey was utilized as a technique to gather data in a quantitative manner. A total of 312 participants from the Egyptian maritime transport industry participated through convenience sampling. Using SPSS20.0, the survey is analyzed using regression analysis. Results showed a significant impact of the adoption of blockchain technology (BCT) on the sustainable supply chain performance (SSCP) through the partial mediation of the Sustainable competitive Advantage (SCA), furthermore a positive moderation role of Sustainable Development Goal (SDG) of the UN was found catalyzing the relationship. The study contributes to increasing literature on Block chain technology in general, and fills a gap on the Egyptian maritime context in particular. Finally, it provides decision makers at maritime with useful guidelines on how to optimally promote Block chain applications among employees

Keywords: Block chain Technology, Sustainable Supply chain Performance, Sustainable competitive advantage, Supply chain- Sustainable development goals

1. INTRODUCTION

In the past, enacting change within industries could take several years; however, today entire industries can experience disruption within just a few months. The rapid development of information systems and the digital economy has fundamentally transformed the global business landscape. Traditional companies are increasingly overshadowed by emerging digital enterprises. Digitalization involves numerous elements, including physical information and communication technology (ICT) infrastructure. It is crucial for businesses to adopt digital transformation (DT) proactively and be among the early adopters of technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, and cybersecurity. Moreover, digital transformations and disruptive technologies are

making strides toward fostering a future society in which new services and values are perpetually created, enhancing people's lives and promoting sustainability. These advancements are vital for the success of businesses (Elgazzar et al., 2022). In addition

to the swift evolution of new technologies, one of the key business issues accelerating corporate transformation in recent times is sustainability (UN, 2023). Significant subjects like the Sustainable Development Goals (SDGs) (UN, 2015) exemplify the way businesses operate today. Despite sustainability's established record of success, many organizations still need guidance in adopting the principles of sustainable supply chain management to remain competitive with alternative supply chains (Christopher, 2005). One of the primary objectives of contemporary supply chain management is the integration of sustainability into the supply chain (Nimsai et al., 2020; Gartner, 2022). All stakeholders must collaborate to develop sustainable supply chains, as sustainability is perceived as integral to fostering both supply chain resilience and economic growth (Jiang et al., 2021; Accenture, 2023). While numerous firms have successfully enhanced their performance and engaged in collaborative efforts, others have faced challenges and failed to attain the intended results. Despite the proliferation of blockchain applications, organizations often struggle to achieve the desired outcomes while maintaining an appropriate pace of change. Scholars have recognized the significance of blockchain research, with an increasing interest in supply chains within the maritime sector, particularly in developing nations. Nonetheless, much of the research has focused on blockchain adoption as a whole, with limited exploration of the specific factors influencing maritime supply chains' readiness for blockchain applications. Additionally, there has been scarce investigation into moderating and mediating factors, particularly in the context of Egypt. With its large population and gradual acceptance of new technology, Egypt boasts one of the region's oldest and most significant maritime industries. Consequently, this study aims to provide a comprehensive analysis of readiness for blockchain. In this context, the study seeks to emphasize the mediating and moderating factors while offering an in-depth examination of the maritime industry's preparedness for blockchain applications. Specifically, the research aims to conduct a thorough investigation into the adoption of blockchain technology within the maritime sector and to highlight the various mediating and moderating influences at play. To achieve the objectives of this research, the study seeks to answer the following questions: (1) What are the key factors influencing the adoption of blockchain technology in the maritime supply chain? (2) What mediating and moderating factors impact the adoption of blockchain technology within the maritime supply chain? The paper is structured into five sections: Section 1 presents the research background; Section 2 reviews the literature; Section 3 outlines the research framework and hypotheses; Section 4 details the data collection and analysis; and Section 5 concludes with recommendations, theoretical implications, practical consequences, and concluding remarks.

2. LITERATURE REVIEW

The term "digital economy" encompasses a vast array of social and economic activities that leverage digital technologies, with the potential to drastically impact organizations of all types. The trend of digitalization has emerged from the ability to convert traditional goods and services into their digital counterparts, which offer distinct advantages over physical products (Abd el.Aziz et al., 2020). Moreover, the variety and sophistication of digital technologies capable of transforming established business practices have significantly broadened in recent decades (Hisrich & Soltanifar, 2021). Tidd and Bessant (2020) argue that digital technologies transcend geographical and temporal boundaries, thereby revolutionizing various aspects of daily life, including how people engage, consume, and work.

Digital transformation is characterized by the reconfiguration of business models utilizing an array of cutting-edge technologies such as big data, blockchain, cloud computing, and artificial intelligence. This transformation has become essential for long-term survival and

growth. Effective strategies and implementation remain the cornerstones of successful digital transformation (Facchini et al., Citation 2020). Consequently, some companies have already started to see positive outcomes from using digital transformation to boost operational efficiency and innovation (Silin et al., 2023). The notion that innovation drives business growth was originally articulated in Bower and Christensen's 1995 paper titled "Disruptive Technologies," marking the inception of disruptive innovation theories (Roblek et al., 2021). American academic M. Clayton Christensen first identified disruptive technologies over 20 years ago in his 1997 book "The Innovator's Dilemma." In this seminal work, he discussed technologies characterized by features valued by a wide range of consumers (Helmut Schindlwick, 2021). According to Christensen et al. (2018), disruptive technologies serve as the foundation for creating products or services that incorporate technologies initially applied in simpler, lower-cost contexts. In their original forms, these goods and services are reasonably priced and constructed from straightforward, affordable components. Competitors recognize the market potential of these offerings, which can completely transform specific industries (Roblek et al., 2021). Furthermore, disruptive technology is a comprehensive concept that encompasses various interconnected aspects of disruption, including technological advancements and their implications for product and business model strategies. It has emerged as one of the most discussed and significant business concepts of the early twenty-first century. Today, all e-commerce applications, travel platforms, blogging sites, and news websites are regarded as disruptive technologies. Alongside this growth, digitalization has rendered disruptive technologies commonplace. Various disruptive technologies, including artificial intelligence (AI), blockchain, affective computing, biological computing, cloud computing, emotion theory, human-computer interaction, Internet of Things (IoT), predictive analytics, probabilistic methods, swarm intelligence, socio-cognitive neuroscience, quantum computing, and web intelligence, are poised to play pivotal roles. The time has arrived for organizations to embrace these technologies and equip themselves to leverage them in the present and future as they reshape the economic landscape (Helmut Schindlwick, 2021).

2.1.Different industries utilize blockchain technology

Blockchain technology (BCT) has emerged as a disruptive force within the rapidly changing landscape of digital transformation, altering how companies innovate and operate. Proponents of blockchain, including developers, entrepreneurs, and technology enthusiasts, argue that the technology has the potential to fundamentally reshape current political, legal, and cultural environments (Julie Frizzo-Barker et al., 2020).

2.1.1. Evolution of Blockchain technology

Initially introduced in 1991 as the foundation for cryptocurrencies like Bitcoin (Martin Garriga et al., 2020), a blockchain consists of interconnected data blocks specifically designed to maintain transaction records. Each block contains transaction data, a timestamp, and a cryptographic hash from the previous block (Du et al., 2019). The market for blockchain technology is expected to grow to $72 billion by 2026, reflecting a compound annual growth rate (CAGR) of 51.8% during that period. Using encryption to enable secure internet connectivity, information can be documented in blocks, safeguarding sensitive details among involved parties. Companies across various sectors are increasingly focusing on investing in blockchain technology to enhance their business operations (ReportLinker, 2021). Essentially, blockchain functions as a series of blocks utilized by a decentralized network of nodes for data storage, and its implementation has the potential to accelerate digital transformation by alleviating challenges like data management complexities. However, like any emerging technology,

its true potential has yet to be demonstrated, as it relies more on expectations than on proven data. Additionally, the blockchain can be programmed with smart contracts that execute automatically. However, it gained widespread attention only during the Bitcoin surge. Today, it has evolved into a versatile tool with applications across numerous sectors, including finance, retail, healthcare, energy, supply chain management, government services, smart homes, smart vehicles, and social networks (Bharati M. Ramageri et al., 2020; Baev et al., 2020; Md Ashraf Uddin et al., 2021; Javaid et al., 2022).

2.1.2. Blockchain in financial sector

Blockchain technology is classified as a type of financial technology (FinTech). Although the Bitcoin boom initially overshadowed blockchain, it has recently begun to gain recognition as a critical component of the FinTech sector (Du, Pan, Dorothy, Leidner, & Yinga, 2019). According to Du et al. (2019), blockchain is among the most promising leading-edge technologies within the entire FinTech arena. Beyond merely facilitating Bitcoin transactions, blockchain was originally conceived as a distributed ledger and has the potential to transform various business operations across financial and other sectors (Kshetri, 2018; Underwood, 2016). The application of blockchain technology in banking has undergone extensive research, encompassing technical, economic, and accounting perspectives. When properly implemented within an accounting context, blockchain technology can enhance the quality of financial reports (McComb & Smalt, Citation 2018). Blockchain enables the development of new banking and financial services and products, shared operational models, cost-effective procedures, and more transparent, inclusive, and secure business networks. Additionally, it can expedite financial services audits. Leveraging blockchain technology, companies may compute credit scores using alternative criteria. Notably, blockchain can be employed to manage credit scores, thereby achieving greater system transparency. Lenders can utilize immutable blockchain records of financial transactions to assess an individual's creditworthiness while ensuring that smart contracts do not expose or compromise an applicant's personal data. Financial institutions can maintain the confidentiality of their users' personal, sensitive, and legal information within blockchain technology. Investment firms can track users' identities and intentions with the help of immutable smart contracts. Thus, the implementation of blockchain in financial services can enhance transparency throughout the investment process (Guo Y., Liang C., 2016; Yaksick R., 2019; Antoniadis et al., 2019; Zhang et al., 2021).

2.1.3. Blockchain in software sector

Enterprise Software Platforms (ESP), which interfaces with blockchain, are considered the core of any company's operations. These platforms encompass functions such as finance, HR, and customer relationship management (CRM). For instance, blockchain initiatives have been pursued by companies such as Microsoft, SAP, Oracle, and Salesforce. In the future, blockchain technology solutions are expected to serve as the operational backbone for all enterprises and sectors. By integrating blockchain with enterprise resource planning (ERP) systems, companies can enhance data integrity and facilitate improved data sharing (Heiskanen, 2017). A study by Maurizio Massaro (2023) provides insight into expectations for blockchain deployment in the healthcare industry by comparing outcomes from content analyses of papers and patents. This report aims to bridge the gap between research and practice by contrasting data from patents and published works and illustrating how expectations for blockchain implementation in healthcare are evolving. A forthcoming study in 2024, focusing on how blockchain technology can enhance supply chain visibility and combat counterfeit medicines,

emphasizes the growing importance of digital technologies in ensuring efficiency and transparency within pharmaceutical supply chains (Sundarakani et al., 2024). According to blockchain blogs, many governments are anticipated to develop or adopt virtual currencies by 2030 (website, 2016). Use cases for data stored on blockchain-based identity platforms include ticketing, government records (e.g., birth dates), document management, reputation and trust scores (such as credit history), certifications (like university diplomas), tax identification records, and employment records (Bharati and Maithili, 2020).

2.1.4. Blockchain in aviation

Among the industries anticipated to experience substantial growth in the digital age is aviation. Since the inception of blockchain technology, new technological innovations have emerged in this sector, paving the way for enhanced transparency. The implementation of blockchain has also played a role in managing flight data and passenger information security to prevent unforeseen events (Caro and Martens, 2019). According to Markets and Markets (2021), blockchain technology in aviation reached USD 421 billion in 2019 and is projected to grow to USD 1,349 billion by 2025, with a compound annual growth rate (CAGR) of approximately 22.1%. Additionally, improvements in traceability and transparency have significantly enhanced customer experience, driving industrial growth. Consequently, as the aviation sector focuses on digitalized operations, blockchain technology presents increased opportunities for expansion. The trends surrounding blockchain technology hold potential applications within aviation (Orji et al., 2020). Considering that luggage and goods frequently change custody upon deposit, blockchain enables immutable and reliable tracking of their locations. Furthermore, it enhances transparency and visibility in tracking luggage along the designated value chain. Tracking passenger identities has also become more manageable due to blockchain technology, which assists in efficiently managing aircraft maintenance through track-and-trace capabilities for malfunctioning parts. Blockchain technology holds immense potential for fostering the development of improved smart communities that enhance living standards and operational efficiency. To realize this potential, technology must be empowered to challenge the status quo, embrace innovation, and undergo transformative changes (Raed et al., 2019).

2.2. Block chain in Supply chain Management

Blockchain technology is enhancing supply chain management (SCM) in various significant ways. One of its key applications in SCM is the use of smart contracts, which enhance automation, transparency, flexibility, security, and overall efficiency in managing supply chains (Vishakhaben Modi, 2024). By employing blockchain technology, products can be tracked and traced throughout their entire lifecycle, reducing the risk of corruption and fraud. The "trustless" nature of blockchain helps alleviate trust issues among participants in the supply chain (Gautami Tripathi et al., 2023). Additionally, blockchain can monitor product conditions, such as temperature; for instance, food or pharmaceutical products can be tracked during shipment to ensure that consumers receive safe and high-quality goods (Singh et al., 2020). According to Tarafdar and Qrunfleh (2017), supply chain performance reflects how well a supply chain meets client demands and expectations regarding product availability and delivery timelines. The capability of a supply chain to reduce costs, address deficiencies, and fulfill customer expectations is indicative of its performance (Meredith, 2022). Alahmad (2021) notes that several characteristics influence the performance of supply chain systems, determining their effectiveness and efficiency. A study by Tarun Kumar Agrawal et al. (2021) sought to establish technology-

based trust among supply chain participants by presenting a distributed ledger system capable of recording and authenticating supply chain transactions. Additionally, a blockchain-based traceability system would offer each partner a unique opportunity, freedom, and capacity to trace their supply chain activities while establishing an open and sustainable supply chain. Another investigation conducted by Ayman Abdalmajeed Alsmadi et al. (2023) analyzed the implementation of blockchain technology within Malaysia's supply chain. The study surveyed 256 respondents, utilizing statistical software (SPSS) and a single-sample t-test for analysis. It found that perceived ease of use, inter-organizational trust, perceived usefulness, data transparency, and confidentiality significantly influence the utilization of blockchain technology in supply chains. The rise of blockchain technology and its integration with intelligent transportation systems are increasingly gaining traction in 2024, driving the logistics sector towards enhanced security and optimized business processes. This trend emphasizes contributions to the theories and practices of digital transformation within supply chain management and suggests a new framework to assist the logistics industry during disruptive technological changes, particularly in light of the challenges posed by the COVID-19 pandemic (Sundarakani, B., Manikas, I., & Gunasekaran, A). Moreover, adopting blockchain technology facilitates improved consumer trust and product tracking within supply networks. This study evaluates a three-tier supply chain comprising a manufacturer, a retailer, and a supplier, noting the potential for both the producer and the supplier to inadvertently produce substandard goods. Furthermore, this research provides valuable management insights for practitioners of blockchain technology (Xue-Yan Wu et al., 2024).In today's interconnected environment, sustainability transcends being merely a buzzword—it has become a strategic necessity. Innovative strategies that harmonize environmental, social, and economic sustainability can foster a thriving enterprise while safeguarding the environment and communities. Sustainability involves achieving a balance among three pillars: economic, social, and environmental responsibility (Elkington, 1997; Helmi Hannila, 2021; UN, 2023). A balanced approach to these pillars is essential for realizing the Sustainable Development Goals (SDGs) (Nuttasorn Ketprapakorn and Sooksan Kantabutra, 2022) Sustainable Supply Chain Management (SSCM) has gained prominence within the field of supply chain management in recent years. This strategy seeks to incorporate social, economic, and environmental sustainability within the planning, execution, and control of supply chain operations (Ahi and Searcy, 2015). SSCM involves sustainable interactions among a focal company, suppliers, and customers, influenced by government and other stakeholders (Seuring & Müller, 2008a). These driving factors provide a meaningful context for developing and implementing new practices. Supply chain partners collaborate through SSCM to improve economic performance while minimizing harmful impacts on the environment and society. One of the primary drivers behind SSCM is the increasing awareness of the environmental and societal effects of supply chains (Carter & Rogers, 2008). Liu et al. (2017) and Saberi et al. (2019) suggest that organizations can achieve their sustainability goals by collaborating with other entities. According to Kamble et al. (2021) and Kolinski et al. (2019), achieving sustainable materials and practices throughout the supply chain may necessitate forming partnerships with suppliers, manufacturers, and other stakeholders. Organizations can reap several benefits from establishing sustainable supply chains, including cost reduction, satisfaction of stakeholder and customer expectations, enhanced corporate reputation, and a competitive market advantage. Implementing SSCM practices can also help companies comply with social and environmental sustainability standards and regulations, such as SA8000 and ISO 14001 (Das, 2018).

2.3. Sustainable supply chain management (SSCM)

In today's interconnected environment, sustainability transcends being merely a buzzword—it has become a strategic necessity. Innovative strategies that harmonize environmental, social, and economic sustainability can foster a thriving enterprise while safeguarding the environment and communities. Sustainability involves achieving a balance among three pillars: economic, social, and environmental responsibility (Elkington, 1997; Helmi Hannila, 2021; UN, 2023). A balanced approach to these pillars is essential for realizing the Sustainable Development Goals (SDGs) (Nuttasorn Ketprapakorn and Sooksan Kantabutra, 2022). Sustainable Supply Chain Management (SSCM) has gained prominence within the field of supply chain management in recent years. This strategy seeks to incorporate social, economic, and environmental sustainability within the planning, execution, and control of supply chain operations (Ahi and Searcy, 2015). SSCM involves sustainable interactions among a focal company, suppliers, and customers, influenced by government and other stakeholders (Seuring & Müller, 2008a). These driving factors provide a meaningful context for developing and implementing new practices. Supply chain partners collaborate through SSCM to improve economic performance while minimizing harmful impacts on the environment and society. One of the primary drivers behind SSCM is the increasing awareness of the environmental and societal effects of supply chains (Carter & Rogers, 2008).nLiu et al. (2017) and Saberi et al. (2019) suggest that organizations can achieve their sustainability goals by collaborating with other entities. According to Kamble et al. (2021) and Kolinski et al. (2019), achieving sustainable materials and practices throughout the supply chain may necessitate forming partnerships with suppliers, manufacturers, and other stakeholders. Organizations can reap several benefits from establishing sustainable supply chains, including cost reduction, satisfaction of stakeholder and customer expectations, enhanced corporate reputation, and a competitive market advantage. Implementing SSCM practices can also help companies comply with social and environmental sustainability standards and regulations, such as SA8000 and ISO 14001 (Turzo and Chirielesion, 2024; Nawrocka et al., 2009).

2.4. Blockchain and Sustainable Supply Chain Management

The integration of sustainable supply chains allows businesses to strengthen their relationships with customers, shareholders, and stakeholders. As consumers become increasingly conscious of how their purchasing decisions impact the environment, businesses are linking consumer purchases to specific components of their supply chain. Achieving transparency and traceability in supply chains is vital; however, it is currently a considerable challenge. Many experts view blockchain as a key solution for enabling sustainable supply networks. By exploring the capabilities of blockchain technology, its implementation in supply chains not only enhances efficiency and reduces costs but also fosters better relationships among all stakeholders (Queiroz et al., 2019). Concurrently, it offers valuable opportunities to supply chain management professionals focusing on sustainability. The role of blockchain technology in digitally transforming supply chain operations is crucial. Its expanded potential has improved corporate transparency and operations by altering traditional business functions (Ioannidis, 2023). Blockchain has enhanced corporate strategies and supply chain efficiency inalignment with its primary commitments. Several key components ensure the successful implementation of blockchain technology within a supply chain structure that prioritizes sustainability (Yousefi and Tosarkani, 2022). In the digital era, technology presents significant promise for enhancing supply chain sustainability, reliability, and transparency (Chang et al., 2019). As a revolutionary tool, blockchain technology is becoming increasingly recognized for its potential to guarantee sustainability in global supply chains (Marsal-Llacuna, 2018). As noted by Kshetri (2018), blockchain impacts various key supply chain management objectives, including cost, quality, speed, reliability, risk mitigation, sustainability, and

flexibility. Di Vaio and Varriale (2020) examined the relationship between sustainable supply chain management, operations management, and blockchain technology, while Yadav and Singh (2020) explored the potential of blockchain to support efficient and sustainable supply chain management. Additionally, Sunmola and Apeji (2020) studied the attributes of blockchain technology and its impact on sustainable supply chain visibility. Esmaeilian et al. (2020) provided an overview of blockchain technology in conjunction with Industry 4.0 to promote supply chains towards sustainability. Kouhizadeh et al. (2021) investigated challenges in implementing blockchain technology for managing sustainable supply chains using the DEMATEL technique.

2.5. Sustainable Competitive Advantage

In today's landscape, companies can achieve steady growth by developing a deeper understanding of sustainable competitive advantages and corporate sustainability. The advancement of sustainability allows businesses not only to increase profits but also to take responsibility for their environmental and societal impact (Goodland, 1995; Zeyu Wang, 2021). Thus, establishing a sustainable competitive advantage is a critical determinant of business success, enabling companies to maintain market dominance through unique products and services over time (Kazemi et al., 2024). According to Arasli (2021), sustainable competitive advantage arises from an organization's unique capabilities, resources, and strengths that enable it to outperform competitors in fulfilling consumer needs. A brand's long-term advantage over its competitors is typically derived from a distinctive attribute associated with the firm, product, or service. Organizations of all sizes and industries must prioritize sustainability as a fundamental principle. A corporate strategy that integrates the economic, ecological, and social aspects of business sustainability can ensure sustained success (Zeyu Wang, 2021). Furthermore, to achieve sustainable competitive advantages, companies need to focus on aspects such as working conditions, ethics, and innovation in addition to the elements highlighted in their financial reports. Consequently, innovation plays a significant and positive role in fostering long-term (sustainable) competitive advantages (Kuncoro and Suriani, 2018). Additionally, companies must continually improve various areas, including strategic management, technology, human resources, and resource management, to secure a lasting competitive advantage. These advancements not only enhance business efficiency but also enable the organization to outperform rivals (Jurksiene and Pundziene, 2016; Kazemi et al., 2024). Given the recent technological advancements, blockchain technology stands out as a promising tool capable of enhancing trust within supply chains (Hossain et al., 2019). A descriptive analysis by Ali Abdulnassir Mohamud (2020) concluded that the benefits of blockchain technology outweighed the drawbacks, enhancing transparency and trust among stakeholders. However, careful planning and strategic foresight are essential prior to implementation due to its high costs and the significant resources required for achieving sustainable competitive advantages. According to Kant (2021), blockchain is a widely adopted technological innovation that presents considerable potential and could serve as a strategic intangible resource for organizations seeking a sustainable edge. Wunsche et al.

(2022) discovered that blockchain technology is gaining traction for its capability to bring transparency to complex global supply chains, thereby promoting improved sustainability and efficiency. Another study examined the critical factors that can provide a sustained competitive advantage to the food industry through the application of blockchain technology in the supply chain. The research identified five key indicators: permanent data storage, supply chain coordination, enhanced performance metrics, simplification of international transactions, and traceability coupled with fraud prevention (Leila et al., 2023).Furthermore, a study in the tourism sector indicated that the relationship between

sustainable supply chain strategy (SSCS) and sustainable competitive advantage (SCA) is mediated by blockchain technology adoption. Additionally, the connection between SSCS and blockchain technology adoption is significantly moderated by digital transformation, while the link between blockchain adoption and SCA is notably influenced by sustainable supply chain practices (Muddassar Sarfraz et al., 2023). Ultimately, sustainable supply chain approaches can assist organizations in gaining a competitive advantage and achieving long-term success. By embedding Sustainable Supply Chain Management (SSCM) into their overall strategic framework, companies can enhance profitability while simultaneously tackling environmental and social challenges (Negash Shebeshe and Sharma, 2024).

2.6. Sustainable Development Goals (SDGs)

As a result of the 2020 pandemic, governments worldwide are prioritizing digital transformation to bridge the digital divide, ensuring that no one is left behind. The United Nations Development Programme (UNDP) Strategic Plan (SP) 2022-2025 outlines the advantages of digital transformation, emphasizing three main areas of change: structural transformation, inclusivity, and resilience building. In this frame, digitization, alongside strategic innovation and development financing, is identified as a vital enabler of sustainable development. The adoption of the Sustainable Development Goals (SDGs) in 2015 underscored the commitment of global leaders to pursue a more sustainable trajectory towards inclusive and equitable growth. The 17 Sustainable Development Goals, referred to as Agenda 2030, address a diverse array of development challenges and encompass 169 targets and 304 indicators that address various development-related issues (ElMassaha and Mohieldin, 2020), including water, poverty, education, energy, gender equality, biodiversity, economy, climate action, and more (Teri, 2019). The SDGs build upon decades of progress in sustainable development. Over the last twenty years, the Arab region has experienced a remarkable increase in its online population, with internet users rising to 327 million, a significant increase from 28.8% in 2012 to 70.3% in 2022 (https://www.undp.org). The Egyptian government is leveraging Information Communications and Technology (ICT) to promote sustainable development by establishing partnerships with various entities—both public and private—to implement digital initiatives and projects aimed at enhancing social, economic, and environmental sectors. These initiatives are designed to develop human resources by equipping individuals with essential digital skills and creating job opportunities, recognizing that human resources are critical to success across all industries. Additionally, they encompass a wide range of sectors, including education, health, energy, business, legislation, and infrastructure. Importantly, advancements in one area can positively influence others (Esam Mohamed Elgohary, 2022). Blockchain and Industry 4.0 technologies present opportunities for some countries to catch up while allowing others to progress further. To harness this new wave of technology, developing nations should enhance their innovation infrastructure and prioritize inclusive and sustainable blockchain applications (Mattila et al., 2022). Furthermore, blockchain technology has been suggested for facilitating sustainable development in various ways, such as through carbon credit trading, energy systems, and supply chain management (Mulligan et al., 2024). Notably, blockchain can enhance traceability, provenance tracking, transparency, and help minimize environmental impact within the food supply chain. It also plays a role in achieving the sustainable development goals set forth by the United Nations (Chandan et al., 2023). Blockchain technology is relevant to several Sustainable Development Goals, including Goal 1 (No Poverty), Goal 8 (Decent Work and Economic Growth), Goal 9 (Industry, Innovation, and Infrastructure), Goal 10 (Reduced Inequality), Goal 11 (Sustainable Cities and Communities), and Goal 17 (Partnerships for the Goals) (Cooper and Kruglikova, 2022).Supply chains are increasingly being associated with environmental friendliness and

sustainability. Sustainable supply chain management aims to enhance corporate image, nminimize waste, innovate, generate profits, and secure a competitive advantage. Additionally, integrating the principles of SSCM into the SDGs enables entrepreneurs to develop advanced and sophisticated supply chain management strategies, leading to more stable, efficient, and ethical supply chains. It is crucial to note that the sustainable development goals have been established to engage with businesses and foster synergistic economic outcomes (Willis, 2016; Zimon, 2019). SSCM can significantly contribute to the achievement of the SDGs if perceived as a process with interconnected components (Campagnoli et al., 2018). Similarly, Sudusinghe et al. (2018) emphasize the importance of interconnections that co-create supply chains, which are rooted in the SDGs. To align SSCM practices with the UN SDGs, one can apply the methodology developed by Costanza et al. (2016), which groups the 17 UN SDGs into three clusters: efficient allocation to foster a living economy (economic aspect), equitable distribution to protect the potential for flourishing (social aspect), and sustainable scale to operate within planetary boundaries (environmental aspect). This classification categorizes the SDGs into three focal areas: economic goals (SDGs 7-9, 11-12), social goals (SDGs 1-5, 10, 16-17), and environmental goals (SDGs 6, 13-15). Following a deliberate and iterative mapping process, the SDGs are linked with relevant SSCM practices based on their scope and objectives. Moreover, specific SSCM approaches will concentrate on how the SDGs are addressed through supply chain activities. SDG 12 (Responsible Consumption and Production) is frequently highlighted in the literature due to its prevalence. Following SDG 12, SDGs 7 (Affordable and Clean Energy) and 13 (Climate Action) are also prominent, with SDG 9 focusing on industry, innovation, and infrastructure. Amani and Sarkodie (2022) advocated for the integration of artificial intelligence in the supply chain to automate the differentiation of healthy and spoiled meats. This approach can be applied in shipping, storage, and retail settings, reducing human error. It may also enhance the shelf life of meat, minimize losses, and increase productivity, thereby supporting SDGs 9 and 12. Mina et al. (2021) utilized multi-criteria decision-making and fuzzy inference systems to evaluate and rank suppliers within a circular supply chain.

2.7. Sustainable Supply Chain in the Maritime Industry

The maritime industry is facing mounting pressure to implement sustainable practices and reduce its environmental footprint (Oloruntobi et al., 2023). As concerns regarding climate change and pollution intensify, the demand for green technology and practices in maritime logistics is escalating to secure a sustainable future (Vienažindienė et al., 2021). Recent insights into green technology in marine logistics include the adoption of alternative fuels, energy-efficient vessels, and emissions reduction strategies (Vidović et al., 2023). These innovations play an essential role in decreasing the maritime industry's carbon emissions and promoting environmental responsibility. Sustainable supply chain

management within the maritime sector represents a critical issue for study, as companies strive to reduce waste, enhance efficiency, and improve their overall environmental performance (Patra, 2018). Moreover, strategies to lower carbon emissions in maritime logistics include establishing emission control areas, adopting slow steaming practices, and utilizing shore power. These measures are vital for achieving emissions reduction goals and complying with environmental regulations. The exploration of renewable energy sources for maritime transport, such as wind and solar power, is also crucial, as these alternative resources offer a cleaner substitute for traditional fossil fuels and can contribute to the reduction of greenhouse gas emissions in the maritime sector. Ultimately, this highlights the importance of adopting green maritime logistics for a

sustainable future. By embracing green technologies, sustainable supply chain management practices, and methods to reduce carbon emissions, the maritime industry can contribute to a healthier, cleaner environment for future generations (Jabor Al-Sulaiti, 2024). Additionally, the issues surrounding green technology and sustainability in relation to logistics and transportation extend to the maritime logistics and transport sector (Vidović et al., 2023). Given that oceans cover 71% of the Earth's surface, the transportation of goods across seas is a vital component of global supply chains. Notably, approximately 8 million pieces of plastic enter the oceans each day, emphasizing the need for a global approach to the maritime industry that incorporates perspectives from Asia, Africa, and the Americas. The aim is to comprehend our individual and professional roles in influencing our industry and to explore innovative solutions (Ullah et al., 2023). According to the United Nations Conference on Trade and Development (UNCTAD, 2020), maritime transport accounts for approximately 80% of international trade involving the movement of people and goods/cargo (Rodrigue, 2017). Consequently, maritime transport is crucial for economic development, particularly in developing nations, and must be pursued sustainably.

2.8. Background of Maritime Industry

The maritime sector is a key component of international commerce, transporting up to 90% percent of all goods around the globe by weight. Its premised on a multifactorial approach; this sector apparently encompasses shipping and port activities that from the foundation structure of international trade through various businesses like logistics, energy transportation services etc. (Market Research Reports, 2024). In this age of increasing globalization, the international maritime industry is increasingly becoming the bridge that connects different countries and enables movements of goods across countries, with the shipping route being the highways of economies. Nevertheless, there are challenges that the maritime industry had to endure which impeded the seamless operations of the industry. With increasing geopolitical tussles and trade wars, the transport of goods across the globe was affected, directly leading to a modification in trade routes and reduction in shipping volumes (UNCTAD, 2023).

2.9. The Egyptian Maritime Industry

The maritime sector plays an essential role in Egypt's economic growth. With 15 seaports on the Mediterranean and 33 on the Red Sea, Egypt’s strategic location at the crossroads of Europe, Asia, and Africa is highlighted. The Nile River and the Suez Canal connect these continents (Elbarky et al., 2024). The Suez Canal is the most efficient shipping route between Europe and Asia, significantly contributing to Egypt's foreign exchange reserves (AmCham Egypt, 2020). Seaborne and maritime transportation services constitute approximately 90% of Egypt's foreign trade, making them a vital driver of economic growth. This highlights the Egyptian economy's reliance on the maritime industry to maintain stability.

Egypt's 2030 sustainable development strategy aims to build the infrastructure necessary to enhance industrial competitiveness and foster the growth of innovative industries. Therefore, the construction of several seaports is anticipated to increase port capacity by 2030 (Akram, 2020). Recent global changes and emerging trends may affect the performance of this industry. Such developments have heightened uncertainty, fundamentally altering the landscape while reflecting the modest expansion of global trade and economic activity. According to UNCTAD’s 2019 reports, shipping and port companies must embrace technology adoption and transfer to avert a decline in maritime capabilities and to secure increased funding and investment for expanding

infrastructure and services (UNCTAD, 2019). Furthermore, stakeholders in the shipping industry are redefining their business and relationship structures by leveraging digitization and new technologies, including blockchain, collaborative platforms, and solutions. Ultimately, these efforts aim to promote efficient and secure trade through the use of electronic documentation and improved visibility within the supply chain, benefitting consumers who rely on shipping services. Recent studies emphasize the significance of digitalization in alleviating the adverse effects of external disruptions and other emerging trends on the sector's performance (Nguyen et al., 2022; Vivien Andresen & Mathilda Björn, 2022).

2.10. Challenges and Benefits of Block chain adoption in maritime sector

Deploying blockchain in the maritime industry for operations and transparency has a lot of potential. Automation of work while decrease the amount of work required for documentation will allow shipment tracking to be done in real time while improving services using blockchain smart contracts. This would also cut operational expenditure and increase reciprocation among stakeholders (CSIS, 2021; MarineLink, 2024). The thriving technology would further enhance integration thereby optimizing the chain and speeding decision-making process (MDPI, 2024).

Nevertheless, there are barriers to mass adoption. There first out of the many is initial implementation costs such as training and equipment purchases which are required as prerequisites to using the technology which by nature propels off risks fighting lower job loss against higher levels of spending therefore making them quite unfeasible especially for small businesses (PMC, 2020). Coupled with issues such as systems being unable to support integration alongside not being able to scale, all this adds up into considerable Soviet levels of difficulties while trying to traverse into using blockchain technology (MarineLink, 2024). Due to the chain of people involved in the maritime sector the problem of achieving different technologies working together only escalates (ResearchGate, 2024). Even as different waves of technology emerge from the rest the periods of lag for adoption are expanding with supporting reason being differences in laws between countries' scope of naval territory (MarineLink, 2024). The increasing benefit to the cost ratio then when adopted can blank collectively all the above challenges and majorly aid in revolutionizing the maritime sector as a whole.

2.11. Readiness and Challenges for Blockchain in Egyptian Maritime Sector

The adoption of blockchain technology in Egypt's maritime sector faces several significant challenges related to technical infrastructure and readiness. One of the primary issues is the existing infrastructure gap, which is estimated at around $49 billion (World Bank, 2021), impacting the development of modern port facilities and logistics systems necessary for implementing advanced technologies like blockchain. The current ports suffer from fragmentation due to inadequate planning and limited geographical connectivity, hampering efficient operations and the integration of new technologies (Egyptian Ministry of Transport, 2022). Although the government has initiated various projects to upgrade ports, many are still under development, leaving a crucial gap in readiness for blockchain applications. Additionally, organizational resistance poses a significant barrier; there is often insufficient commitment from senior management to drive the adoption of innovative technologies (El- Sayed & El-Shafie, 2023). Effective implementation of blockchain requires collaboration across various stakeholders in the supply chain, yet external parties may be reluctant to share data or integrate new

systems (Hassan et al., 2022).

The high costs associated with transitioning to blockchain can further deter organizations, particularly in a sector already facing substantial infrastructural challenges (Khan & Khedher, 2023). Moreover, the regulatory environment presents additional hurdles; the existing legal framework does not adequately address the complexities of blockchain technology, creating uncertainty for organizations considering its implementation (Abdelkader et al., 2023). Concerns over security also play a critical role, as stakeholders are wary of moving sensitive documents and processes onto a digital platform due to potential cyber threats (Mohamed & Moustafa, 2023).

Consequently, while there is significant potential for blockchain technology to enhance efficiency and transparency in Egypt's maritime sector, overcoming these infrastructural, organizational, and regulatory challenges will require concerted efforts from both the government and private sector to create an environment conducive to technological innovation

3. THEORETICAL FRAMEWORK AND HYPOTHESES

Following a comprehensive review of the relevant literature, the researcher identified several emerging trends and disruptions impacting the performance of the maritime industry. These include climate change, blockchain technology, digital twins, advancements in artificial intelligence (AI), the Internet of Things (IoT), port disruptions, structural shifts in globalization, and various external disturbances. It was also noted that there are few studies that draw on international reports and reviews (UNCTAD, 2019; Sahar et al., 2024). Therefore, this current study will emphasize the integration of additional significant trends within the maritime sector, particularly in the context of developing countries. The proposed research framework is depicted in Fig. 1. This model incorporates variables related to the adoption of blockchain technology, which have been highlighted across various studies: 'Traceability,' 'Transparency,' 'Resilience,' and 'Confidentiality.' These variables are viewed as precursors to 'sustainable supply chain performance.' The researcher has also suggested 'sustainable competitive advantage' as a mediator in the relationship between the research variables and 'sustainable supply chain performance.' Furthermore, the 'SDGs' have been introduced as a moderator in the model. Consequently, the first five hypotheses were formulated to examine whether these factors remain significant within this context.

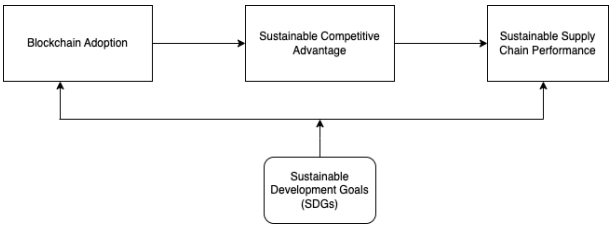

Figure 1: Proposed Research Model for sustainable

Therefore, the four constructs mentioned above are considered as the factors affecting the Sustainable Supply chain Performance in Egypt, and they are mediated by Sustainable competitive advantage, and moderated by Sustainable Development Goals. Thus, the research hypotheses could be developed as follows:

H1: There is a significant impact of Block chain adoption (Research variables) on Sustainable Supply Chain Performance.

H2: There is a significant impact of Block chain adoption (Research variables) on Sustainable competitive advantage.

H3: There is a significant impact of Sustainable Competitive Advantage on Sustainable Supply Chain Performance.

H4: Sustainable Competitive Advantage mediates the relationship between Block chain adoption (Research variables) and Sustainable Supply Chain Performance.

H5: Sustainable Development Goals (SDGs) moderates the relationship between Block chain adoption (Research Variables) and Sustainable Supply Chain Performance.

Through this comprehensive hypothesis testing framework, the research aims to provide empirical evidence regarding the significance of blockchain technology adoption in enhancing sustainable performance within the maritime industry, particularly in the context of developing nations. The findings will contribute to a deeper understanding of the strategic implications of blockchain adoption and its role in fostering sustainability.

4. RESEARCH METHODOLOGY

This research could be classified as a descriptive deductive research that started with reviewing previous literature. The research was considered conclusive and had a descriptive purpose as it aimed at gaining more information and identifying particular characteristics within a certain field of study. Survey research was chosen for the empirical validation due to the exploratory nature of this research paper. The data was collected through a questionnaire that was first pretested by two academics and two practitioners prior to its distribution to check its clarity. The research study used a cross sectional design. The research context is the Egyptian maritime sector where, the units of analysis were maritime companies in Alexandria. The reason behind these decisions was twofold. Firstly, the maritime sector is one of the cornerstones of the Egyptian economy at large. Secondly, for reasons of convenience and data accessibility as such industry is considered a major indicator to the understanding of the topic at hand. The sample included three companies in the industry operating in the Alexandrian port to ensure the collection of an adequate sample in a relatively short period of time in order to test the hypotheses. Questionnaires were sent out through emails and respondents were asked if they were willing to participate in a brief research study. The questionnaires were targeting mainly supply chain managers and logistics operatives because they were expected to have the sufficient knowledge. In total, 312 questionnaires were received and after filtering the cases that were not familiar with the block chain technology, 263 useable questionnaires were included in the study. According to past scholars ten participants per item should be regarded as an acceptable sample (Lance *et al.*, 2006; Yurdugul, 2008 and Samules, 2015). The variables and measures in this study were adopted from various studies in the literature. The independent variable (BCT) was measured using 5 items adapted from the studies of Liu *et al.*, (2023), Ben Farah *et al.*, (2024) and Grover *et al.*, (2024). These items are considered comprehensive as they were commonly used in previous literature to capture the full domain of the block chain technology adoption. The respondents were asked to rate the block chain dimensions impact on the company's sustainable supply chain performance using a five-point Likert scale where 1 indicated strong disagreement and 5 indicated strong agreement. A mediating variable (SCA) was measured using 4 items, divided into two groups to measure efficiency and innovation informed by the work of Wang *et al.*, (2022). Again a five-point Likert scale was used to assess the degree of each item where 1 indicated strongly no agreement while 5 indicated strongly agreement. A moderating variable (SDG) was measured using 5 items from previous study of Mansell *et al.*, (2020) in addition to the

UN- reports. The five-point Likert scale that was used evaluated the moderating role of the sustainability development goals of the united nation on the company's overall sustainable performance from a supply chain point of view. The 1 indicated strong disagreement to the influence of such goals and 5 indicated strong agreement. The 4 items used to measure the dependent variable (SSCP) were adapted from the work of Cruz Goncalves and Chkoniya (2022). These measures captured the dimensions of SSCP which included functionality and effectiveness. A five-point Likert scale was used to assess the company's sustainable supply chain performance. 1 indicated strong disagreement and 5 indicated strong agreement in relation to the company's sustainable performance of its supply chain when gaining a sustainable competitive edge because of adopting the technology of block chain. Following the data collection phase, data was analyzed

using SPSS 20.0® (Statistical Package for Social Science) to test the hypotheses and conduct further examination.

5. RESEARCH FINDINGS AND ANALYSIS

Scale validity and reliability

The data analysis started with testing the validity and reliability of the proposed measures using factor analysis and Cronbach's Alpha tests. First, the reliability analysis was conducted to see if the scales created were reliable to use in this study. This analysis illustrated whether the scales were consistent, dependable, and steadfast to be used in the Egyptian context especially the maritime industry. All the scales used in this study had Cronbach's α greater than 0.7, which suggested a satisfactory reliability level (Hair et al., 2010). Secondly, the validity analysis was conducted aiming to evaluate the accuracy and relevance of the measurement instrument utilized. The results demonstrated that all the scales were valid. Results from this test provided essential insights into the reliability and accuracy of the research instruments. In addition, the test ensured confidence in the results and conclusions that were drawn from this study.

Hypotheses testing

For testing the hypotheses multiple regression analysis was conducted with the (SSCP) as the dependent variable and the (BCA) as the independent variable. Moreover, the mediating role of (SCA) and moderating role of (SDG) on the (SSCP) were also tested. The regression analysis was conducted over a five steps process. First, the dependent variable (SCA) was regressed on the independent variable (BCA). In specific, the results showed that there is a significant positive impact of BCA on SCA which supported hypotheses (H1). Results indicated an adjusted R squared of .462, a beta coefficient of .682 and a significant p-value < 0.001. The logic behind this result could be due to the transformative disruptive changing nature of the operations in the maritime companies. For example, Block chain technology facilitates traceability of materials and stimulates responsible operations thus productions. Such practices comply with environmental regulations to adopt sustainable practices. As a result, such commitment appeals environmentally conscious consumers and partners which revitalize the global partnership for sustainable development. Second, the dependent variable (SSCP) was regressed on the independent variable (SCA). When testing the next hypothesis, the results showed that the relationship was significant with an adjusted R squared of .278, a beta coefficient of .530 and a significant p-value < 0.001 which supported H2. The significant impact of sustainable competitive advantage on the overall sustainable performance of supply chain in the maritime organizations can be attributed to several interconnected factors. As an example, the improved operational efficiency that was

facilitated through the block chain reduced costs while optimizing the utilization of resources which enhanced the competitive edge within the supply chain hence, the overall organization performance from a sustainable stance. Third, the dependent variable (SSCP) was regressed on the independent variable (BCA). It was revealed that the relationship is significant with an Adjusted R squared of .349, a beta coefficient of .591 and a significant p-value < 0.001 accordingly, H3 was supported. Block chain provides several edges to organizations especially within the supply chains. A few examples would be ledgering transactions which offer transparency and precise traceability complying better with sustainability standards and fostering accountability among stakeholders. Moreover, the enhancement of supply chain data security promoting sustainable practices. Never the less, block chain adoption allowed successful adaptation to changes in the environment which goes along with successful implementation of sustainable initiatives. Fourth, the interaction between (BCA) as a mediating variable and (SCA) was added to the regression analysis to test the research hypothesis. The interaction was partially positive and statistically significant with a p value of .000 and a beta coefficient of .430 which supported the mediating impact of SCA on the BCA-SSSP relationship. These results indicated empirical support for hypothesis 4. By strengthening efficiency and encouraging innovation, sustainable competitive advantage amplifies the positive effects of block chain on supply chain sustainable performance. This mediation highlights the sustainable importance of strategic competence along with distributive advancements when performing in a sustainable manner that leads to the realization of the company's full potential. Fifth, we assessed the interaction between Sustainable Competitive Advantage (SCA) and the United Nations Sustainable Development Goals (SDG) in relation to Sustainable Supply Chain Performance (SSCP) to explore moderation effects. The results indicated a positive and statistically significant interaction between SCA and SDG, with a p-value of .000. Notably, our respondents expressed strong support for four specific SDGs, identifying them as the most relevant to the subject matter. The goal of Decent Work and Economic Growth emerged as the top choice, endorsed by 62.1% of respondents. It was closely followed by Industry, Innovation, and Infrastructure, which received approval from 56.6%. Third in line was Sustainable Cities and Communities, cited by 45.3% of participants, and finally, Responsible Consumption and Production was selected by approximately 42.3%. These preferences highlight the critical areas where respondents believe sustainable practices can significantly enhance supply chain performance. Such result indicated a positive moderation impact of SDG on the SCA-SSCP relationship which in turn provided empirical support for hypotheses (H5). To conclude, these results highlighted the urge for organizations to mastering disruptive technologies which is now becoming the main element for The normal text should be written single-spaced, justified, using 11pt (Times New) Roman in one column. The first line of each paragraph must be indented 0.5cm. There is not inter-paragraph spacing.

	Hypotheses	Status
H1	There is a significant impact of Block chain adoption (Research variables) on Sustainable Supply Chain Performance.	**supported**
H2	There is a significant impact of Block chain adoption (Research variables) on Sustainable competitive advantage.	**supported**
H3	There is a significant impact of Sustainable Competitive Advantage on Sustainable Supply Chain	**support**

	Performance	**ed**
H4	Sustainable Competitive Advantage mediates the relationship between Block chain adoption (Research variables) and Sustainable Supply Chain Performance.	**support ed**
H5	**Sustainable Development Goals (SDGs) moderates the relationship between Block chain adoption (Research Variables) and Sustainable Supply Chain Performance.**	**support ed**

6. DISCUSSION

This research study reveals that all hypotheses were significantly supported, indicating a positive relationship between BCA and SSCP, enhanced by SCA and partially mediated by the Sustainable Development Goals (SDG). These findings pair with some prior studies of (Caro & Martens, 2019), which declared that given the maritime industry's complexity, where multiple parties are involved, blockchain's ability to offer a transparent, resilience, traceability, security, can significantly enhance overall operational reliability, thereby enhancing transactional efficiency (Hossain et al., 2019). The results declared that the rationale for the positive relationships between blockchain technology adoption (BCA), sustainable supply chain performance (SSCP), enhanced by SCA and partially mediated by the Sustainable Development Goals (SDG) is built on several key insights. First, BCA enhances transparency and real-time visibility in supply chains, allowing companies to efficiently track products and ensure compliance with sustainability standards, as noted by Sundarakani et al. (2024). This not only improves operational processes but also boosts customer satisfaction (Caro & Martens, 2019; Tidd & Bessant, 2020). Second, organizations that prioritize SCA by integrating sustainable practices into their operations can achieve significant efficiencies and build brand loyalty, which is crucial in a competitive market (Zeyu Wang, 2021). Research by Arasli (2021) supports this by indicating that sustainable practices enhance reputational benefits and customer loyalty, directly impacting supply chain performance (Kazemi et al., 2024). The positive partial mediation effect of Sustainable Development Goals (SDGs) underscores the need for businesses in the maritime sector to integrate responsible practices within their operations. Leveraging blockchain technology aids in aligning operational strategies with broader sustainability goals, thus fulfilling both stakeholder expectations and regulatory requirements (ElMassaha & Mohieldin, 2020). Furthermore, SCA acts as a catalyst for maximizing the benefits of blockchain technology, enabling firms committed to sustainability to leverage these tools effectively (Du et al., 2019; Hossain et al., 2019). Aligning blockchain initiatives with SDGs helps organizations measure their contributions to sustainability, enhancing their public image and stakeholder trust. Collectively, these insights illustrate how the interplay between blockchain technology adoption, sustainable supply chain performance, and sustainable competitive advantage fosters enhanced performance in the maritime industry while supporting global sustainability initiatives.

7. CONCLUSION

In conclusion, this study provides valuable insights into the transformative potential of

blockchain technology in improving sustainable supply chain performance within the maritime sector. The identified positive relationships between BCA and SSCP, moderated by SCA and mediated by SDGs, highlight the significance of blockchain as a foundational technology for enhancing transparency, security, and reliability in logistics operations. As industries globally increasingly prioritize sustainability, this research reinforces the idea that blockchain acts not only as a catalyst for operational efficiency but also as a vehicle for achieving broader environmental and social objectives. The findings suggest that maritime organizations seeking to maintain a competitive edge must embrace digital transformation through blockchain adoption. By incorporating BCA into their operational frameworks, companies can boost their resilience, meet regulatory requirements, and contribute to global sustainability efforts. Future research should further examine implementation strategies for blockchain within maritime supply chains, addressing potential barriers and the long-term impacts on operational performance. Highlighting the importance of innovation and proactive strategic planning in adopting digital technologies will be essential for organizations aiming to succeed in an increasingly complex and competitive environment.

8. RESEARCH LIMITATIONS

- Although the study involved 300 participants, the reliance on convenience sampling may restrict the generalizability of the findings. This approach might not adequately represent the entire maritime industry in Egypt.
- Furthermore, the study's focus on the Egyptian maritime sector may not accurately reflect the realities or challenges encountered in other regions or countries, thus limiting the applicability of the findings to broader contexts.
- Given that the data were collected via an online survey, there is a potential risk of self-selection bias, with individuals who have a heightened interest in blockchain technology being more likely to respond, which could skew the results.
- The rapidly evolving nature of blockchain and related technologies may render the findings outdated quickly, as new factors could emerge that were not considered in the current study.
- The questionnaire was based on participants' perceptions and opinions regarding blockchain adoption and its influencing factors, which introduces a degree of subjectivity that may affect the reliability of the results.
- Additionally, the quantitative approach may miss important qualitative insights, such as organizational culture, leadership attitudes, and employee engagement, all of which can significantly influence technology adoption.
- The operationalization of constructs like 'sustainable competitive advantage' and 'readiness for IoT applications' may not fully capture the complexity of these concepts, potentially restricting the depth of the analysis.
- While SDGs were included as a moderator, other relevant factors that could influence blockchain technology adoption may not have been addressed in the study.
- The use of convenience sampling might affect the representativeness of the sample. This could be improved by adopting random sampling or expanding the

participant pool to include more diverse maritime companies.

9. FUTURE RESEARCH DIRECTIONS

In light of the results and limitations of this study, several avenues for future research can be identified. First, subsequent studies could include participants from various countries or regions to facilitate comparisons of blockchain adoption across different maritime industries, thereby enhancing the generalizability of the findings. Second, incorporating qualitative methods such as interviews or focus groups could provide deeper insights into organizational culture, leadership perspectives, and employee attitudes toward blockchain adoption, enriching the understanding of barriers and facilitators. Third, conducting longitudinal studies could help track changes in perceptions and blockchain technology adoption over time, particularly as the technology matures and gains wider acceptance.

Moreover, future research could examine additional variables that may influence blockchain adoption, including organizational size, technological infrastructure, and external pressures such as regulatory changes or competitive dynamics. Furthermore, studies could evaluate the actual impact of blockchain implementation on supply chain performance metrics, sustainability outcomes, and competitive advantage in the maritime sector to validate the proposed relationships. Investigating the integration of emerging technologies, such as IoT and AI, could also provide a more comprehensive perspective on how these technologies interact to enhance supply chain performance.

Ultimately, future research should explore the viewpoints of various stakeholders—including regulators, shipping companies, and technology providers—to obtain a holistic understanding of the factors affecting blockchain adoption. Ongoing research should prioritize developing implementation strategies and identifying best practices for blockchain within maritime supply chains. Analyzing the long-term effects of blockchain adoption on operational performance and sustainability metrics will yield valuable insights into its effectiveness and drive

10. PRACTICAL IMPLICATIONS

The outcomes of this research offer valuable insights into how the adoption of blockchain technology (BCA) can significantly enhance sustainable supply chain performance (SSCP) within Egypt's maritime sector. The established positive relationships among BCA, sustainable competitive advantage (SCA), and the Sustainable Development Goals (SDGs) indicate several practical implications for stakeholders in this field.

a) Improving Operational Efficiency:

Maritime organizations can utilize blockchain technology to enhance transparency, real-time visibility, and traceability across their supply chains. By implementing BCA, companies can optimize their product tracking processes and ensure compliance with sustainability standards, ultimately leading to greater operational reliability. Improved efficiency can enable firms to respond more effectively to regulatory demands and customer expectations concerning sustainability.

b) Incorporating Sustainable Practices:

The research suggests that organizations prioritizing sustainable practices through SCA

can achieve significant gains in brand loyalty and operational performance. Maritime companies are encouraged to weave sustainable practices into their operational frameworks, as this not only aligns with global sustainability efforts but also boosts customer loyalty and competitive edge. This can be accomplished by evaluating and integrating sustainability metrics into supply chain processes, ensuring that all stakeholders understand their contributions toward the SDGs.

c) Engaging Stakeholders and Building Trust:

By aligning blockchain initiatives with the Sustainable Development Goals, maritime organizations can better assess their contributions to sustainability. This alignment can enhance trust and engagement among various stakeholders, including customers, regulators, and members of the community. Developing a strategic communication plan that showcases sustainability initiatives through blockchain will be essential for improving public perception and strengthening stakeholder relations.

d) Strategic Implementation of Digital Tools:

For maritime organizations to unlock the full potential of blockchain technology, strategic planning for its implementation is essential. This includes addressing potential barriers to the adoption of digital tools and nurturing a culture of innovation within organizations. Stakeholders should invest in training and development initiatives to equip employees with the skills necessary to utilize blockchain effectively and to promote digital transformation throughout their operations.

e) Policy Recommendations:

Policymakers in Egypt's maritime sector should aim to establish a conducive regulatory framework that promotes the adoption of blockchain technologies. This framework could include incentives for companies that incorporate sustainable practices, thereby aligning economic growth with social and environmental objectives. Collaboration among industry stakeholders is also critical to developing best practices and frameworks that facilitate the integration of blockchain in maritime supply chains.

By implementing these practical implications, maritime organizations in Egypt can position themselves as leaders in sustainable practices and digital transformation, effectively addressing market demands while contributing to broader environmental

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