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Article

Exploring the Role of Information Technology in Supporting Sustainability Efforts in Saudi Arabia

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Abstract: This study explores the role of information technology (IT) in supporting sustainability efforts in Saudi Arabia. Through an analysis of four case studies, we examine how technology has been implemented by Saudi Arabian companies to advance sustainability goals. The findings demonstrate a notable shift towards green initiatives in the country, with the adoption of technologies such as the Internet of Things (IoT), blockchain, and artificial intelligence. These technologies have been instrumental in enhancing energy efficiency and waste reduction. The study highlights the significance of policy interventions and public-private partnerships in achieving both environmental sustainability and economic growth. To ensure widespread adoption of sustainable practices, it is crucial for the government to focus on building digital capacity in companies and removing technological barriers. The case studies of four companies serve as illustrative examples of sustainable practices and the corresponding technological support in Saudi Arabia. The research underscores the importance of leveraging information technology and collaboration to accelerate progress towards the nation's sustainability goals.

Keywords: accounting; environment; information technology; innovation; sustainability

1. Introduction

Sustainability is a critical issue facing the world today, and information technology (IT) is playing an increasingly important role in promoting sustainability in developing countries [1]. The rapid pace of technological innovation is presenting new opportunities to address a wide range of environmental and social challenges, and developing countries are embracing these technologies to improve sustainability and create a more sustainable future. In recent years, the concept of sustainability has specifically gained significant attention across various sectors, including finance and accounting [2]. The role of IT in supporting sustainability initiatives has also become increasingly prominent, offering new opportunities for companies to enhance their sustainability performance. This study aims to explore the role of IT in supporting sustainability practices specifically within the context of Saudi Arabian companies. Sustainability focuses on integrating sustainability principles into financial reporting, risk management, decision-making processes, and overall business strategies [3]. It involves tracking and assessing various sustainability indicators, such as greenhouse gas emissions, energy consumption, waste management, social impact, employee well-being, and community engagement.

The significance of this research lies in the growing importance of sustainability for businesses worldwide. Saudi Arabia (SA), as the largest economy in the Middle East, plays a crucial role in regional and global markets [4]. As SA continues its efforts to diversify its economy beyond oil, it is imperative for companies to adopt sustainable practices that align with global standards and contribute to the achievement of national and international sustainability goals. The purpose of this study is to investigate how IT can facilitate the integration of sustainability practices within Saudi Arabian companies. By examining the use of IT, this research aims to shed light on the best practices for leveraging IT in sustainability initiatives.

The current state of research in this field indicates a growing interest in the intersection of IT and sustainability. Several studies have explored the adoption and impact of IT on sustainability practices in various industries and countries. [5] proposed a conceptual framework that explores how businesses can leverage Internet of Things (IoT) and blockchain IT to promote the United Nations' Sustainable Development Goals (SDGs). They highlight that IoT enables real-time and accurate data measurement, while blockchain ensures transparent and trustworthy data recording and reporting. By utilising these technologies, businesses can develop innovative solutions for measuring and managing their activities in line with the SDGs, driving sustainability and creating new business opportunities [6] investigate the relationship between Industry 4.0 and sustainability accounting and reporting. They suggested three levels of maturity for Industry 4.0, aligned with relevant sustainability topics. [6] noted that AI-based analytics and automation require more time to mature and ongoing technical and training programs are required. The role of IoT, blockchain, and Industry 4.0 in driving innovative and sustainable practices is emphasised through accurate data measurement, transparency, and cautious adoption of IT and effective support for sustainability accounting and reporting [5,6]. However, the specific context of Saudi Arabian companies and the role of IT in their sustainability efforts remain relatively underexplored. Therefore, this study seeks to contribute to the existing body of knowledge by focusing on the unique opportunities available to Saudi Arabian companies and examining the extent to which IT can support their sustainability goals.

While some argue that IT can significantly enhance the efficiency and effectiveness of sustainability reporting and performance measurement [7,8], others express concerns about the potential limitations and unintended consequences associated with technological advancements in accounting for sustainability [9,10]. By considering these diverging perspectives, this research aims to provide a comprehensive understanding of the potential impacts and trade-offs of IT adoption in sustainability practices of Saudi Arabian companies.

The main aim of this work is to provide actionable insights and recommendations for Saudi Arabian companies, policymakers, and other stakeholders on how to leverage IT effectively to support their sustainability goals. In summary, the paper contributes the following

- An understanding of the role of (IT) in supporting sustainability efforts in Saudi Arabia. It provides insights into how IT solutions, such as the Internet of Things (IoT), blockchain, and artificial intelligence, have been implemented by companies to enhance energy efficiency and waste reduction, leading to a notable shift towards green initiatives in the country.
- Highlights the significance of policy interventions and public-private partnerships in achieving both environmental sustainability and economic growth.
- Underscores the importance of building digital capacity in companies and removing technological barriers to ensure widespread adoption of sustainable practices. By highlighting the need to address digital disparities, the paper offers practical recommendations for policymakers and organizations to enhance digital literacy and encourage the integration of IT solutions in sustainability efforts.
- The absence of IT-related roles are raised particularly in areas such as community relations, communication, collaboration within the company, employee satisfaction and wellbeing, and education support. It encourages exploring the integration of IT solutions in these social dimensions of sustainability and promote a more holistic approach to sustainable development.

The following sections will present a comprehensive analysis of the current literature, research methodology, findings, discussions and conclusions, with the ultimate goal of advancing sustainable practices in Saudi Arabia.

1.1. Literature review

According to recent studies, 84 % of globally recognised companies are focusing their priorities on environmental conservation efforts to ensure that they alleviate poverty, and they also contribute to operational efficiency [11]. According to the 2021 Morning Star, the United States Sustainability Report reveals that companies with better ESG scores reported 33% higher returns on their income

statements [12]. These results show that corporate sustainability efforts are becoming a key metric in assessing the financial performance of institutions.

Organisations today are looking towards transformative change to improve quality of life and ensure sustainability for the future, as noted by various studies [13,14]. Digital technologies, such as IoT and blockchain, provide new avenues for achieving these goals [5]. However, digitalisation also brings challenges to the business world, requiring a deeper engagement with these technologies and transformations across many [15,16].

The COVID-19 pandemic and other unexpected crises have hastened the adoption of digital technologies in society, presenting a challenge for managers, professionals, and management scholars. As a result, organisations are increasingly seeking to understand their place in society and how it may be shifting [17]. The response to the COVID-19 pandemic has spurred the use of IT and brought more attention to the SDGs, even as it has reduced human interaction and mobility worldwide [18]. In today's environment, sustainability is recognised as a crucial aspect of business that impacts value creation. As a managerial aspect, it drives social change and helps organisations navigate the important shift to digitalisation [19]. As a result, many organisations must incorporate sustainability into their business model, including aspects such as operations, risk management, product creation, and more, which will impact their sustainability performance [20]. This involves balancing financial, environmental, and social objectives in the delivery of core activities to maximise organisational value.

The United Nations Global Partnership for Sustainable Development Data (GPSDD) has made a clear call for a "data revolution for sustainable development" [21] (p.10). The utilisation of IT has the potential to drive sustainable development. The digital transformation highlights that the future of organisations is closely tied to sustainability, which requires the development of organisational, technological, and social capabilities within various ecosystems where different actors play a crucial role in the creation of value. For instance, the Saudi Arabian government and companies believe that sustainability is important in the promotion of socio-economic development. Saudi Arabia has also partnered with other corporations such as the Gulf Corporation Council Councils, nations under the Red Sea Project, and large companies as well as small and medium enterprises in the country to promote sustainable development [22]. The country, in coordination with companies such as the Saudi Telecommunication Company, is focusing on green transformation where environmentally conscious projects and technologies are prioritised. It is expected that these green initiatives will help in the management of toxic wastes, improve conservation efforts, replenish depleted resources, help in reclaiming previous wastelands, and improve mass awareness of conservation. IT is an important part of the promotion of sustainability, reporting, and making conservation efforts visible and relevant [22]. Therefore, this paper focuses on how IT such as the IoT, Blockchain, Artificial Intelligence, and Machine learning can be used in promoting sustainability reporting of major Saudi Companies.

Firms are including their concerns for the environment as a key strength that forms a competitive advantage [23]. In a research that involved data collection from 53 apparel sector firms in Bangladesh, [23] discovered that environmental corporate social responsibility positively improves the ability of the company to survive, sustainably produce, and maintain efficiency and profitability in operational activities. The authors found that there is a direct relationship between green image and green competitive advantage in an organisation. They also found that customer well-being is positively associated with a green image. The main enablers identified were green innovation, people's capacity, consumer well-being, and the company's philanthropic activities. Alam and Islam's findings are related to [24] findings where they found that an increase in community involvement and engagement in sustainability efforts increases the quality of available sustainable infrastructure and the sustainability of resources [23]. While in some cases outcomes of community engagement are not desirable, in most instances, the reciprocity between government, private sectors, and communities can help in resolving some of the conflict-related challenges. According to [24], IT and innovation can be important resources for promoting a company's efforts for sustainability [24]. [24] reported a Loreto Bay Case Study in Mexico where improvement in community engagement and

collaboration was essential for the survival of a project even when it became evident that initial funding sources were pulling away from the project.

1.2. Leveraging Digital Technologies for Sustainable Business Practices

Digital technologies can be used in resolving problems that companies face in the adoption of environmentally sustainable measures. Some of these sustainability problems are managerial and institutional in nature [27]. Institutional hindrances to organisations attempting to improve sustainability focus include corruption, weak legal systems, lack of institutional willingness, conglomerate companies that take advantage of consumers, and lack of stakeholder agreements that can value and increase the strength of corporate sustainability efforts [27]. [27] propose wide-ranging technologies and digital tool kits that can aid in company sustainability efforts but warn that the cost of scaling up these resources should be low for them to have any positive impact. The technologies should be adopted in a collaborative, coordinated sustainable manner that will improve communication and information-sharing capabilities. Technologies such as blockchain, the IoT and Machine Learning can be extensively used in corporate social sustainability efforts if they promote the public good and companies controlling them avoid the exclusivity problem.

According to Salam [28], the IoT is a possible intervention in the management of large forest systems such as the Amazon Forest in South America. The IoT adoption may be limited due to the need to cover huge geographical areas such as the lack of capacity of conservation agents and the inability to improve human capital that will be instrumental in the management of these resources [28]. However, the important strengths of the IoT include prediction, data analysis, big data and actuation can help overcome these limitations. These features have accurate deployment in predicting instances and areas in forests where there is the possibility of forest fires. Companies can use the IoT to predict real-time changes in temperature and variance analysis between normal forest temperature, predicting changes in moisture levels, and transmission of real-time images that show the number of trees that could be affected by pests [28]. [29] also examined the use of IT to promote quality, conservation, and sustainability. [29] noted the use of IT pioneered in Saudi Arabia for Mobile Communications (GSM) module, cloud, and water sensors to conserve water that flows into residential buildings.

Investigations show that some institutions and corporates have an important role to play in promoting continuity during socioeconomic disruptions and climate change situations. The role of financial accounting can help institutions play this role [30]. [30] contend that IASB and FASB may work with international environmental boards to ensure that sustainable accounting standards are also part of the Generally Accepted Accounting Standards and the International Financial Reporting Standards that companies are supposed to adhere to. [30] suggest that previously financial information was given higher materiality in auditing but to increase the prominence of conservation efforts, environmental sustainability information may have higher materiality and therefore help stakeholders in making a decision regarding investments. There is also a recommendation that pollution tax and other incentives for companies that go out of their way in conserving the environment should be included in the calculation of EBIT. The soundness of [30], suggestions on environmental application needs to be considered so that the role of financial accounting and reporting in environmental sustainability efforts does not remain rudimentary and irrelevant in organisational settings. [31] highlighted that International Financial Reporting Standards (IFRS) website note on sustainability reporting and its inclusion in the financial statements of organisations has been done for public relations purposes [31].

Some also contend that not all digital technologies have been adopted in sustainability as research is still in its nascent stages [28]. Some systems adopted in health have a direct bearing on environmental sustainability which can help in other contexts. For example, an application called the Health care Data Gateway (HDG) uses blockchain systems to automate patient medical records, reducing a hospital's usage of paper, help patients in owning information, sharing, and controlling - an effort in digitisation and environmental conservation [23].

[25] and [26] proposed four roles of IT in sustainable supply chain management as Automate, Informate, Transform, and Infrastructure (see Table 1). These roles encompass various functions that IT can fulfill within organisations [25]. The role of Automate corresponds to integration and operational aspects, whereas the role of Informate encompasses communication, coordination, and decision making. The role of Infrastructure relates to integration and knowledge codification and management. The Transform role empowers organisations to re-engineer their business processes. These four IT roles enable organisations to achieve information transparency, performance monitoring and evaluation, flexibility and responsiveness, resource optimisation, value creation, and competitive advantage through the effective utilisation of information and knowledge [26].

Dimension	Key Practice	Information Technology Role			
		Automate	Informate	Transform	Infrastructure
Economic	Reducing costs	Y	Y		Y
	Achieving stakeholders satisfaction		Y		Y
	Enhancing sales	Y	Y	Y	Y
	Creating new business models	Y	Y	Y	Y
	Quality initiatives		Y	Y	Y
	Creating competitive advantage		Y	Y	Y
Environmental	Clean/lean production	Y	Y	Y	Y
	Green distribution/logistics		Y	Y	Y
	Efficient resource consumption		Y	Y	Y
Social	Community relations and communication		Y	Y	Y
	Collaboration within company		Y	Y	Y
	Employee satisfaction and wellbeing		Y	Y	Y
	Education support		Y		Y

Adapted from [25] and [26].

The economic dimension focuses on practices that promote economic sustainability [25]. This includes ensuring healthy cash flow, good profit margins, and a proper return on investment. It includes practices such as business performance improvement, internal and external management practices, and creating competitive advantage through factors like cost, quality, speed, and flexibility contribute to bottom-line performance. The environmental dimension of sustainability involves integrating environmental concerns [26]. This includes energy use, hazardous materials disposal, after-sales service, and green purchasing. The fusion of economic and environmental sustainability adds complexity requiring greater cooperation, collaboration, interdisciplinary focus. Measuring outcomes and balancing economic and environmental imperatives pose challenges and the impact of green initiatives on firm performance remains ambiguous [26]. The social dimension encompasses community issues, corporate governance, diversity considerations, employee relations, human rights, safety, education, and ethical considerations.

2. Methodology

This study examines how four organisations successfully implemented technologies to promote sustainability. We utilise a suitable exploratory method, the case study, to investigate how these organisation introduced IT. To identify the case studies to answer the question on exploring the role of IT in supporting sustainability efforts in Saudi Arabia, the following steps were taken: (i) We clearly outlined the purpose of the study which was to investigate how IT can facilitate the integration of sustainability practices within SA companies. This helped to narrow down our focus and guide the selection of case studies. (ii) We review existing literature by thoroughly analysing relevant academic papers, reports, and articles related to IT and sustainability in Saudi Arabia. This assisted in identifying existing case studies. (iii) We identified potential sources for our case studies by exploring academic databases (Saudi Digital Library (SDL)), research institutes (Prince Sultan Research Center for Environment, Water, and Desert (PSRCEWD)) and internet search. The focus was on looking for organisations, projects, or initiatives that showcase the use of IT to support sustainability in Saudi Arabia. (iv) From a list of 28 potential organisations/projects, we evaluate case

study candidates based on the extent of their IT integration, and the impact of their sustainability efforts. Major considerations were the sector (one sector per project/organization) size of the sustainability projects (a multimillion dollar project/organization) and the extent of IT and innovation within the projects/organisations. (v) Four case studies that best represent a diverse range of IT applications in supporting sustainability efforts in Saudi Arabia were chosen. While there are other cases in SA available on sustainability practices in different organisations, none we found provide the comprehensive details and focus on IT usage as the selected cases. Due to the limited existing studies with in-depth descriptions of IT 's role in supporting sustainability practices, the chosen organisations serves as indicative cases of sustainability practices and the corresponding technological support. Throughout this paper, the organisations are referred to as Company A, Company B, and Company C, and Company D to maintain anonymity.

The comprehensive nature of the published data on Company A, Company B, Company C, and Company D facilitated detailed analysis to address the research question. Content analysis is employed to systematically examine and interpret the available data, aiming to identify patterns, themes, biases, and meanings [32]. Relevant organisational practices related to the sustainability are identified, and patterns associated with the roles of IT are analysed.

2.1. Overview of the Case Studies

Company A project, is a major land and property development project in SA developed as part of the Saudi Vision 2030 program. Initially announced in July 2017, the project focuses on attracting visitors to the Red Sea coast through ecotourism. Work began in 2019, and the project is projected to contribute \$5.86 billion annually to the Saudi Arabian GDP. The phases include the construction of hotels with more than 3,000 rooms, an airport, a yachting marina, historical sites, and recreational facilities. By 2030, Company A project aims to feature more than 50 hotels with 8,000 rooms, along with over 1,000 residential properties spread across 22 islands and six inland sites.

Company B is a publicly traded petroleum and natural gas company headquartered in SA. Company B came into being through a partnership between two countries which include Saudi Arabia. The purpose of the partnership was to transform billions of oils and trillions of gas into various streams of value for Saudi communities. Company B intends to position itself as a top oil-producing company in the world. It holds a prominent position in the global corporate landscape, consistently generating substantial revenue and achieving record-breaking annual profits. Company B boasts the world's second-largest proven crude oil reserves, exceeding 270 billion barrels, and maintains the highest daily oil production among all oil companies. However, it is also recognised as the leading contributor to global carbon emissions since 1965. Company B operates the largest hydrocarbon network worldwide, with numerous oil and gas fields. The company's shares are traded on the Tadawul stock exchange in SA and has been listed within the five largest public companies globally.

Company C is a sovereign wealth fund in SA, established with the aim of investing funds on behalf of the Saudi Arabian government. With an estimated total asset value of more than \$600 billion, Company C ranks among the largest sovereign wealth funds globally. The fund's operations primarily focus on investments within Saudi Arabia, accounting for over 60% of its activities. Company C also directs its investments in foreign assets. Finally, Company D is a major telecommunications operator in SA and the Middle East, offering a wide range of services such as landline, mobile, data, broadband, and cloud computing. Company D operates next-generation networks (NGNs) with a packet-based architecture for efficient communication. It has expanded its services, including obtaining approval for its conversion into a digital bank. Currently, Company D operates as a conglomerate overseeing various assets, subsidiaries, and joint ventures within SA.

To perform content analysis and identify the IT dimension of the economy, environment, and social aspects of the selected case studies, the following steps were taken: (i) The research team consisted of two researchers (one senior and one junior researcher) to reduce research bias. The systematic procedure followed aimed to promote rigor of the content analysis application. (ii) Data was collected from all relevant documents, reports, articles, and any other available materials related

to the selected case studies. This included sustainability reports, project proposals, and IT implementation plans. (iii) A coding framework was developed that captures the key dimensions of IT in relation to the economy, environment, and social aspects of sustainability, with EC representing economy, EN, environment, and SO representing the social aspects of sustainability. (iv) Coded data was systematically analysed and this involved highlighting specific passages, sentences, or paragraphs that reflect the IT dimension in each aspect of sustainability. (v) After completion of the coding is complete, a compilation and summary of the data for each case study was presented in tabular form. This enabled identification of similar patterns and connections between the IT applications and the economy, environment, and social aspects of sustainability.

3. Results

In this section, we show how the implementation of IT by company's A to D assumes diverse roles in supporting various sustainability initiatives. We also emphasize the significant practices of the organisations that are influenced by the adoption of IT.

3.1. Company A and B

Table 1 provides an overview of the key sustainability practices that are enhanced through the implementation of IT. Company A is actively embracing IT to drive sustainability throughout its operations. In terms of renewable energy, the company is employing solar and wind power as alternative energy sources to power its activities, significantly reducing its carbon footprint. IT plays a vital role in enhancing the efficiency and cost-effectiveness of these renewable energy sources [33,34].

Table 1. Key sustainability practices and the role of IT for companies A and B.

Dimension	Key practice	IT role	Description
<i>Company A</i>			
Economic	Reducing costs	Informating and Infrastructure	Using renewable energy sources for cost cutting
Environmental	Renewable energy	Automation, Transformation, Informating and Infrastructure	Using renewable energy sources such as solar and wind power for its operations reducing carbon footprint.
	Water Management	Automation, Informating and Infrastructure	Reducing wastage of water while improving the efficiency of water treatment and distribution by using advanced water treatment technologies
	Energy efficiency	Automation, Transformation, Informating and Infrastructure	Sustainable building design efficiently utilising resources by optimising the design of buildings for energy efficiency
	Renewable energy	Automation, Transformation, Informating and Infrastructure	Reduction of emission of poisonous gas into the atmosphere through investments in hydrogen
	Clean tourism	Automation, Transformation, Informating and Infrastructure	Augmented reality technology with users experiencing what is on offer without harming marine and other terrestrial habitat
Social	-	-	-
<i>Company B</i>			
Economic	Reducing costs	Automation, Transformation, Informating and Infrastructure	Investing in renewable energy sources such as solar and wind power, leveraging technology to improve the efficiency and cost-effectiveness
Environmental	Efficient resource consumption	Transformation, Informating and Infrastructure	Using IoT to enhance process control mechanisms
	Efficient resource consumption	Transformation, Informating and Infrastructure	Using artificial intelligence algorithms to stabilise oil production to promote efficiency in the manufacturing process
	Clean production	Automation, Transformation, Informating and Infrastructure	Carbon capture and storage (CCS) technology to reduce greenhouse gas emissions and

			mitigate the impact of its operations on the environment
	Water management	Automation, Transformation, Informating and Infrastructure	Using technology to reduce waste while improving the efficiency of water treatment and distribution.
Social	-	-	-

Water management is another area of focus for Company A's sustainability initiatives. By utilising cutting-edge IT, the company is optimising its water management practices to minimise water waste and enhance the effectiveness of water treatment and distribution. Advanced water treatment technologies are being implemented to reduce water consumption in operations while improving the quality of water produced [35].

Efficient waste management is another aspect where Company A leverages IT to make a positive environmental impact. By utilising advanced IT, the company is streamlining waste collection processes, reducing waste and emissions, and transforming waste into clean energy. This approach enables Company A to contribute to a circular economy while minimising its environmental footprint [36,37]. Company A is also employing IT to drive sustainable building design. By utilising innovative tools like building information modeling (BIM) and energy simulation, the company optimises the architectural design of its buildings for improved energy efficiency, enhanced comfort, and overall sustainability [38,39].

Through strategic partnerships, Company A has successfully pursued the development of zero-emission flights, recognising the aviation industry's significant contribution to harmful gas emissions. By engaging in these collaborations, the company fosters sustainable tourism practices that prioritise environmental preservation. Company A is also pursuing hydrogen-electric powertrains which have emerged as the most viable, cost-effective, and impactful solution to mitigate aviation's adverse effects on climate change and air quality.

Under the umbrella of the smart destination project, Company A has curated an extensive portfolio of investments that seamlessly integrate various elements, aiming to deliver an unparalleled tourism experience while minimising environmental harm. This holistic approach encompasses diverse sectors such as infrastructure development, security installations, retail, logistics, and even education. Augmented reality IT is leveraged to showcase tourism without endangering marine life or terrestrial habitats, allowing users to virtually experience the offerings in an eco-friendly manner.

3.2. Company B

Company B is utilising digital energy to drive sustainability in mining operations. In one of Saudi Arabia's largest oil fields, the company has implemented IoT technology to enhance process control mechanisms. By deploying sensors in the pipeline management system, the company can swiftly detect any potential leaks, ensuring the integrity of the operations. With over 40,000 sensors deployed across more than 500 oil fields, the company actively promotes energy efficiency in boiler consumption, optimising resource utilisation [41]. Company B has also embraced machine learning IT by employing Artificial Intelligence algorithms to stabilise oil production, leading to increased efficiency in the manufacturing process. This intelligent approach not only enhances operational performance but also contributes to a significant reduction in carbon emissions. By implementing these advanced technologies, Company B has developed effective digital transformation strategies, positioning itself as a market leader in sustainable practices.

The adoption of IoT sensor technology is driven by investment data showcased in Figure 1. Company B has allocated substantial resources to the development of data centers, emphasising the importance of data management in their sustainability initiatives. This strategic investment demonstrates the company's commitment to leveraging digital solutions for optimal operational performance and environmental stewardship.

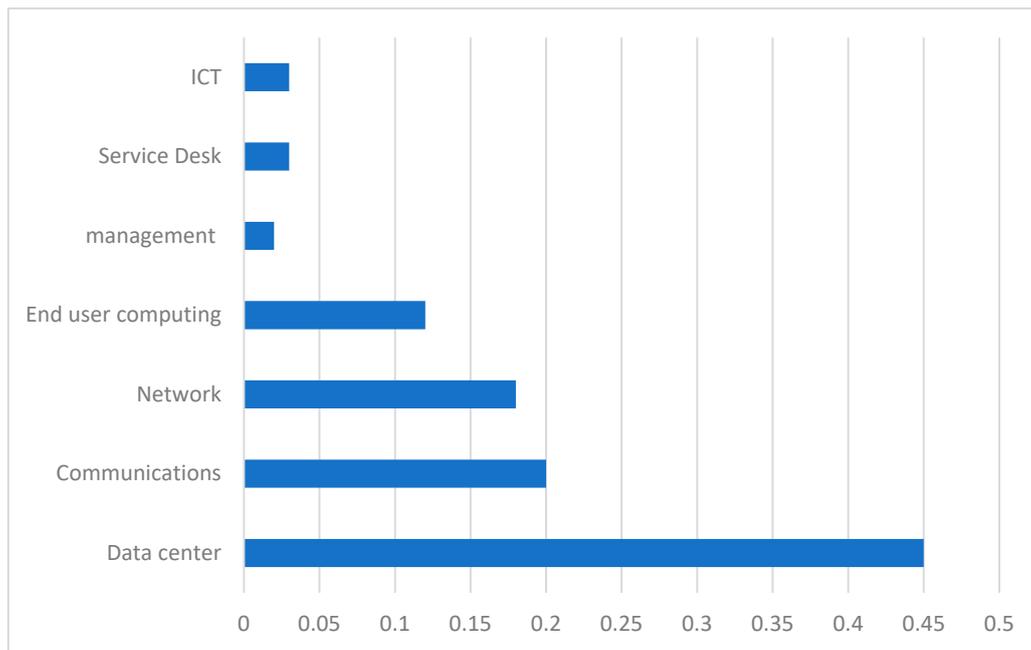


Figure 1. Company B information technology data spend. Source: Company B website.

In its commitment to sustainability, Company B incorporates advanced IT to drive positive environmental impact through the implementation of carbon capture and storage solutions. This strategic investment allows the company to reduce its greenhouse gas emissions and mitigate the environmental footprint of its operations. Leveraging digital technologies, Company B optimises energy usage in real-time, identifying and addressing inefficiencies reducing environmental impact. Company B has also recognised the significance of renewable energy sources, and has invested in solar and wind power. This approach not only reduces reliance on traditional energy systems but also contributes to a more sustainable energy landscape. Company B also harnesses IT to manage its water usage improving the efficiency of water treatment and distribution.

3.3. Company C

Table 2 illustrates how Company C utilises IT to drive sustainability within its investment portfolio. The company embraces technological advancements to integrate sustainable investing principles into its decision-making process. By leveraging advanced data analytics and incorporating environmental, social, and governance (ESG) metrics, the company identifies investment opportunities that align with its sustainability objectives [42,43]. Company C recognises the importance of renewable energy technologies in promoting sustainability and reducing reliance on fossil fuels. Consequently, the company actively invests in such technologies, contributing to the development and expansion of renewable energy sources. In addition to renewable energy, Company C focuses on sustainable infrastructure projects that foster both economic development and environmental sustainability. By utilising IT, the company identifies and evaluates investment opportunities in the infrastructure sector. IT enables the company to monitor the sustainability performance of its infrastructure portfolio, ensuring ongoing alignment with its sustainability goals.

Table 2. Key sustainability practices and the role of IT for companies C and D.

Dimension	Key practice	IT role	Description
<i>Company C</i>			
Economic	Achieving stakeholders satisfaction	Informating and Infrastructure	Integrates sustainable investing principles into its investment decision-making process
	Quality initiatives	Informating and Infrastructure	Leveraging technology to identify and evaluate investment opportunities in the infrastructure sector

Environmental	Renewable energy	Automation, Transformation, Informating and Infrastructure	Reduction of emission and dependence on fossil fuels
Social	-	-	-
<i>Company D</i>			
Economic	Reducing costs	Automation, Transformation, Informating and Infrastructure	Using digital platforms to track sustainability performance of its suppliers and to identify areas for improvement
Environmental	Energy efficiency	Automation, Transformation, Informating and Infrastructure	Implementing digital technologies to optimise energy usage in real-time, addressing inefficiencies
	Efficient resource consumption	Transformation, Informating and Infrastructure	Leveraging technologies such as virtualization, cloud computing, and artificial intelligence to optimise data center performance reducing waste
Social	-	-	-

3.4. Company D

As shown in Table 2, Company D uses IT to drive sustainability in its operations. To enhance energy efficiency and minimise greenhouse gas emissions, the company employs digital technologies to optimise energy usage in real-time and address inefficiencies proactively. This approach not only reduces energy waste but also contributes to a significant reduction in the company's carbon footprint. The sustainability of data centers is a priority for Company D due to their critical role in its operations. By leveraging innovative technologies such as virtualisation, cloud computing, and artificial intelligence, the company optimises data center performance while concurrently reducing energy consumption and waste. Company D extends its commitment to sustainability to its network infrastructure and supply chain. To build a green network, the company adopts IT-driven solutions that diminish the environmental impact while enhancing network performance and reliability. This includes utilising energy-efficient network equipment, deploying low-emission vehicles, and implementing efficient cooling systems to minimise its overall carbon footprint. In its supply chain, Company D employs digital technologies to promote sustainability. By optimising supply chain processes and reducing waste, the company effectively minimises the environmental impact of its operations. For instance, the company utilises digital platforms to monitor the sustainability performance of its suppliers, enabling the identification of areas for improvement and fostering more sustainable practices throughout the supply chain.

4. Discussion

From the results, Company B is spending a significant amount of its ICT budget on data centers. This is due to the realisation that data centers often consume large amounts of energy as they require a lot of heat for their cooling systems. The company has employed a data center infrastructure management tool to track each of its data centers in a bid to obtain additional information on the life cycle of the project. Once this information has been obtained, the company can then come up with a risk management approach and reduce the impact on the environment. Alternatively, Company B can considerably reduce the usage of oil as part of its energy to power data centers and replace this with solar energy.

The use of machine learning by Company B also reveals the importance of algorithms in the management of energy systems. For sustainable energy, companies should work towards updating their load requirements, checking on the length of the battery, and load prediction. Such a strategy has been adopted by Company B and it is paying dividends as far as the management of energy consumption is concerned. The company has also expanded the usage of data analytics so that engineers can have real-time information and do quick repairs to the system in the event of a power failure and energy overload. Data analytics promote economic sustainability where cost savings are made in the event there are massive failures in the system.

The results show that Company B has excelled in the usage of IoT-powered sensors in promoting efficiency in the oil fields. There exist some risks with the usage of this IT. The company should ensure that there is an adequate data protection policy in place. It is not just about ensuring that a data

protection policy is in place but also about implementing it. Putting in place high-level security of systems and then promoting the aspect of physical hardening is a step in the right direction because the company will have ensured that the sensors are in any region or area where they may be deployed [40]. Company C is looking forward to attracting investments as part of its efforts towards putting more money into green finance projects. Investors can only be attracted if there is a right proprietary framework that would ensure that such company funds are not diverted to other projects. A key recommendation would be the inclusion of green finance projects and climate change as part of the high-level conversation in organisational decision-making.

Company C has limited implementation of blockchain IT to activate smart contracts and encourage increased adoption of environmentally friendly practices. Ecologically beneficial initiatives show that increased security systems around blockchain can promote more people to participate in sustainability actions through trade in the bonds and they do not have to wait for long before there is full authorisation. Blockchain technologies may also be used in the promotion of the digital assets exchange that will facilitate the inclusion of digital assets on the stock therefore further expanding interest in the region. The absence of any IT-related role in the social aspects, such as community relations, communication, collaboration within the company, employee satisfaction and wellbeing, and education support, as observed in the analysed documents, is an intriguing finding. It suggests that the focus of the documents and the companies examined may have been primarily on environmental sustainability rather than broader social sustainability. This could indicate a potential gap in the integration of information technology solutions to address social aspects within the sustainability efforts of the companies studied. It raises questions about the extent to which technology-driven initiatives are being leveraged to enhance social engagement, employee wellbeing, and community development. Further research is warranted to explore the reasons behind this apparent neglect of IT's role in these critical social dimensions of sustainability and to identify opportunities for future integration and improvement.

This research has demonstrated potential applications of IT in assisting organizations in addressing the sustainability. The evaluation of IT roles indicates that Informing and Infrastructure roles are widely applicable because data and information play crucial roles in business processes. Therefore, IT is necessary for analysing, processing, managing, and communicating information to achieve business objectives. The presence of an infrastructure, whether virtual or physical, is essential for supporting the delivery of business objectives through information. This study demonstrates that the Infrastructure role is fulfilled by factors such as enhancing process control mechanisms throughout various operational environments. The Informing role is fulfilled by extracting meaningful insights from the infrastructure set up. In areas where automation is crucial, the role is realised through machine-to-machine communication facilitated by wireless sensor networks, reducing human intervention and automating business processes, particularly in support of environmental and economic aspects [26]. The Transformation role seems to significantly support environmental dimensions. This finding confirms that organizations aiming to address and support environmental aspects should re-engineer their business operations to align with environmental dimensions. The study highlights how IT can be leveraged to transform specific organizational aspects across the three main operational areas, leading to more intelligent, efficient, and environmentally friendly operations.

The policy interventions together with public-private partnerships where the government and the public sector combine efforts can assist in having gains in environmental sustainability. Some of the technologies discussed in this paper such as blockchain can be used to show that sustainability is not only the effort of companies but a platform where public investments count towards green projects that can accelerate achievements. The government has an important role to play in building digital capacity of companies in the country. This capacity will ensure that benefits realised through the focus on sustainability can be spread throughout the entire country. The government will also need to carry out needed awareness of digital transformation and sustainability.

5. Conclusions

This study provides valuable insights into the role of information technology (IT) in supporting sustainability efforts in SA. The findings highlight a significant shift towards green initiatives in the country, facilitated by the adoption of technologies such as the Internet of Things (IoT), blockchain, and artificial intelligence. These technologies have played a crucial role in enhancing energy efficiency, waste reduction, contributing to environmental sustainability while also fostering economic growth. The sustainable practice strategies are aligned to Saudi Arabia's vision 2030 on sustainable strategy where the nation seeks to accelerated its energy transition, and Company A, Company B, and Company D can be used as flagship sustainable companies. The study emphasizes the importance of policy interventions and public-private partnerships in achieving sustainable practices and goals. It highlights the need for the government to focus on building digital capacity in companies and removing technological barriers to ensure widespread adoption of sustainable practices across different sectors. By presenting four case studies, the research provides illustrative examples of sustainable practices and the corresponding technological support in Saudi Arabia. These case studies demonstrate how companies have leveraged IT solutions to advance their sustainability goals, thereby serving as examples for other organizations in the country. The study underscores the significance of leveraging information technology and fostering collaboration among various stakeholders to accelerate progress towards Saudi Arabia's sustainability goals. It calls for continued efforts in promoting sustainable practices, increasing digital capacity, and strengthening public-private partnerships to achieve a sustainable and prosperous future for SA.

One possible limitation of this study is its focus on only four case studies, which may not provide a comprehensive representation of the entire SA business landscape. The findings and conclusions drawn from these cases might not be applicable to all companies or sectors within the country. The study's reliance on qualitative analysis of these cases may limit the generalisability of the findings. Future research may investigate the barriers or challenges faced by companies in implementing and adopting IT for sustainability purposes, which was not the focus of this study. Other factors such as cultural, social, and economic considerations other than IT in supporting sustainability efforts may also be examined.

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