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Harnessing the Impact of Digital Twins for Business Process Engineering and Sustainability of Oil and Gas Industry in Nigeria

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Abstract:- This study mainly focused on harnessing the impact of Digital Twins on Business Process Engineering and sustainability in Nigeria's oil and gas industry by identifying challenges, opportunities, and best practices to apply. The study also hinged on Systems Theory and Resource-Based View (RBV) to provide a framework for understanding how organizations can utilize Digital Twin technology to improve operational efficiency and sustainability. The research adopted interpretivism and inductive approaches, which systematically assessed 25 articles and used thematic analysis. Findings show that Digital Twins significantly improve safety protocols, minimize environmental impact, and improve resource management toward a more sustainable operational framework in the oil and gas sector. Consequently, the study concludes that integrating Digital Twin technology significantly benefits oil and gas industry managers through improved data-informed decisions and increased compliance with the law and relevant environmental regulations. Such a knowledge base provides this research with the unique value proposition that Digital Twins brings to operational efficiency and sustainability, thus contributing to and learning from that pool. The implications will be enormous for managers who must prioritize investment in digital technologies and a culture of collaboration and continuous improvement to exploit the possibilities offered by Digital Twins. This study also emphasizes the urgent need for strategic alignment of technology adoption with sustainability goals so that the country would have a more resilient and eco-friendly oil and gas industry in Nigeria.

Keywords: Digital Twins, Business Process Engineering, Sustainability, Oil and Gas Industry

1. Introduction

The oil and gas industry is a vital component of Nigeria's economy and has contributed significantly to government revenue [Ifalade & Adeleke, 2024], foreign exchange earnings [Esiri, Sofoluwe & Ukato, 2024], and employment [Erhueh, Nwakile, Akano, Esiri & Hanson, 2024]. However, the sector faces persistent challenges, including inefficiencies in operations, environmental degradation, and unsustainable practices (Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024). However, this sector has been characterized by challenges such as operational inefficiency, environmental degradation [Haliru, 2024; Ameh, 2024], unsustainability, and now globally by the push of decarbonization and alignment with the United Nations Sustainable Development Goals (SDGs). In this change, Digital Twin (DT) technology was launched into the system for disruptive transformation from the status quo [Bello, 2021; Douglas & Morakinyo, 2023]. According to AlAmir, 2022, DTs are virtual replicas of physical assets, systems, or processes and allow real-time monitoring of operations, predictive maintenance, and optimization of operations. In

the global setting, this adoption of DT has transformed industries to be more efficient, low-cost, and sustainable. In oil and gas operations, there is reduced unplanned downtime and enhanced safety through DT [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. However, Nigeria's oil and gas industry has not adopted this development, hampered by infrastructural, financial, and policy issues [Abusohyon et al., 2021]. How can DTs be leveraged to improve Business Process Engineering and sustainability in the Nigerian oil and gas sector? This study addresses the inefficiencies and aligns the industry with global best practices.

Indeed, Nigeria's oil and gas industry is characterized by inefficiencies, high operational costs, and environmental challenges. Operations are traditionally managed reactively, thus occasioning frequent equipment failure, unplanned downtime, and safety hazards. For instance, the Niger Delta region has been subjected to disastrous environmental degradation due to oil spills and gas flaring, causing adverse health effects and significant loss in biodiversity in the local communities [Douglas and Morakinyo, 2023]. Moreover, fossil fuels continue to be relied upon by the sector, which adds to global greenhouse gas emissions contrary to global decarbonization efforts [Bello, 2021; Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. In terms of digital turnarounds (DTs), countries like the United States, Norway, and Saudi Arabia have been able to adopt such technology for solving similar challenges [Bello, 2021; Douglas & Morakinyo, 2023; however, Nigeria appears to be lagging in terms of adopting this transformative technology [Haliru, 2024; Ameh, 2024]. The country is hampered by an inadequate policy framework, infrastructural insufficiency, and limited technical competence to implement DTs [Aliyu et al., 2021; [Esiri et al., 2024]. An urgent need has arisen that can be fulfilled by a comprehensive study to determine how DTs can be adopted locally to overcome those hindrances and boost sustainable development in Nigeria's oil and gas sector.

Several issues hinder the adoption of DTs in Nigeria's oil and gas industry. First, there is a lack of infrastructure and technological expertise to implement and maintain DT systems [Abusohyon et al., 2021]. Second, financial constraints and low investments in digital transformation have inhibited the adoption of advanced technologies [Ameh, 2024]. Third, policymakers and industry leaders' lack of awareness and support has created resistance to change [Arinze et al., 2024]. Lastly, there is no precise regulation regarding the process of digital transformation in the oil and gas sector [Bello, 2021; Douglas & Morakinyo, 2023, which has also brought about uncertainty and investment discouragement [Esiri et al., 2024]. This has created considerable damage in the past [Haliru, 2024; Ameh, 2024]. The frequent failures of equipment and the resultant unplanned downtime have caused losses running into billions and environmental damage [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021] failure by the absence of predictive-maintenance frameworks [Douglas & Morakinyo, 2023]. Due to global climate change, the traditional method has reduced the industry's capacity to optimize its operations and reach a low carbon footprint [Bello, 2021]. Hence, addressing these issues has become a priority for Nigeria's sustainable oil and gas operations.

Various essential tools such as IoT analytics (IBM Watson and ANSYS Twin Builder), Enterprise Systems, cloud applications, blockchain, artificial intelligence (AI), Microsoft Azure Digital Twins, and Siemens MindSphere are specifically geared towards harnessing the impact of Digital Twins for business process reengineering and

sustainability in oil and gas. DT is a central aspect of Digital Twin Technology (DT) with the creation of a virtual representation of physical assets, real-time monitoring, and predictive analytics for optimizing operations and improving decision-making processes (Brockhoff et al., 2021; Di Salle et al., 2024). Other tools include Business Process Modeling (BPM), which is further used in this aspect for visualizing and analyzing the workflows while facilitating the integration of the Digital Twins in the current business processes. These include Business Process Model and Notation (BPMN), SAP Business Process Management, ARIS Business Process Management, and IBM Business Automation Workflow, all of which play an essential part in improving efficiency and sustainability in the oil and gas sector (Dorrer, 2020; Meza et al., 2024). Such tools boost operational efficiency and facilitate the more optimal strategic alignment of business processes with sustainability goals, creating space for further innovation in the industry (Erhueh et al., 2024; Hanson et al., 2023), as depicted in Figures 1 and 2.

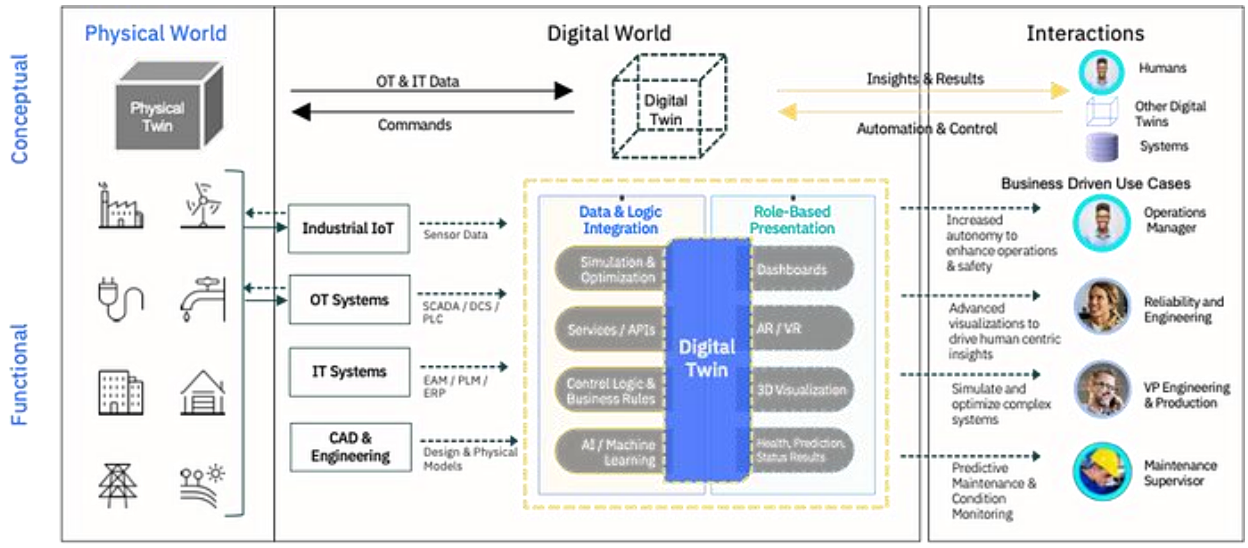

Figure 1: Digital Twin Context

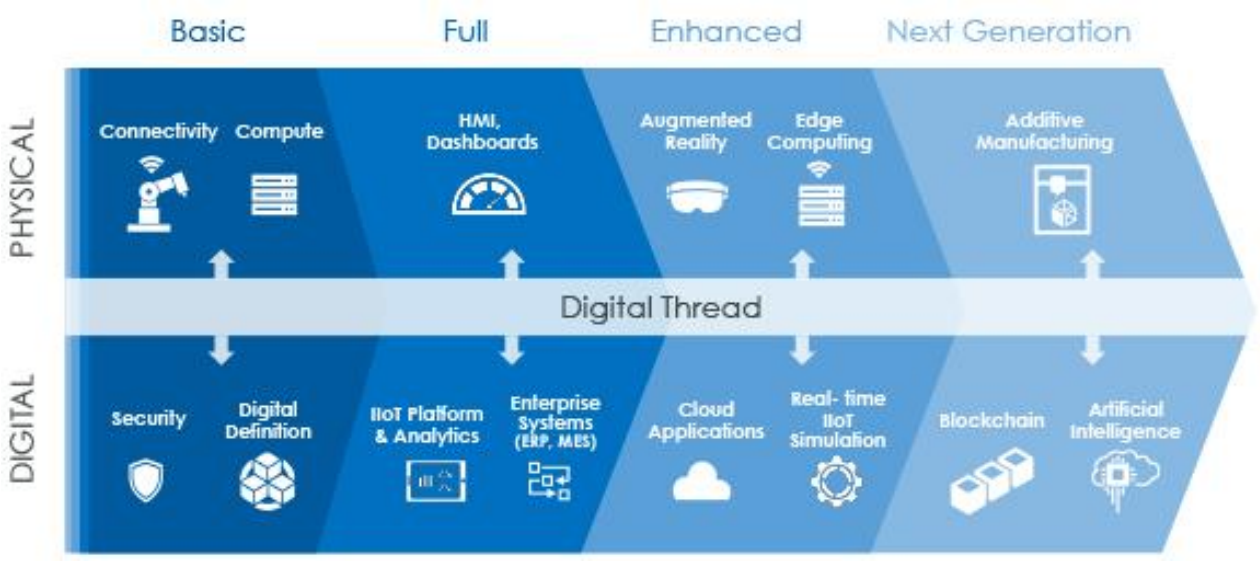

Figure 2: Digital Twin Tools for Business Process Engineering

Many countries across the globe have succeeded in integrating DTs into their oil and gas operations, achieving fabulous results [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. The U.S. has been a frontrunner in the adoption of DTs; examples are Chevron and ExxonMobil, which use this technology to optimize operations and reduce costs [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. According to Chevron, its maintenance cost declines by 20% when applying DTs [Al-Rbeawi, 2023]. Norway's oil and gas industry used DTs to develop a safer and more sustainable environment. Equinor uses DTs to monitor offshore platforms, reducing accidents by 15% and improving the efficiency of monitoring [AlAmir, 2022]. Saudi Aramco has adopted DTs to optimize its supply chain and reduce emissions, which aligns with the country's Vision 2030 for sustainability [Bello, 2021]. The United Kingdom used DTs in the North Sea and reported a 25 percent reduction in unplanned downtime and substantial cost savings [Al-Rbeawi, 2023]. In Chinese oil companies, DTs have increased operation efficiency by up to 30% while improving the performance of oil and gas assets and reducing environmental impacts [Meza et al., 2024]. In India, DTs optimize process operation in refineries, leading to up to 10% energy savings and increased productivity by around 15% [Arinze & Jacks, 2024]. Nigeria remains far from embracing DTs fully; therefore, there is an urgent need for investment and policy support to bridge this gap [Aliyu et al., 2021].

The adoption of Digital Twins in Nigeria's oil and gas industry has adverse effects far beyond the country itself [Haliru, 2024; Ameh, 2024]. Constant breakdowns of equipment and breakdowns have cost the industry billions of dollars in yearly losses [Douglas & Morakinyo, 2023]). Environmental pollution due to oil spills and flaring of gas destroyed ecosystems in the Niger Delta; such pollution resulted in many adverse effects, both on biodiversity and on health within affected communities [Bello, 2021]. The efficiency of the industry has also diminished the competitiveness of Nigeria's oil industry in the global market [Bello, 2021; Douglas & Morakinyo, 2023, adversely affecting GDP [Ameh, 2024]. It has thus become imperative to change how the industry typically revolves [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. Digital Twins, then, would help Nigeria solve its problems, enhance efficiency, and bring about sustainability in its realm of operations [Esiri et al., 2024].

This study is critical for several reasons [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. First, it attempts to modernize Nigeria's oil and gas industry with technological innovations such as Digital Twins. This will improve efficiency, lower costs, and reduce the industry's environmental footprint [AlAmir, 2022]. Second, the study gives Nigeria a global context, outlining how it will fulfill its obligations under the Paris Agreement and the United Nations SDGs [Bello, 2021]. Third, it highlights the transformational potential of DTs in the Business Process Engineering sphere [Douglas & Morakinyo, 2023], providing insights into the reality of how technology can be applied in the uniquely Nigerian context [Abusohyon et al., 2021]. Finally, the study is a yardstick for policymakers and industry heads whose concerns about adopting DTs include finances and expertise [Aliyu et al., 2021]. By proving the merits of DTs with applicable prescriptions, the study sparks the digital transformation of Nigeria's oil and gas sector to become sustainable and competitive globally [Esiri et al., 2024]. Thus, this study sought to harness the impact of Digital Twins on Business Process Engineering and the sustainability of Nigeria's oil and gas industry. Therefore, specifically, this research will provide answers to the following research questions.

Research Questions

i. What are managers' main challenges and opportunities in adopting Digital Twins for business process engineering?
ii. What organizational strategies and policies have managers implemented to facilitate Digital Twins for business process engineering?
iii. What are the implications of widespread Digital Twins for Business Process Engineering on the sustainability of the oil and gas industry in Nigeria?
iv. What are the global best practices in Digital Twins for Business Process Engineering to promote sustainable performance of Nigeria's oil and gas industry?

2. Literature Review

2.1 Business Process Engineering

Business Process Engineering is the strategic method for analyzing, designing, and optimizing business processes to improve an organization's ability to perform [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. It rethinks and redesigns workflows for better efficiency, reduced costs, and greater customer satisfaction [Haliru, 2024; Ameh, 2024]. BPE is chiefly associated with Business Process Reengineering (BPR), which argues for radical change and not incremental improvements [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. Therefore, the objective of BPE is to realize spectacular improvement in critical performance measures, such as quality, speed, and responsiveness to customer needs [Dorrer, 2020].

BPE covers a wide array of techniques and tools, such as process mapping, performance metrics, and most digital technologies that aid in transforming business operations [Haliru, 2024; Ameh, 2024]. Data analytics and automation identification create efficiencies in workflows and best practices. This systematic approach would optimize existing processes and create a culture that fosters continuous organizational improvement [Bickford et al., 2020]. Industry innovation and sustainability are turning integrated advanced technologies, including artificial intelligence and the Digital Twin, into a more significant part of BPE [Arinze et al., 2024], as depicted in Figure 3.

Figure 3: Importance of Business Process Engineering
Source: Križanić & Vrček (2023); Ifalade & Adeleke (2024)

The advantages of Business Process Engineering are vast and many-sided. First, BPE leads to improved operational efficiencies through the optimization of workflows and reduction in cycle times. For example, a manufacturing firm that implemented BPE-it achieved a 30% reduction in product production time, making it highly nimble in responding to customer demands [Brockhoff et al., 2021]. Second, BPE has processed linked benefits that push through for improved customer experience [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. Some customers have indicated increased retention levels and better service experience due to the application of BPE; they can quickly respond to customer needs [Erhueh et al., 2024].

Mainly, Business Process Engineering is an important instrument that organizations should use in increasing their operational level performance and achieving continued growth [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. Countries like America, Germany, and Japan have successfully installed Business Process Engineering schemes, dramatically improving their respective industrial sectors. In the U.S., For example, companies like Ford and General Electric employed BPE to upgrade manufacturing processes, yielding increased productivity and reduced operations costs [Bello, 2021]. Such is the phenomenon that the German automotive industry has put BPE tenets into practice, thus turning around its fortunes due to efficient production. Toyota has famously adopted BPE through lean manufacturing principles as part of Japan's car-making landscape. This created wonders in the automobile industry by reducing waste and maximizing value, thus creating an operational excellence benchmark worldwide [Hanson et al., 2023].

2.2 Digital Twins for Business Process Engineering

Digital Twins (DTs) are virtual representations of objects, systems, or processes with real-time monitoring, simulation, and analysis tools [Haliru, 2024; Ameh, 2024]. DTs can be dynamic models. In Business Process Engineering, they state the current condition of business processes in an organization and allow them to visualize, analyze, and optimize their operations [Esiri et al., 2024]. Incorporating data from multiple sources, including sensors and enterprise systems,

DTs provide business insight into the performance of a process, thus enabling organizations to make informed decisions and realize improvements [Dorrer, 2020]. This technology rapidly spreads across various fields, especially manufacturing, logistics, and oil and gas, since it promotes better processing and optimizes operation [Brockhoff et al., 2021].

The application of Digital Twins in BPE allows organizations to simulate different scenarios and predict outcomes based on various inputs. Specifically, it has helped understand bottlenecks, optimize resource allocation, and improve the overall performance of processes [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. For example, companies in the oil and gas industry have used DT to monitor drilling activities and predict equipment failure, thus minimizing downtime and enhancing safety [Douglas & Morakinyo, 2023]. Rising corporations are integrating digital transformation strategies with DT applications within BPE, thereby increasing the competitive edge and future sustainability [Erhueh et al., 2024].

This functionality is particularly useful in recognizing emergencies in the process regarding the optimization of existing resources and improving overall process performance, such as drilling operations in the oil and gas sector [[Esiri et al., 2024], where companies have deployed DT technology to detect equipment failures, thus reducing downtime while increasing safety during drilling operations [Douglas & Morakinyo, 2023]. For companies' rapidly increasing digital transformation, the growing trend in integrating DTs into BPE frameworks will be pertinent for achieving competitive advantages and driving sustainable growth [Erhueh et al., 2024].

Digital Twins thus present deep and multifaceted advantages in Business Process Engineering [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. First, the operational efficiencies that DTs can bring in real-time visibility of process performance significantly increase such measures dramatically, reducing operational costs while improving productivity in organizations that employ this technology. One area in which organizations have successfully deployed DTs is Manufacturing, such as Siemens, which has been able to post a 20% increase in productivity with good waste reduction through optimization of production lines using DTs [Galli et al., 2019]. The ability to respond speedily to changes in demand and ever-increasing changes in marketing environments would synch the ability and overall agility of the organization in the market, thus leading to increased performance.

Second, Digital Twins achieve better decision-making for organizations by simulating possible scenarios and evaluating the potential results before any change is made [Haliru, 2024; Ameh, 2024]. By such predictability, logistics and supply chain management have significantly benefited. For instance, DHL used DTs to finalize its logistics operations, which resulted in a 15% decrease in delivery time and better customer satisfaction [Di Salle et al., 2024]. More than that, countries such as Germany and Japan that have ended their studies on DT in their different industrial processes have realized great strides in efficiency and sustainability. While the automotive manufacturers in Germany have capitalized on DT technology to facilitate production processes, Japan's Toyota has also embraced DTs for better Lean Manufacturing, creating a standard for operational excellence worldwide [Hanson et al., 2023].

Employees' Perspective of Digital Twins for Business Process Engineering

From the employee's point of view, Digital Twin (DT) technology in Business Process Engineering is exciting and daunting [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. On one side, employees can see the potential of DTs to create a more operationally efficient workplace and improve decision-making. For instance, in industries such as manufacturing and logistics, they have said that DT allows operations to be monitored in real-time, leading to faster responses to issues and resource allocation. In this way, a more dynamic work environment can exist in which employees feel empowered to make knowledgeable decisions from accurate data. Integration with DT can also introduce a new dimension to training and skills development, where employees can step into simulated virtual environments closely resembling real-world scenarios, thus helping them better understand typically complex processes. However, there are also some serious employee concerns regarding adopting DT technology. An increasingly common fear regarding reliance on this highly digital environment is the fear of losing jobs or decreasing job security, particularly in some regions where automation progresses rapidly [Haliru, 2024; Ameh, 2024]. In Europe, examples include concerns of manufacturing sector workers regarding the potential replacement of their jobs by direct labor through DTs, which has raised calls for retraining programs and support for smooth transitions to the next role. Another example is that employees might have difficulty adjusting to the new technology without proper training and guidance. Therefore, resistance to the new changes can impede the smooth implementation of DTs since employees feel either overwhelmed by such technology or skeptical about its value.

Employers' Perspective of Digital Twins for Business Process Engineering

According to employers, Digital Twin technology offers a conservative means for improving business efficiency and competition [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. The argument follows that DTs generate relevant process performance data that have the potential to disclose latent inefficiencies and even optimal workflows [Esiri et al., 2024]. For instance, implementations of DTs have produced cost savings from and/or improved service delivery within supply chains in the U.S. Employers use such real-time and predictive analysis for making decisions that drive innovation and greater productivity. However, employers also face challenges in the integration of DT technology. The initial investment required for implementing DT systems can be substantial, and many organizations may struggle to justify these costs without a clear understanding of the return on investment [Haliru, 2024; Ameh, 2024]. An increase in digital systems increases the likelihood of breaches and interruptions in activity due to increasingly broken national security agencies. Some employers have cited the rapid technological advancement of the Asian region as a barrier to entry due to the difficulty in finding necessary expert skilled labor to manage DT systems. Thus, such an underdeveloped workforce reduces the potential of using DTs and processes in this part of the globe, highlighting the necessity for skilled development training initiatives for the workforce to acquire the competencies.

2.3 Sustainability of the Oil and Gas Industry in Nigeria

The sustainability of the oil and gas industry in Nigeria is a critical concern, given the sector's significant contribution to the national economy and its profound environmental and social impacts [Haliru, 2024; Ameh, 2024]. Nigeria is one of Africa's major oil producers, and today, oil revenues constitute about 90% of the country's foreign exchange earnings and account for roughly 60% of the total revenue of the government. The oil industry has faced some sustainability challenges, especially in the Niger Delta, which has experienced oil spills, gas flaring, and degradation of the environment with significant ecological and health consequences. For example, since the 1970s, over 13 million barrels of oil have been spilled in the Niger Delta, seriously affecting local ecosystems and communities. According to the World Bank, oil spills in the region generate more than $1 billion in annual economic losses because they damage fisheries and agriculture [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. Hence, promoting this industry with sustainable practices is urgently necessary.

Moreover, the sustainability challenges in the Nigerian oil and gas industry are made worse by poor regulatory frameworks and governance issues. Some estimates show that around 60% to 70% of the citizens lack clean and modern energy services, revealing a significant disparity in energy distribution and access. Reliant mainly on fossil fuels, Nigeria faces a challenge in that it has to align with global climate goals. However, it tries to meet the demands of the growing population for a transition toward more sustainable energy usage. Compounding the problems of low investment in renewable energy technologies and infrastructure, it limits the potential of the oil and gas sector to realize sustainable development. These indeed require serious efforts by the Nigerian Government, stakeholders in the industry, and civil society to achieve robust regulatory frameworks for transparency and the first consideration of the people's immediate well-being.

There are a variety of factors that hinder oil and gas sustainability in Nigeria. The first of these is the hefty degradation of the environment due to oil extraction activities, particularly in the Niger Delta. Oil spills, gas flaring, and deforestation harming not just local biodiversity but also the health and livelihoods of communities depending on these ecosystems- have cooperatively turned the situation worse for humanity. The Nigerian National Petroleum Corporation (NNPC) has claimed that gas flaring in the country is about 10% of the world's output because it produces non-potable gas [Esiri et al., 2024]. This gas is then associated with greenhouse gas emissions and deterioration of air quality. Furthermore, exposure to pollution by oil brings with it a host of health problems like respiratory diseases and skin problems. This makes matters worse for local regulated communities.

The absence of good governance and regulatory challenges makes it more difficult to attain sustainability in the oil and gas sector [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. This allowed the industry to continue operating with little accountability by oil companies due to corruption, a lack of transparency, and poor enforcement of environmental regulations; impunity has allowed environmental violations to occur without facing punishment, leaving local communities to suffer adverse impacts from harmful industry practices. Moreover, the conflicts resulting from a lack of effective promotion of community engagement and corporate social responsibility programs have further exacerbated the practice of assertive, sustainable behavior in the oil and gas sector. Addressing all these issues

would require a concerted effort from the Nigerian government, stakeholders in the industry, and civil society, strengthening the regulatory frameworks, assuring transparency, and prioritizing the well-being of affected communities.

2.4 Development of Research Questions

To apply Digital Twin technology and implement it into business process engineering, managers contend with distinct challenges and different opportunities. Some of the primary challenges with Digital Twin technology deployment are the associated integration of legacy systems with the new frameworks for Digital Twin creation, for which there is usually a huge capital outlay needed in the technology and training domains [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. Data silos and legacy systems often detract many businesses from attaining that seamless information flow required for successful Digital Twin implementation [Brockhoff et al., 2021]. Additionally, Digital Twin technology also comes along with a steep learning cost as it takes much time, among others, for employees to learn how to use the tools, leaving employees who are generally apprehensive of adopting new tools resistant to implementing the technology [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. However, Digital Twins take opportunities to a much higher level. They provide enhanced predictive analytics, allowing managers to simulate various scenarios and optimize the processes in real-time. For example, companies in the manufacturing industry could use a Digital Twin to minimize downtime and increase productivity, thereby resulting in considerable savings and gains in productivity [Di Salle et al., 2024]. In light of these challenges, the first pertinent research question emerges

> **Research Question I: What are managers' main challenges and opportunities in adopting Digital Twins for business process engineering**?

Managers and chief executives have formulated different organizational strategies and policies to facilitate the integration of Digital Twins into business process engineering. This includes establishing cross-functional teams with IT, operations, and business analysts as members through which interfacing functions can be implemented to ensure that perspectives are covered during implementation [Dorrer, 2020]. Such teams will make room for a culture of innovation and pool knowledge, which is necessary to clear technical barriers such as those that come with Digital Twin technology. Companies also conduct training programs to ensure that staff members become adept at taking advantage of Digital Twins; specialized training modules are, for instance, developed by oil and gas companies concerning using Digital Twins for asset management and operational efficiency [Esiri et al. 2022]. However, organizations have included such methodologies under agile project management concerning fast iteration and changing the strategy depending on real-time feedback for the effective Digital Twin initiative. In light of these challenges, the second salient research question emerges:

> **Research Question 2: What organizational strategies and policies have managers implemented to facilitate Digital Twins for business process engineering?**

Digital Twins are pivotal in the evolution of business process reengineering processes, with their potential for widespread adoption in Nigeria. Leveraging Digital Twins with real-time data and predictive analytics, companies can streamline operations, reduce waste, and minimize environmental impacts. For instance, the implementation of Digital Twin technology empowers Nigerian oil companies to monitor gas flaring activities more effectively, thereby reducing emissions and ensuring compliance with environmental regulations [Douglas & Morakinyo, 2023]. Furthermore, Digital Twins facilitate efficient resource management, enabling companies to optimize resource allocation and utilization while cutting operational costs [Riss, Maus, Javaid & Jilek, 2020; Lawal & Afolalu, 2024]. This is particularly significant in Nigeria, where the oil and gas sectors play a crucial role in the economy but face sustainability challenges due to environmental degradation and social unrest. In light of these challenges, the third research question becomes crucial: What specific metrics can measure the sustainability impacts of Digital Twin implementations?

> **Research Question 3: What are the implications of widespread Digital Twins for Business Process Engineering for the sustainability of the oil and gas industry? This question is crucial in understanding the potential impact of Digital Twins on the sustainability of the oil and gas industry, making it a topic of significant interest and relevance.**

Several countries that have fully embraced Digital Twin technology for Business Process Engineering serve as excellent examples of best practices that the oil and gas sector in Nigeria can adopt to enhance sustainable performance. For instance, in Germany, companies like Siemens have successfully integrated Digital Twins into their manufacturing processes, leading to significant reductions in energy consumption and waste generation [Galli et al., 2019]. Similarly, firms in the US oil and gas sector have effectively utilized Digital Twins to enhance safety protocols and drilling practices, thereby improving environmental performance and reducing operational risks [Meza et al., 2024]. These international best practices underscore the potential of aligning Digital Twin initiatives with sustainability goals, such as reducing carbon footprints and enhancing community engagement [Arinze, Izionworu, Isong, Daudu & Adefemi, 2024; Aliyu, Ganiyu, Oyefolahan & Djitog, 2021]. By adopting similar approaches, Nigerian oil and gas companies can leverage Digital Twin technology to optimize operational efficiency and contribute more to broader sustainability objectives. In light of these opportunities, the fourth research question arises:

> **Research Question 4: What are the global best practices in Digital Twins for Business Process Engineering to promote sustainable performance?**

2.5 Theoretical Justification

One salient theory relevant to the impact of Digital Twins on Business Process Engineering and sustainability is the Systems Theory, which Ludwig von Bertalanffy notably advanced in the 1960s. This theory holds that a complex system must be seen as a whole instead of broken down into constituent parts; specific emphasis is then accorded to the mutual interdependence of components inside a system. The scope of Digital Twins brings forward the need to integrate different business processes into a coherent whole, which can model real-world interactions and outcomes.

The assumption is that with a sound understanding of the relationships and dynamics within a system, organizations will be better off optimizing their processes. For instance, Brockhoff et al. (2021) demonstrated how Digital Twins predict processes in that managers can be better informed to see inefficiencies and apply improvements from within a holistic view of operations (Brockhoff et al., 2021)]. In this sort of argument, oil and gas industries would benefit the most, seeing their highly complex interaction between equipment, personnel, and environmental factors; such influences can be turned around in sustainability outcomes. Therefore, organizations can use systems theory, integrated Digital Twins, or their operational practice to devise sustainable practices considering their operations' broader impact.

Another pertinent theory is the Resource-Based View (RBV), which Jay Barney popularized in the early 1990s. This theory argues that a firm's competitive advantage is a function of its unique resources and capabilities, which can be used for superior performance. The RBV links to Digital Twins in that it implies that an organization that has adopted Digital Twin technology would further improve its operational capacities, leading to lower costs or enhanced sustainability. For instance, Di Salle et al. (2024) describe the potential of Digital Twins in optimizing waste management activities since they provide real-time data and insights that can assist organizations in curbing waste and optimizing resource use [Di Salle et al., 2024]. Such a theory is most pertinent for Nigeria's oil and gas industry, in which resource management is essential for economic viability and environmental sustainability. Technology such as Digital Twins will allow companies to improve resource management, reduce operational costs, and reduce environmental footprints to align with sustainability ideals. In this regard, the RBV sheds light on future strategic importance among the corporate. While Digital Twins make it a critical resource that could bring about business practices, it emphasizes sustainability.

3. Methods and Materials

3.1 Research Philosophy

Interpretivism is a research methodology employed to look at the impact of Digital Twins on Business Process Engineering and the sustainability of Nigeria's oil and gas industries. This approach aligns with the intricate nature of human behavior and the individual ideas related to the perceived issues associated with the impact of Digital Twins on Business Process Engineering and sustainability of Nigeria's oil and gas industry. This philosophical view accepts that there are standards regarding strategies and concerns related to Digital Twins for Business Process Engineering and sustainability of the oil and gas industry. This also allows the extraction of primary and secondary sources, including emails, scribbles, annual reports, newspapers, web content, etc., to ease understanding. In other situations, interpretivism includes the theory of a study and its appreciation of the context of the study specific to Africa (Saunders & Bezzina, 2015). This approach seeks to understand a particular context critical to interpreting the gathered data, contrary to the previous ones where the opposite was done, especially for the founders of positivism. This approach aided in evaluating the strategies, challenges, and risks of Digital Twins for Business Process Engineering and sustainability of Nigeria's oil and gas industry.

3.2 Research Approaches:

The study adopted an inductive approach. This means there is an organized and step-by-step procedure for interpreting the research data. Each stage builds upon the other, enabling a complete comprehension of the available data. For instance, this technique helped lay out the results of the research study in a logical and orderly manner. Everything explained above is the process one goes through until one understands all the information gained. Besides aiding in the completeness of the cross-interpretation of data, findings, and discussions in the several studies used in this study, the systematic and organized method also improved the consistency of the results, making them replicable. More precisely, this approach soberly and systematically presents the method, analysis, and findings addressing the issue. One can trust systematic reports as they are painstaking, workable, and honest. The use of a meta-analysis approach complimented this. The thorough review clarified that the meta-analysis was essential for this study because it combined findings from 25 relevant empirical studies. This approach gave a clearer picture of the various challenges and opportunities Digital Twins faces in Business Process Engineering and sustainability of the oil and gas industry. By bringing together data from different sources, the meta-analysis strengthened the reliability of the conclusions and revealed patterns and insights that might have been missed in prior studies.

3.3 Literature Search Strategy

In discussing the research methodology, it is pertinent to mention that there has been a clear and considerable effort to identify all available and appropriate academic literature and other sources related in one way or another to the strategies, challenges, and impact of Digital Twins for Business Process Engineering and sustainability of oil and gas industry in Nigeria (Lê & Schmid, 2022). Searches of various online databases involve phrases like “Digital Twins in the oil and gas industry,” “Business Process Engineering with Digital Twins,” “sustainability challenges in the oil and gas sector,” “Impact of Digital Twins on operational efficiency,” “Digital Twin technology for waste management in oil and gas,” “predictive maintenance using Digital Twins in Nigeria,” “digital transformation in Nigeria's oil and gas industry,” “benefits of Digital Twins for sustainability in oil and gas,” “case studies of Digital Twins in oil and gas operations,” “Digital Twins and environmental impact assessment in Nigeria,” “strategies for implementing Digital Twins,” “role of Digital Twins in enhancing safety in oil and gas,” “Digital Twins for asset management in Nigeria's oil sector,” “future trends of Digital Twins” and “policy implications of Digital Twins for sustainable practices.”

Also, there is a comprehensive manual search of the relevant journals and reference lists. Therefore, only recent empirical and theoretical publications were included because they offered up-to-date information on the subject matter. Regarding the inclusion and exclusion criteria, it turned out that 66 publications were first assessed concerning the topic. Following filtration processes and assessment of meta-analysis results, 25 publications addressed the strategies, challenges, and impact of Digital Twins for Business Process Engineering and sustainability of the oil and gas industry were retrieved for review assessment.

Table 1: A 10-Year - Inclusion and Exclusion Criteria

Year under review	**2014 -2024**

Search Terms	Boolean operators (AND, OR) combine these phrases to produce search strings for databases such as Google Scholar, DOAJ, CPCI, and Scopus. The requirements of each database and the study's emphasis were considered while adjusting the search technique. Among the search phrases are: "Digital Twins in the oil and gas industry," "Business Process Engineering with Digital Twins," "sustainability challenges in the oil and gas sector," "Impact of Digital Twins on operational efficiency," "Digital Twin technology for waste management in oil and gas," "predictive maintenance using Digital Twins in Nigeria," "digital transformation in Nigeria's oil and gas industry," "benefits of Digital Twins for sustainability in oil and gas," "case studies of Digital Twins in oil and gas operations," "Digital Twins and environmental impact assessment in Nigeria," "strategies for implementing Digital Twins," "role of Digital Twins in enhancing safety in oil and gas," "Digital Twins for asset management in Nigeria's oil sector," "future trends of Digital Twins" and "policy implications of Digital Twins for sustainable practices."
Sample journals	▪ Journal of Upstream Oil and Gas Technology ▪ Processes ▪ Open Access Research Journal of Engineering and Technology ▪ Engineering Science & Technology Journal ▪ Systems Engineering ▪ Baze University Journal of Entrepreneurship and Interdisciplinary Studies ▪ Global Journal of Research in Science and Technology ▪ Engineering Science & Technology Journal ▪ Global Journal of Advanced Research and Reviews ▪ Journal of Intelligent Manufacturing ▪ Journal of Organization Design ▪ Sensors ▪ Computers & Chemical Engineering ▪ Business & information systems engineering ▪ Journal of Artificial Intelligence, Machine Learning and Data Science ▪ Sustainability ▪ Journal of Management and Operations ▪ Journal of Management Studies ▪ Journal of Management & Organization ▪ Organizational Dynamics ▪ Journal of International Management ▪ International Journal of Business and Management ▪ Global Strategy Journal
Inclusion	Studies that specifically discussed the application of Digital Twin technology in Nigeria's oil and gas industry will be included for reference from the local perspective. Research highlighting the advantages of Digital Twins for Business Process Engineering and sustainability, such as predictive maintenance, increased operational efficiency, etc., will also be included to justify the topic. It would include publications with case studies or real-world empirical examples of Digital Twin implementation in the oil and gas industry, showing practical results through experience on both sides. Sources dealing with how Digital Twins fit within the extended technology stack, such as what will need to connect with IoT and data analytics, would also include an exploration of the tech framework needed for functions of successful implementation.

Exclusion	Studies focusing on Digital Twin applications outside the oil and gas industry will be excluded to maintain a specific focus on the relevant sector. Publications that do not provide empirical data or case studies related to Nigeria's oil and gas industry will be excluded to ensure the inclusion of evidence-based insights. Articles that discuss Digital Twin technology in a purely theoretical context without practical implications or applications will be excluded to prioritize actionable information. Sources that are outdated or published before 2014 will be excluded to ensure that the information reflects the most current advancements and trends in Digital Twin technology.
Database	Google Scholar, DOAJ, CPCI, Scopus, etc
Publication	Publications in Africa

The selected journals and papers are crucial for this study as they provide specialized insights into applying Digital Twins and Business Process Engineering within the oil and gas sector. For instance, the *Journal of Organization Design* discusses the implications of Digital Twins for organizational structure, which is essential for understanding how these technologies can enhance operational efficiency (Lyytinen et al., 2023). Additionally, the *Sensors* journal offers in-depth analyses of tools and technologies specifically tailored for the oil and gas industry, ensuring that the study is grounded in the latest empirical research (Meza et al., 2024; Prackwieser, 2024). Furthermore, the *Computers & Chemical Engineering* journal presents frameworks for optimizing supply chain processes, which is vital for effectively integrating Digital Twins into business operations (Perez et al., 2022).

After applying inclusion and exclusion criteria, 25 of the original 66 publications and relevant articles were retained to assess the strategies, challenges, and impact of Digital Twins for Business Process Engineering and sustainability of the oil and gas industry in Nigeria. The number of findings and the studies recorded and extracted using the meta-analysis approach are shown in the flowchart of the systematic overview, which is based on the PRISMA criteria (see Figure 1).

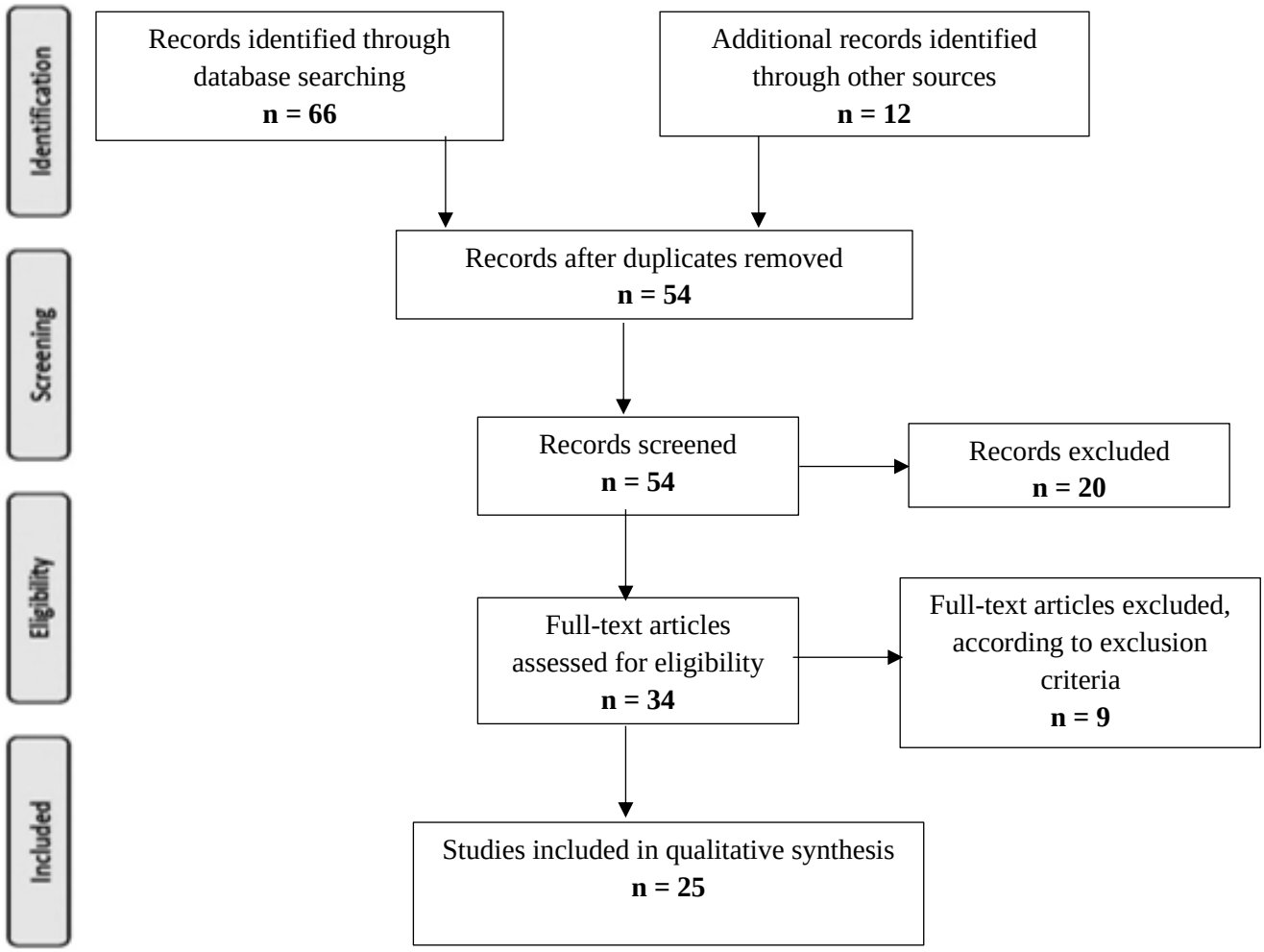

Figure 1: Systematic review flow diagram based on PRISMA guidelines

Only articles/journals indexed in reputable printing companies, such as Sage Publications, Elsevier Publication, Inderscience Publishing, Springer, Allied Academies Publishing, Academy of Management Publishers, Scopus/WoS, Google Scholar, and Taylor & Francis Publications, were selected for this study, as shown in Table 2

Table 2: No of Selected Publications

SN	Publisher	No of Papers Assessed for Eligibility [N=66]	No of Papers Selected for Qualitative Synthesis [N=25]
1	Sage Publications	7	2
2	Elsevier Publications	10	5
3	Google scholars	31	11
4	Taylor & Francis Publications	8	3
5	Scopus/Springer Nature	10	4
Total		66	25

3.4 Techniques and Procedures

The study used a purposeful selection of articles to harness the impact of Digital Twins for Business Process Engineering and sustainability of Nigeria's oil and gas industry, as it is more precise in achieving the study's objective. Specifically, purposive selection was adopted by the researcher to ensure that only pertinent and significant materials are included in this work. The authors supported this methodological choice to enhance the rigor of research and, thus, limited the review to the articles that addressed the remote working issues in Nigeria in depth. This study provides the researcher with a framework of qualitative data collection to assess the complexities and implications of Digital Twins for Business Process Engineering and sustainability of Nigeria's oil and gas industry.

3.5 Analysis and Synthesis

This research focuses on the impact of Digital Twins on Business Process Engineering and the sustainability of Nigeria's oil and gas industry. The analysis focused on manual thematic analysis because of its flexibility, systematization, and appropriateness to qualitative research. In this approach, the text material is searched for patterns, themes, and categories through a thorough and iterative process of coding and interpretation. (Braun & Clarke, 2006). The initial phase involves systematically coding data collected from case studies, interviews, and/or written materials. These codes encapsulate central issues that are relevant to specific themes. The manual thematic analysis is helpful for this study since it considers a broader scope concerning the risk interventions regarding the impact of Digital Twins on Business Process Engineering and sustainability of Nigeria's oil and gas industry (Lê & Schmid, 2022). Also, by doing everything manually, the researcher can maintain the richness and multitude of the participants' understanding and experiences concerning the strategies, challenges, and impact of Digital Twins for Business Process Engineering and sustainability of the oil and gas industry in Nigeria. This is in line with the interpretive form of the method.

4. Analysis and Discussions Based on the Research Objectives

This section presents and discusses the assessment of the impact of Digital Twins on Business Process Engineering and sustainability of the oil and gas industry in Nigeria. The themes were identified in this chapter and are critically examined through empirical studies, providing a comprehensive understanding of their implications and relevance in the industry context. The analysis was done based on the four (4) research objectives formulated for this study:

4.1 Discussions on Research Objective 1: What are the main challenges and opportunities managers face in adopting Digital Twins for Business Process Engineering within the context of the Oil and Gas industry?

The adoption of Digital Twins would undoubtedly face myriad challenges and offer several benefits to managers in the oil and gas industries in Nigeria regarding business process engineering. Therefore, a systematic literature search was conducted in several databases to identify relevant studies using keywords like "Digital Twin challenges," "adoption opportunities," "oil gas management," "process engineering," and "technology integration." Studies were included solely based on the criteria of conducting empirical research within the specified geographic region: the result of the extensive review. As a result of the exhaustive review, the meta-analysis was crucial for this study as it allowed for the comprehensive synthesis of findings from 20 relevant studies. The use of meta-analysis provided a robust understanding of the complex challenges and opportunities managers face when adopting Digital Twins for Business

Process Engineering within the context of the oil and gas industry in Nigeria. By aggregating data from multiple sources, the meta-analysis enhanced the conclusions' reliability and highlighted patterns and insights that individual studies may have overlooked (See Table 3).

Table 3: Themes on the main challenges and opportunities faced by managers in adopting Digital Twins for Business Process Engineering in the Oil and Gas industry (N=20)

SN	Themes	Number of articles in which the theme has appeared	Importance Rank
A. Challenges in adopting Digital Twins for business process engineering			
1	Data Integration Issues	14	2
2	Change Resistance	10	4
3	High Implementation Costs	16	1
4	Skill Shortages	13	3
5	Cybersecurity Risks	7	5
B. Opportunities of adopting Digital Twins for business process engineering			
1	Process Optimization	13	2
2	Enhanced Decision-Making	15	1
3	Competitive Advantage	7	5
4	Sustainability Improvements	10	3
5	Predictive Maintenance	8	4

Note: 'n' means the number of papers reviewed

The analysis reflected in Table 3 identified significant challenges and opportunities facing a manager while adopting a Digital Twin transformation of Business Process Engineering activities in the oil and gas industry. The findings reveal that implementation costs are considerations (ranked first), and data integration comes next (ranked second). These two challenges greatly emphasize managers' need to develop strategic financial planning and robust integrating frameworks for adopting this technology. The skills and change resistance further suggest that managerial training and change management will be attributed factors to internal barriers. On the opportunity side, enhanced decision-making is number one, and process optimization is number two, showing that managers who manage Digital Twins effectively can realize higher operational efficiency and better make decisions that drive performance. The challenge and opportunity findings regarding adopting Digital Twins for Business Process Engineering in oil and gas management corroborate the assertions of Bello (2021), who emphasized digitalization as a cure for operational inefficiencies in the oil and gas sector. It also coincided with the research by Ameh (2024), whereby the emphasis had been on capability-in-resilience supply chain management as the important factor for successfully implementing emerging technologies. This merged viewpoint would support the call for a proactive approach to managing challenges while taking advantage of Digital Twins's implicit promises for the future of operational excellence and sustainability in oil and gas.

4.2 Discussions on Research Objective 2: What organizational strategies and policies have managers implemented to facilitate Digital Twins for business process engineering?

This research question aims to determine the organizational strategies and policies managers implemented to facilitate Digital Twins for business process engineering. A systematic literature search was conducted across various databases using appropriate keyword collection and search strategies. The search terms for achieving this objective include: "Digital Twin implementation strategies," "business process policies," "change management frameworks," "technology adoption roadmap," "training and development programs," "data governance policies," "cross-functional collaboration," "risk management strategies." After a thorough review, 23 relevant studies were included in the meta-analysis. This meta-analysis purposively reviewed twenty-three (23) papers and identified the multifaceted organizational strategies and policies put in place or implemented by managers to facilitate Digital Twins for Business Process Engineering (See Table 4).

Table 4: Themes on the organizational strategies and policies implemented by managers to facilitate Digital Twins for Business Process Engineering (N=23)

SN	Themes	Number of articles in which the theme has appeared	Importance Rank
1	Technology Infrastructure Investment	**15**	4
2	Change Management Strategies	21	1
3	Training and Skill Development	19	2
4	Cross-Departmental Collaboration	11	5
5	Performance Measurement Frameworks	6	7
6	Risk Assessment and Mitigation	10	6
7	Data Integration Policies	16	3

Note: 'n' means the number of papers reviewed

The analysis in Table 4 reveals key themes regarding the organizational strategies and policies that managers have implemented to facilitate the adoption of Digital Twins for Business Process Engineering in the oil and gas industry. Change management strategies emerge as the most critical theme (ranked 1), indicating that effectively managing the transition to Digital Twin technology is essential for success. Equally important- and most important- is Training and Skills Development (Rank 2), which underscores the need to equip employees with technology skills. Data integration policy ranks closely at number 3, making the compatibility and harmonization of disparate data sources possible for building a reliable Digital Twin. Lower-ranked themes like cross-department diversity (rank 5) and risk assessment and mitigation (rank 6) imply that while they are important, they may not be prioritized as highly as the foundational strategies. Study insights into the organizational strategies and policies enacted by managers to facilitate Digital Twins are well aligned with those of Esiri et al. (2024), who approach policy requirements and implementation strategies as key components of successful adoption of Digital Twin technology. The finding also confirms Arinze and Jacks's

(2024) assertion to integrate artificial intelligence and digital tools to enhance operational efficiency and safety in oil and gas operations. Overall, managerial implications were obvious as incorporating successful transformation change management, sound training, and data integration would yield maximum return in Digital Twins' implementations in efficiency and innovation within the oil and gas sector.

4.3 Discussions on Research Objective 3: What are the implications of widespread Digital Twins for Business Process Engineering on Nigeria's sustainability oil and gas industry?

This research question aims to determine the implications of widespread Digital Twins for Business Process Engineering in Nigeria's sustainability oil and gas industry. An attempt was made to identify scholarly articles published in different journals available in different databases using keyword and search terms. The papers were included based on the following criteria: all collected papers were regarded as empirical studies conducted in the given context. An initial search yielded seventeen (17) articles, with fifteen (15) related to the meta-analysis properly. Reviews for this objective entailed fifteen (15) papers, and the following meta-analysis findings henceforth assessed the implications of widespread Digital Twins for Business Process Engineering on Nigeria's sustainability oil and gas industry (See Table 5).

Table 5: Themes on the implications of widespread Digital Twins for Business Process Engineering on the sustainability oil and gas industry in Nigeria (N=18)

SN	Themes	Number of articles in which the theme has appeared	Importance Rank
1	Improved Safety Protocols	10	4
2	Long-term Asset Sustainability	5	7
3	Enhanced Resource Management	13	2
4	Cost Savings through Efficiency	12	3
5	Facilitation of Regulatory Compliance	8	5
6	Reduced Environmental Impact	16	1
7	Support for Renewable Energy Integration	6	6

Note: 'n' means number of papers reviewed

The findings presented in Table 5 highlight significant implications of widespread Digital Twins for Business Process Engineering in the sustainability of the oil and gas industry in Nigeria. The most critical theme, reduced environmental impact (ranked 1), underscores the potential for Digital Twins to significantly lower emissions and enhance eco-friendly practices, which is vital for addressing environmental concerns in the industry. Based on the findings, enhanced resource management (ranked 2) indicates that Digital Twins can optimize resource utilization, leading to more sustainable operations. The emphasis on cost savings through efficiency (ranked 3) implies that Digital Twins would not only increase the returns on sales but also free up some resources for sustainable programs. Highlighting the importance of improved safety protocols (which is ranked 4), Digital Twins also play an essential role in making

workplaces safer, which is thus highly crucial in facilitating the execution of sustainable operations. Low ranking in case of this category is indicated by themes such as long-term asset sustainability, ranked 7, and support for renewable energy integration, ranked 6. Nevertheless, the themes reflect the broad greater potential that Digital Twins have in contributing towards a more sustainable future. The widespread adoption of Digital Twins for Business Process Engineering impacts the oil and gas industry's sustainability in Nigeria. These findings support those of Douglas and Morakinyo (2023) regarding the role of digital technology in facilities management in reducing environmental impacts. In addition, it aligns with insights from Fornari et al. (2024), who advocate digitization of practices incorporating Digital Twins into the traditional industries. All of these suggest that the adoption of Digital Twins promotes sustainability practice advancement within Nigeria's oil and gas sector while striking a balance between operational efficiency and environmental stewardship.

4.4 Discussions on Research Objective 4: What are the global best practices in Digital Twins for Business Process Engineering to promote sustainable performance of oil and gas industry in Nigeria?

This research question aims at identifying the global best practices in Digital Twins for Business Process Engineering to promote sustainable performance of oil and gas industry in Nigeria. The study employed random searches on several databases and a subject-issued list of the keywords and search terms were used. Criteria used to identify required studies for review included subject area and type of research that have to be conducted in the given context. From scanning decade of literature, finally, a total of twenty (20) empirical studies including the meta-analysis studies were incorporated. For this objective of the study, twenty (21) papers were considered and the conclusion of this meta-analysis reveals the global best practices in Digital Twins for Business Process Engineering to promote sustainable performance of oil and gas industry in Nigeria as shown on Table 6 below.

Table 6: Themes on the global best practices in Digital Twins for Business Process Engineering to promote sustainable performance of oil and gas industry in Nigeria (N=20)

SN	Themes	Number of articles in which the theme has appeared	Importance Rank
1	Collaboration Across Stakeholders	8	5
3	Real-time Monitoring and Analytics	17	1
4	Data-Driven Decision Making	10	4
5	Integration of Renewable Energy Sources	14	2
6	Standardization and Governance Frameworks	12	3

The findings in Table 6 highlight critical global best practices in the implementation of Digital Twins for Business Process Engineering aimed at promoting sustainable performance in Nigeria's oil and gas industry. The most prominent theme, real-time monitoring and analytics (ranked 1), emphasizes the necessity of leveraging real-time data to enhance operational efficiency and sustainability. With a close proximity, the integration of renewable energy sources, ranked 2nd, denotes increased consideration and recognition of the importance of introducing such

sustainable energy solutions to the conventional oil and gas ways of operation. Data-driven decision making, ranked 4th, further underscores the importance of using data analytics to give strategic choices towards sustainability. The standardization and governance frameworks theme, ranked 3, suggests that clear guidelines and standards are essential for success in Digital Twins implementation. Lastly, collaboration across stakeholders, ranked fifth, stresses the necessity for synergies and all forms of relationships across subcontractors in realizing the benefits from the Digital Twin technologies.

The identification of global best practices in Digital Twins for Business Process Engineering to promote sustainable performance in Nigeria's oil and gas industry contributes to the existing literature by providing a framework for effective implementation. The findings resonate with the works of Lim et al. (2020), who emphasise the application of state-of-the-art techniques in Digital Twin adoption. Such an endeavor further complements Križanić's and Vrček's (2023) research on business process modeling toward maximizing the benefits of Digital Twin technology. Overall, this means that by implementing such best practices, it is possible to actually deliver very healthy benefits toward increased sustainability within the oil and gas sector in Nigeria.

5. Conclusion and Policy Recommendations

In conclusion, this research study on leveraging the potential of Digital Twins for engineering business processes and sustainability has great potential for advancing operational efficiency in Nigeria's oil and gas industry, and environmental stewardship. The study shows that the implementation of Digital Twin technologies would have better safety measures, lower environmental impacts, and better resource management. Such new findings complement the existing body of knowledge by offering immersive insights into how Digital Twins can be transformative tools in the oil and gas sector, especially in developing countries like Nigeria, where sustainability challenges are most eminent.

A recommended strategy for harnessing the impact of Digital Twins in the oil and gas industry in Nigeria is the Integrated Digital Twin Framework (IDTF). This framework focuses on creating a cohesive Digital Twin ecosystem that integrates real-time data from exploration, production, and supply chain processes to enhance operational efficiency and sustainability. Implementation can be achieved through partnerships with technology providers to develop customized Digital Twin solutions, alongside comprehensive training programs for employees to ensure effective utilization of the technology. The implications of adopting the IDTF include improved decision-making capabilities, reduced operational costs, and a significant decrease in environmental impact.

To effectively strengthen the Digital Twin benefits across certain main players like government agencies, oil and gas companies, technology providers, and regulatory bodies, important steps should be taken into policy recommendations. More specifically, such regulatory framework development should encourage investments in Digital Twin technologies by the government while ensuring environmental standard compliance. Oil and gas companies should work towards skills development and training for their employees- to maximize the potential offered by-superior Digital Twin technology. Last but not least, they'll enhance the user experience of their systems for real-

time monitoring and data integration by helping companies make better decisions aligned with environmental and social goals.

These results, in fact, have far-reaching implications for not only improving the operational performance of the oil and gas sector but also creating a viable future for Nigeria as a whole. Digital Twin technology can encourage stakeholders to substantially improve their efficiency and safety while minimizing their environmental footprints. In summary, introducing such advanced technologies into the traditional industries emphasizes the need for a more sustainable oil and gas sector to act as a safeguard against the looming challenges of the 21st century.

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