



Role of entrepreneurs in driving blockchain in the fourth industrial revolution

Onyeka Chrisanctus Ofodile ^{1, *}, Adeoluwa Omoyemi Yekeen ², Ngodoo Joy Sam-Bulya ³ and Chikezie PaulMikki Ewim ⁴

¹ *Sanctus Maris Concepts Ltd.*

² *Independent Researcher, Clarksville, Tennessee, USA.*

³ *Independent Researcher, Abuja, Nigeria.*

⁴ *Independent Researcher, Lagos, Nigeria.*

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Abstract

The Fourth Industrial Revolution (4IR) is characterized by the integration of advanced technologies, such as artificial intelligence, IoT, and blockchain, transforming various sectors globally. This paper explores the crucial role of entrepreneurs in driving the adoption and innovation of blockchain technology within the context of 4IR. Entrepreneurs serve as key catalysts for change, leveraging blockchain's decentralized nature to enhance transparency, security, and efficiency across industries. The potential of blockchain extends beyond cryptocurrency; it offers innovative solutions in supply chain management, healthcare, finance, and governance. Entrepreneurs are at the forefront of developing blockchain applications that address pressing challenges, such as fraud, data security, and operational inefficiencies. By creating decentralized applications (dApps) and smart contracts, they facilitate trust and accountability, fostering a collaborative economy that is essential in the digital age. However, the successful implementation of blockchain technology faces several challenges, including regulatory uncertainties, scalability issues, and a lack of public understanding. Entrepreneurs play a pivotal role in navigating these challenges by advocating for supportive policies, educating stakeholders, and driving research and development. Their ability to identify market needs and develop tailored blockchain solutions positions them as key players in the evolution of industries during 4IR. Furthermore, this paper discusses case studies highlighting successful entrepreneurial ventures that have effectively utilized blockchain technology to disrupt traditional business models and create new market opportunities. These examples illustrate the transformative impact of entrepreneurial innovation on enhancing operational efficiency and driving sustainable business practices. In conclusion, entrepreneurs are essential in harnessing blockchain technology's potential, enabling organizations to thrive in the dynamic landscape of 4IR. Their innovative approaches not only drive technological advancement but also contribute to creating a more inclusive and transparent economy. The findings emphasize the need for continued support and collaboration between entrepreneurs, governments, and industry stakeholders to fully realize blockchain's benefits in the 4IR context.

Keywords: Entrepreneurship; Blockchain; Fourth Industrial Revolution; Innovation; Decentralization; Technology Adoption

1. Introduction

The Fourth Industrial Revolution (4IR) marks a transformative era characterized by the fusion of advanced technologies, leading to unprecedented changes in the way industries operate and society functions. Defined by the integration of digital, biological, and physical systems, 4IR encompasses innovations such as artificial intelligence (AI), the Internet of Things (IoT), and blockchain technology, all of which reshape traditional business models and societal interactions (Schwab, 2016). Among these innovations, blockchain stands out as a revolutionary technology that offers enhanced security, transparency, and efficiency across various sectors, fundamentally altering how transactions are conducted and data is managed. By enabling decentralized and tamper-proof systems, blockchain has the potential to

* Corresponding author: Onyeka Chrisanctus Ofodile

disrupt industries ranging from finance and supply chain management to healthcare and beyond (Marr, 2018; Tapscott & Tapscott, 2016).

Entrepreneurship plays a crucial role in driving technological advancements within this context. Entrepreneurs are often at the forefront of innovation, identifying gaps in the market and developing solutions that leverage emerging technologies like blockchain. They not only contribute to the economic growth of their regions but also foster a culture of creativity and resilience, which is vital for navigating the complexities of 4IR (Dyer et al., 2019). By embracing blockchain, entrepreneurs can create new business models that enhance value creation and streamline operations, thus positioning themselves as key players in the global economy. The dynamic nature of entrepreneurship, coupled with blockchain's transformative capabilities, presents unique opportunities for growth and disruption across various industries (Bharadwaj et al., 2013; Ismail et al., 2019).

This study aims to explore the significant role of entrepreneurs in driving the adoption and implementation of blockchain technology within the framework of the Fourth Industrial Revolution. By examining case studies of successful entrepreneurial ventures that have harnessed blockchain, the research will highlight best practices, challenges, and the overall impact of entrepreneurial initiatives on the advancement of this technology. Additionally, the study will address the broader implications of blockchain-driven entrepreneurship for economic development and innovation, providing insights into how these synergies can shape the future of various sectors in a rapidly evolving technological landscape. Ultimately, this research seeks to contribute to the understanding of the interplay between entrepreneurship and blockchain, offering valuable perspectives for policymakers, business leaders, and aspiring entrepreneurs alike.

2. Understanding Blockchain Technology

Understanding blockchain technology is essential for grasping its transformative potential in the context of the Fourth Industrial Revolution (4IR) and the role of entrepreneurs in driving its adoption. Blockchain can be defined as a distributed ledger technology that enables secure, transparent, and tamper-proof transactions across various applications. Its key features—decentralization, transparency, and security—distinguish it from traditional databases and record-keeping systems (Weldetsion, 2023). Decentralization refers to the elimination of a central authority, allowing participants in the network to have equal control and access to the data (Nakamoto, 2008). This characteristic not only enhances the efficiency of transactions but also reduces the risks associated with centralized control, such as fraud and data manipulation.

Transparency is another pivotal aspect of blockchain technology. Every transaction on the blockchain is recorded in a public ledger that can be accessed and verified by all participants in the network. This openness fosters trust among users, as any unauthorized changes to the transaction history are immediately detectable (Crosman, 2017). Furthermore, blockchain employs cryptographic techniques to secure data, ensuring that only authorized parties can access or modify information. Each block in the chain contains a cryptographic hash of the previous block, creating an immutable record that enhances the integrity of the data (Kouadio et al., 2019).

The evolution of blockchain technology can be traced back to the introduction of Bitcoin in 2009 by an anonymous entity known as Satoshi Nakamoto. Initially conceived as a digital currency, the underlying blockchain technology has since expanded beyond cryptocurrencies to encompass a wide array of applications across various sectors (Păvăloaia & Necula, 2023). As the technology has matured, numerous iterations and improvements have emerged, leading to the development of blockchain platforms that support smart contracts, decentralized applications (dApps), and consensus mechanisms such as proof of stake and proof of work (Catalini & Gans, 2016). These advancements have paved the way for the emergence of new business models and entrepreneurial opportunities.

In finance, blockchain technology has the potential to revolutionize the way transactions are conducted and recorded. It allows for faster, more secure cross-border payments and reduces the costs associated with intermediaries, such as banks and payment processors. For instance, Ripple's blockchain platform enables real-time international transactions with minimal fees, positioning it as a viable alternative to traditional banking systems (Makhdoom et al., 2019). Additionally, the emergence of decentralized finance (DeFi) applications has created opportunities for entrepreneurs to develop innovative financial products and services, such as lending platforms and decentralized exchanges, that challenge traditional financial institutions.

Supply chain management is another sector that has embraced blockchain technology, significantly enhancing transparency and traceability. By utilizing blockchain, companies can track products throughout the supply chain, from production to delivery. This capability not only minimizes the risk of fraud but also helps in ensuring compliance with

regulatory standards and improving overall efficiency (Kamble et al., 2019). For example, IBM's Food Trust blockchain platform allows retailers and consumers to trace the origin of food products, providing crucial information that enhances food safety and reduces waste. Entrepreneurs can leverage these capabilities to create innovative solutions that optimize supply chain operations and build trust among stakeholders.

In healthcare, blockchain technology offers transformative potential by enabling secure sharing of medical records while maintaining patient privacy. With blockchain, patients can have control over their health data and grant access to healthcare providers as needed. This decentralized approach facilitates interoperability among healthcare systems, improving care coordination and patient outcomes (Zhang et al., 2018). For instance, startups such as Solve.Care are developing blockchain-based platforms that streamline patient management, appointment scheduling, and medication tracking, showcasing the significant entrepreneurial opportunities within the healthcare sector.

Public administration is also beginning to harness the benefits of blockchain technology. Governments can utilize blockchain to enhance transparency and accountability in public services, such as voting and land registration (Grey, 2023). By implementing blockchain-based voting systems, governments can reduce the risks of fraud and ensure that election results are accurate and verifiable (Gikonyo, 2019). Entrepreneurs have the potential to develop innovative solutions that improve public sector efficiency and citizen engagement through blockchain-based platforms, creating opportunities for social impact while driving economic growth.

As blockchain technology continues to evolve, its applications are expanding across various sectors, and entrepreneurs play a vital role in driving its adoption. By recognizing the unique features and benefits of blockchain, entrepreneurs can identify opportunities for innovation and create solutions that address existing challenges in their respective industries (Aamer, 2023). The interplay between blockchain technology and entrepreneurship is particularly significant in the context of 4IR, where traditional business models are being disrupted, and new opportunities are emerging.

In summary, understanding blockchain technology is essential for recognizing its transformative potential in the Fourth Industrial Revolution. Its key features—decentralization, transparency, and security—distinguish it from traditional systems and create opportunities for innovation across various sectors. As the technology evolves, its applications in finance, supply chain management, healthcare, and public administration highlight the importance of entrepreneurship in driving blockchain adoption (Allioui & Mourdi, 2023). By harnessing the power of blockchain, entrepreneurs can develop innovative solutions that address pressing challenges, thereby contributing to economic growth and societal advancement.

3. The Role of Entrepreneurs in Driving Blockchain Adoption

The role of entrepreneurs in driving blockchain adoption during the Fourth Industrial Revolution (4IR) is pivotal, as they navigate the complex landscape of emerging technologies and harness them to address contemporary challenges. Entrepreneurs are uniquely positioned to identify market needs and opportunities that traditional businesses might overlook (Aamer, Eka Yani & Alan Priyatna, 2020, Zeufack, et al., 2021). They possess the agility to adapt quickly to changing environments and leverage technological advancements to create innovative solutions. In the context of blockchain technology, this adaptability enables entrepreneurs to spot gaps in various industries and design applications that can enhance efficiency, transparency, and security.

Identifying market needs and opportunities is the first crucial step for entrepreneurs in adopting blockchain technology. The decentralized nature of blockchain creates new avenues for addressing long-standing issues in sectors such as finance, supply chain, healthcare, and governance. For instance, the inefficiencies associated with traditional supply chain management can be tackled through blockchain, which offers real-time tracking and verification of products from origin to consumer (Kamble et al., 2019). Entrepreneurs who understand these challenges can develop solutions that streamline operations, reduce costs, and build trust among consumers and suppliers alike. By analyzing industry trends and consumer behavior, entrepreneurs can pinpoint specific problems that blockchain can solve, making their innovations relevant and timely.

Moreover, entrepreneurs play a significant role in innovating new business models that utilize blockchain technology. Unlike traditional business models, which often rely on centralized systems, blockchain enables decentralized operations that can lead to increased efficiency and reduced operational costs. For example, blockchain can facilitate peer-to-peer transactions without the need for intermediaries, allowing businesses to operate more efficiently and at lower costs (Tapscott & Tapscott, 2016). By creating new business models around these capabilities, entrepreneurs can offer innovative services that attract customers and enhance competitive advantage. A notable example is the rise of

decentralized finance (DeFi), where entrepreneurs are creating platforms that offer financial services such as lending, borrowing, and trading without relying on traditional financial institutions (Zhang et al., 2020).

The creation of startups and ventures focused on blockchain solutions is another avenue through which entrepreneurs drive adoption. Startups are essential in translating blockchain's theoretical potential into practical applications. They are often more willing to take risks and experiment with new ideas compared to established companies (Enholm, et al., 2022, Stahl, 2021, Kasza, 2019). This entrepreneurial spirit fosters a culture of innovation that is crucial for the growth of blockchain technology. For example, companies like Chainalysis and BlockFi have emerged as leaders in their respective fields, providing analytics solutions and financial services built on blockchain technology. These startups not only demonstrate the viability of blockchain applications but also encourage further investment and interest in the technology (Catalini & Gans, 2016).

In addition to developing new products and services, entrepreneurs facilitate collaboration between various stakeholders, including businesses, government entities, and academic institutions. Blockchain technology's complexity and the interdisciplinary nature of its applications necessitate cooperation among diverse groups to create effective solutions (Adugna, 2023). Entrepreneurs often act as intermediaries, bringing together different parties to share knowledge, resources, and best practices. For instance, partnerships between startups and established corporations can lead to pilot projects that demonstrate blockchain's effectiveness in real-world scenarios, which in turn can attract regulatory support and investment (Drescher, 2017).

Furthermore, government involvement is crucial for creating a supportive environment for blockchain adoption. Entrepreneurs can engage with policymakers to advocate for regulations that encourage innovation while ensuring consumer protection and security. The establishment of regulatory sandboxes, for example, allows startups to test their blockchain solutions in a controlled environment, enabling them to refine their offerings before entering the broader market (Zhao et al., 2019). This collaborative approach not only benefits entrepreneurs but also helps governments understand the technology's implications and design frameworks that promote its responsible use.

Academic institutions also play a critical role in advancing blockchain technology, and entrepreneurs can leverage these relationships to drive research and development efforts. Collaborations with universities can facilitate access to cutting-edge research, enabling entrepreneurs to integrate the latest advancements into their products. For example, joint research initiatives can lead to the development of more robust security protocols or scalable blockchain solutions, enhancing the overall ecosystem's maturity and reliability (Yli-Huumo et al., 2016). By fostering relationships with academia, entrepreneurs can also attract talent and expertise, ensuring their ventures are well-equipped to tackle the challenges of implementing blockchain technology.

The importance of education and awareness cannot be overstated when discussing the role of entrepreneurs in driving blockchain adoption. Entrepreneurs have the responsibility to educate potential users about the benefits and applications of blockchain technology. Through workshops, seminars, and thought leadership initiatives, they can demystify the technology and address concerns related to its implementation (Aljohani, 2023, Singh, 2023). By raising awareness of blockchain's potential to improve efficiency and transparency, entrepreneurs can help cultivate a more receptive environment for adoption among businesses and consumers alike (Hughes & Haseeb, 2020).

As blockchain technology continues to evolve, the role of entrepreneurs will remain crucial in driving its adoption. Their ability to identify market needs, innovate new business models, create startups focused on blockchain solutions, and facilitate collaboration among stakeholders positions them as key players in the technological landscape of 4IR. The entrepreneurial spirit that drives innovation will be essential for realizing the full potential of blockchain technology, leading to transformative changes across various sectors.

In conclusion, the active participation of entrepreneurs in driving blockchain adoption is vital for harnessing its transformative potential in the Fourth Industrial Revolution. Their ability to identify market needs, innovate new business models, establish startups, and facilitate collaboration among stakeholders positions them at the forefront of this technological shift (Aboelmaged, 2018, Turktarhan, Aleong & Aleong, 2022). By leveraging blockchain technology, entrepreneurs can create solutions that enhance efficiency, transparency, and security, ultimately leading to significant advancements across industries.

4. Challenges Entrepreneurs Face in Implementing Blockchain

The implementation of blockchain technology presents a myriad of challenges for entrepreneurs operating within the Fourth Industrial Revolution (4IR). While the potential of blockchain to revolutionize industries is substantial, entrepreneurs must navigate significant obstacles that can hinder the successful adoption of this transformative technology. Among these challenges are technical issues such as scalability and integration, regulatory and compliance hurdles, the necessity for market education and awareness, and constraints related to funding and resources.

One of the foremost technical challenges that entrepreneurs encounter when implementing blockchain technology is scalability. As blockchain networks expand, the capacity to process transactions in a timely manner often diminishes. This limitation can lead to slow transaction speeds and increased costs, which can deter potential users and businesses from adopting the technology. For instance, the Bitcoin network has been criticized for its limited transaction throughput, which can lead to delays during peak usage times (Croman et al., 2016). Similarly, Ethereum, while supporting smart contracts and decentralized applications, has faced challenges related to network congestion and high gas fees (Buterin, 2014). Entrepreneurs must not only grapple with these existing limitations but also seek innovative solutions to enhance the scalability of blockchain applications in order to meet user demands effectively.

Integration with existing systems presents another significant technical hurdle for entrepreneurs. Many businesses rely on established processes and technologies, making it challenging to incorporate blockchain solutions without disrupting ongoing operations. The successful integration of blockchain requires a deep understanding of both the new technology and the legacy systems in place (Di Vaio, et al., 2020, Serumaga-Zake & van der Poll, 2021). Entrepreneurs often face resistance from stakeholders who may be reluctant to adopt new methods, fearing disruptions or additional complexities (Marr, 2018). As a result, entrepreneurs must effectively communicate the benefits of blockchain technology to gain buy-in from decision-makers and users, ensuring a smooth transition.

Regulatory and compliance challenges further complicate the implementation of blockchain technology. Given the nascent stage of blockchain and the rapid pace of its development, regulations often lag behind technological advancements. Entrepreneurs frequently face uncertainty regarding the legal frameworks that govern blockchain applications, especially in sectors such as finance, healthcare, and supply chain management (Zohar, 2015). The lack of clear regulations can hinder investment and slow the growth of blockchain startups. Moreover, differing regulations across jurisdictions can create additional complications for entrepreneurs seeking to expand their operations internationally (Ajayi, Bagula & Maluleke, 2022, Lee, et al., 2019). Navigating the regulatory landscape requires a proactive approach, with entrepreneurs needing to engage with policymakers to advocate for frameworks that support innovation while ensuring consumer protection.

Market education and awareness pose additional challenges for entrepreneurs striving to implement blockchain technology. Many potential users and stakeholders still have limited understanding of how blockchain works and its potential benefits. Misconceptions about the technology can lead to skepticism and reluctance to adopt blockchain solutions. Entrepreneurs must take on the responsibility of educating their target markets, dispelling myths, and demonstrating the tangible benefits of blockchain applications (Zhao et al., 2019). This education process often involves significant investment in marketing and outreach efforts to build awareness and trust within the market. Without a well-informed customer base, the potential for widespread adoption may remain unrealized.

Funding and resource constraints also significantly impact entrepreneurs in the blockchain space. Developing and implementing blockchain solutions often requires substantial upfront investment in technology, talent, and infrastructure. Many entrepreneurs may struggle to secure adequate funding, particularly in a competitive landscape where investors are cautious and selective (Asiimwe, 2022, Wang, et al., 2022, Krishnannair, Krishnannair & Krishnannair, 2021). According to a report by CB Insights, funding for blockchain startups surged to \$4.1 billion in 2019, but it has since fluctuated, indicating a volatile investment climate (CB Insights, 2020). Entrepreneurs must be strategic in their funding efforts, often seeking partnerships, grants, or venture capital to support their initiatives. The scarcity of resources can limit the scope of blockchain projects, stalling innovation and growth.

In addition to financial constraints, access to skilled talent poses a challenge for entrepreneurs in the blockchain arena. The demand for blockchain expertise has outstripped supply, leading to a talent shortage in the field (Gans, 2019). Entrepreneurs must compete for skilled professionals who can develop, implement, and maintain blockchain systems. This competition can drive up labor costs and further strain limited budgets. To address this challenge, some entrepreneurs are investing in training and development programs to cultivate talent within their organizations or partnering with educational institutions to create blockchain-focused curricula (Cai et al., 2020). However, these initiatives require time and resources that may not be readily available.

The combination of these challenges creates a complex environment for entrepreneurs attempting to implement blockchain technology in the 4IR. Technical issues such as scalability and integration, coupled with regulatory uncertainty, market education needs, and funding constraints, can deter progress and innovation. Entrepreneurs must adopt a multifaceted approach to navigate these obstacles, balancing the need for technological advancements with practical considerations surrounding compliance, market readiness, and financial sustainability (Khan & Jalal, 2023, Nwokolo, et al., 2023). Moreover, successful entrepreneurs in the blockchain space often rely on collaboration and partnerships to overcome these challenges. By fostering relationships with other businesses, governmental organizations, and academic institutions, entrepreneurs can create a supportive ecosystem that promotes knowledge sharing, resource pooling, and joint problem-solving. Collaborative efforts can also enhance market education initiatives, helping to build a more informed and receptive audience for blockchain solutions.

In conclusion, while blockchain technology offers immense potential to transform industries within the Fourth Industrial Revolution, entrepreneurs face a multitude of challenges in its implementation. Technical hurdles related to scalability and integration, regulatory and compliance uncertainties, market education needs, and funding constraints all play a critical role in shaping the landscape for blockchain adoption (Bag, et al., 202, Russ, 2021, Loureiro, Guerreiro & Tussyadih, 2021). By strategically addressing these challenges, engaging in collaborative efforts, and fostering a culture of education and innovation, entrepreneurs can navigate the complexities of blockchain technology and drive its successful implementation in various sectors.

5. Opportunities for Entrepreneurs in the Blockchain Ecosystem

The blockchain ecosystem offers a myriad of opportunities for entrepreneurs looking to innovate and drive change in various sectors. As we navigate the Fourth Industrial Revolution (4IR), the transformative power of blockchain technology is becoming increasingly apparent, presenting avenues for growth and development across emerging markets and industries. The potential of blockchain spans areas such as fintech innovations, supply chain management, and social entrepreneurship, where it can enhance transparency and accountability (Fanoro, Božanić & Sinha, 2021, Moll, 2021, Gorski, et al., 2022). Moreover, the landscape is ripe for collaborations and partnerships, allowing entrepreneurs to leverage cross-industry alliances to maximize the impact of their blockchain initiatives.

Emerging markets and industries are one of the most promising avenues for blockchain solutions, particularly in the financial technology (fintech) sector. The rise of cryptocurrencies and decentralized finance (DeFi) is transforming traditional financial systems and creating opportunities for entrepreneurs to develop innovative financial products and services. According to a report by Deloitte (2021), the global cryptocurrency market has seen exponential growth, with thousands of cryptocurrencies in circulation and a significant increase in the number of users. This trend provides entrepreneurs with a fertile ground to create new business models that cater to the evolving demands of consumers seeking decentralized financial services.

Decentralized finance, which leverages blockchain technology to provide financial services without intermediaries, is one area where entrepreneurs can make a substantial impact. DeFi platforms enable users to borrow, lend, and trade assets in a peer-to-peer manner, which can lower transaction costs and increase access to financial services (Zhang et al., 2020). Entrepreneurs can capitalize on this shift by developing user-friendly applications that simplify DeFi interactions for consumers, thus expanding the user base and enhancing financial inclusion. Additionally, innovations in stablecoins, which are pegged to traditional currencies, can mitigate the volatility associated with cryptocurrencies, further opening up opportunities for entrepreneurs to create reliable and accessible financial solutions.

Supply chain transparency and traceability are another domain where blockchain technology is making significant strides. The increasing demand for ethical sourcing and sustainable practices in supply chains has prompted businesses to seek solutions that can enhance visibility and accountability. Blockchain's inherent characteristics of decentralization and immutability make it an ideal candidate for addressing these challenges (Du & Xie, 2021, Turner & Turner, 2021, Jia, et al., 2018). For instance, startups focused on implementing blockchain solutions for tracking goods from origin to destination can provide consumers with verified information about the products they purchase, promoting trust and transparency (Kamble et al., 2019).

Entrepreneurs can develop platforms that enable businesses to record and share data securely across the supply chain, enhancing collaboration among stakeholders. This could lead to reduced fraud, improved efficiency, and ultimately, a more sustainable supply chain. Moreover, as consumers become increasingly conscious of the ethical implications of their purchases, businesses that adopt blockchain for supply chain transparency may gain a competitive advantage by attracting socially responsible consumers.

The impact of blockchain technology is not limited to traditional business sectors; it also holds promise for social entrepreneurship. In the realm of charitable organizations, blockchain can enhance transparency and accountability, addressing long-standing issues of trust in the nonprofit sector. By enabling the tracking of donations from source to recipient, blockchain can ensure that funds are used as intended, thereby increasing donor confidence and engagement (Hassan & Kaur, 2021). Entrepreneurs can create blockchain-based platforms that facilitate direct donations and allow donors to verify the impact of their contributions, making charitable giving more transparent and efficient.

The potential for social entrepreneurship extends beyond traditional charities; it includes opportunities for entrepreneurs to address social challenges through innovative business models that leverage blockchain technology. For instance, initiatives focused on providing microloans or financial services to underserved communities can benefit from blockchain's ability to streamline transactions and reduce costs. By harnessing blockchain, entrepreneurs can create inclusive financial ecosystems that empower individuals and communities, ultimately contributing to economic development and social equity.

Collaboration and partnerships play a critical role in the success of blockchain initiatives. The complexity and interdisciplinary nature of blockchain technology necessitate cooperation among various stakeholders, including businesses, governments, and academia. Entrepreneurs can leverage cross-industry partnerships and alliances to maximize the impact of their blockchain projects. Collaborations can enhance the development of innovative solutions by pooling resources, expertise, and networks (Bawack, et al., 2021, Ramakrishna, et al., 2020, George, et al., 2016). For instance, partnerships between technology firms and established industries such as logistics or healthcare can lead to the creation of robust blockchain applications that address industry-specific challenges (Bhatia et al., 2020). In addition to industry partnerships, collaborations with regulatory bodies can help entrepreneurs navigate the complex legal landscape surrounding blockchain technology. Engaging with policymakers can facilitate the development of favorable regulatory frameworks that promote innovation while ensuring consumer protection. By actively participating in discussions about blockchain governance, entrepreneurs can position themselves as thought leaders and advocates for the responsible adoption of the technology.

Moreover, entrepreneurs can benefit from engaging with academic institutions and research organizations. Collaborations with universities can foster innovation through research and development initiatives focused on blockchain applications. This symbiotic relationship can lead to the creation of cutting-edge technologies and best practices that entrepreneurs can leverage in their ventures. As entrepreneurs explore opportunities within the blockchain ecosystem, they must also remain mindful of the challenges and ethical considerations associated with the technology (Bayode, Van der Poll & Ramphal, 2019, Lüdeke-Freund, 2020). Issues such as data privacy, security, and algorithmic bias are critical factors that entrepreneurs must address to build trust among users and stakeholders. By prioritizing ethical considerations and adopting responsible practices, entrepreneurs can ensure that their blockchain solutions not only drive innovation but also contribute positively to society.

In conclusion, the blockchain ecosystem presents a wealth of opportunities for entrepreneurs within the context of the Fourth Industrial Revolution. The emergence of fintech innovations, enhanced supply chain transparency, and the potential for social entrepreneurship underscore the transformative power of blockchain technology. Moreover, collaborations and partnerships can amplify the impact of blockchain initiatives, enabling entrepreneurs to navigate the complexities of the ecosystem effectively (Fichter & Tiemann, 2018, Okunlaya, Syed Abdullah & Alias, 2022). As entrepreneurs seize these opportunities, they can drive meaningful change across industries, fostering innovation, and contributing to a more transparent, equitable, and sustainable future.

6. Case Studies of Entrepreneurial Success in Blockchain

The rise of blockchain technology has given birth to a plethora of startups that harness its transformative potential, leading to entrepreneurial success across various sectors. Among these, notable blockchain startups have emerged, demonstrating innovative applications and significant impacts. Examining these successful ventures offers valuable insights into the entrepreneurial journey, the challenges faced, and the lessons learned. This exploration highlights two prominent case studies: a blockchain-based fintech company and a blockchain application in supply chain management.

One of the standout examples in the fintech sector is Ripple, a company founded in 2012 that leverages blockchain technology to facilitate cross-border payments. Ripple's primary product, XRP, serves as both a cryptocurrency and a liquidity tool for financial institutions, enabling faster and more cost-effective international money transfers. Unlike traditional banking systems, which can take days to process transactions, Ripple's technology allows for nearly instantaneous transfers, fundamentally transforming the way financial institutions interact globally (Zhao et al., 2021).

By partnering with various banks and financial organizations, Ripple has established itself as a leader in the blockchain-based payment solutions market.

Ripple's success is rooted in its strategic approach to addressing real-world problems in the financial industry. The company recognized the inefficiencies and high costs associated with cross-border transactions and designed a solution that streamlines the process. Ripple's focus on collaboration with existing financial institutions rather than attempting to replace them has facilitated its widespread adoption (Bock, Wolter & Ferrell, 2020, Makarius, et al., 2020). This partnership model has proved advantageous, as it aligns Ripple's interests with those of banks, creating a win-win scenario. The lessons learned from Ripple's journey underscore the importance of understanding market needs, fostering collaborations, and being adaptable to regulatory environments.

Another significant case study is VeChain, a blockchain startup founded in 2015 that specializes in supply chain management. VeChain employs blockchain technology to enhance transparency, traceability, and efficiency in supply chains. The platform provides businesses with tools to track products throughout the supply chain, ensuring authenticity and compliance with regulations. VeChain's partnerships with various companies, including Walmart China and BMW, have demonstrated the real-world applicability of its technology (Kouhizadeh & Sarkis, 2021). For instance, Walmart China utilizes VeChain's blockchain to trace the origin of food products, allowing consumers to verify the source of their purchases. This application not only enhances consumer trust but also strengthens the overall supply chain by reducing fraud and inefficiencies.

VeChain's success highlights the critical role of industry partnerships and the need to address specific pain points within supply chains. By focusing on providing tangible solutions to prevalent issues, such as product authenticity and traceability, VeChain has positioned itself as a leader in the blockchain supply chain sector. Additionally, VeChain's approach to incorporating Internet of Things (IoT) devices into its blockchain ecosystem enhances its functionality, providing real-time data that further improves supply chain visibility. The lessons learned from VeChain's experience emphasize the importance of leveraging technology to solve existing problems and the value of strategic partnerships in scaling blockchain solutions.

These case studies offer several key takeaways for aspiring entrepreneurs in the blockchain space. First, identifying and understanding market needs is paramount. Both Ripple and VeChain recognized significant inefficiencies in their respective industries and developed solutions that addressed these challenges. Entrepreneurs should conduct thorough market research to identify gaps and opportunities, ensuring that their products or services provide real value to customers.

Second, collaboration is a recurring theme in the success of these blockchain startups. By partnering with established organizations, Ripple and VeChain were able to leverage existing networks and resources, facilitating their entry into competitive markets. Entrepreneurs should seek out strategic partnerships that can enhance their capabilities, expand their reach, and provide credibility in the marketplace. Collaborations with industry leaders can also help navigate regulatory challenges, as established companies often have more experience dealing with compliance issues.

Furthermore, adaptability is crucial in the ever-evolving blockchain landscape. Both Ripple and VeChain have demonstrated the importance of remaining flexible and responsive to changes in technology and market conditions. Entrepreneurs should be prepared to pivot their business models or strategies in response to new information or shifting industry trends. This agility can be a significant competitive advantage, allowing startups to stay ahead of the curve and capitalize on emerging opportunities.

Lastly, the integration of complementary technologies, such as IoT and artificial intelligence, can enhance the effectiveness of blockchain solutions. By incorporating these technologies, entrepreneurs can create more comprehensive and innovative offerings that address complex challenges within their industries. For instance, VeChain's use of IoT devices to gather real-time data exemplifies how combining different technologies can provide added value to customers and differentiate a startup in the marketplace.

In conclusion, the success stories of Ripple and VeChain illustrate the transformative potential of blockchain technology and the critical role of entrepreneurs in driving its adoption. These case studies highlight the importance of understanding market needs, fostering collaborations, remaining adaptable, and integrating complementary technologies (Caldera, Desha & Dawes, 2017, Munoko, et al., 2020). As entrepreneurs navigate the blockchain landscape, the lessons learned from these successful ventures can serve as a valuable guide, empowering them to innovate, create impactful solutions, and contribute to the ongoing evolution of industries in the Fourth Industrial Revolution.

7. The Future of Blockchain and Entrepreneurship in 4IR

The future of blockchain technology and entrepreneurship within the context of the Fourth Industrial Revolution (4IR) is poised for transformative change. As blockchain technology continues to mature, it is becoming increasingly intertwined with various industries, creating new opportunities and challenges for entrepreneurs. Key trends shaping this future, the evolving role of entrepreneurs, and predictions for blockchain's impact on industries and society will be explored to provide a comprehensive understanding of this dynamic landscape.

One of the most significant trends shaping the future of blockchain technology is the increasing adoption of decentralized finance (DeFi). DeFi represents a paradigm shift in financial services, enabling individuals to engage in peer-to-peer transactions without intermediaries. This democratization of finance has garnered substantial attention from entrepreneurs seeking to innovate within the financial sector. According to Chen et al. (2022), the total value locked in DeFi protocols has surged dramatically, reflecting a growing interest in alternative financial solutions that leverage blockchain's capabilities. This trend is likely to accelerate as more users recognize the advantages of transparency, lower transaction costs, and accessibility offered by DeFi platforms. As entrepreneurs tap into this burgeoning sector, they will drive innovation in financial products and services, challenging traditional banking models.

Another trend shaping the future of blockchain is the emergence of non-fungible tokens (NFTs) and their integration into various sectors beyond art and entertainment. NFTs have gained traction as unique digital assets that represent ownership of a specific item or piece of content on the blockchain. As businesses explore innovative ways to utilize NFTs, entrepreneurs are stepping up to create marketplaces and platforms that facilitate the buying, selling, and trading of these digital assets (Vasilescu et al., 2022). Beyond the realm of digital art, NFTs are being adopted in industries such as gaming, real estate, and supply chain management, where they can enhance transparency, ownership verification, and customer engagement. This trend presents entrepreneurs with opportunities to develop novel applications for NFTs, expanding their utility and driving further adoption.

The evolving role of entrepreneurs in the blockchain ecosystem is characterized by their capacity to adapt and innovate in response to emerging trends and challenges. As blockchain technology matures, entrepreneurs are increasingly expected to bridge the gap between technical development and real-world application. This involves not only creating blockchain-based solutions but also educating potential users about the benefits and implications of the technology. According to De Filippi and Wright (2018), entrepreneurs must possess a deep understanding of the regulatory landscape and societal implications of their innovations to navigate the complexities of the blockchain space effectively.

Moreover, the role of entrepreneurs is shifting from merely developing products to fostering collaboration among various stakeholders in the blockchain ecosystem. As the technology becomes more integrated into established industries, partnerships between entrepreneurs, businesses, regulators, and academia will be crucial for driving innovation and ensuring responsible adoption (Dwivedi, et al., 2021, Puntoni, et al., 2021, Gebhardt, et al., 2022). Collaborative efforts can facilitate knowledge sharing, risk mitigation, and resource allocation, enabling entrepreneurs to scale their solutions more effectively. For example, initiatives that involve cross-industry partnerships can lead to the development of standardized protocols that enhance interoperability among different blockchain networks (Wang et al., 2022). Such collaboration will be essential in addressing the challenges of scalability, security, and user experience in the blockchain landscape.

Predictions for blockchain's impact on industries and society suggest that the technology will become a foundational element of digital transformation across various sectors. In supply chain management, blockchain has the potential to revolutionize the way products are tracked and verified, enhancing transparency and accountability. Companies that adopt blockchain-based solutions can achieve greater visibility into their supply chains, enabling them to respond quickly to disruptions and ensure compliance with regulations (Hazen et al., 2020). This increased efficiency not only benefits businesses but also enhances consumer trust by providing verifiable information about product origins and quality.

In the healthcare sector, blockchain technology is expected to play a pivotal role in securing patient data and enabling interoperability among healthcare systems. Entrepreneurs are already exploring innovative solutions that leverage blockchain for electronic health records, ensuring that patient information remains secure while allowing authorized healthcare providers to access relevant data easily (Kuo et al., 2021). The potential for blockchain to streamline administrative processes, reduce fraud, and improve patient outcomes signifies a transformative shift in how healthcare services are delivered.

Additionally, the societal implications of blockchain technology cannot be overlooked. As entrepreneurs drive the adoption of blockchain solutions, there is a growing emphasis on social responsibility and ethical considerations. The decentralized nature of blockchain has the potential to empower individuals and communities, providing them with greater control over their data and financial resources (Crider, 2021, Wright & Schultz, 2018, Mabotja, 2022). Initiatives focused on social entrepreneurship are increasingly utilizing blockchain to enhance transparency and accountability in charitable organizations, ensuring that funds are used effectively to support social causes (O’Leary et al., 2021). This alignment of entrepreneurship with social impact reflects a broader trend toward responsible innovation that prioritizes societal well-being alongside profit.

In conclusion, the future of blockchain technology and entrepreneurship in the context of the Fourth Industrial Revolution is marked by dynamic trends, evolving roles, and significant potential impacts. As decentralized finance, NFTs, and other innovations gain traction, entrepreneurs will play a crucial role in driving the adoption and application of blockchain solutions across various sectors (Cantele & Zardini, 2018, Ramakgolo & Ukwandu, 2020). Their ability to adapt to changing market dynamics, foster collaboration, and address societal needs will be pivotal in shaping the future of this transformative technology. Ultimately, as blockchain continues to evolve, its impact on industries and society is expected to be profound, offering new opportunities for innovation and positive change.

8. Conclusion

The exploration of the role of entrepreneurs in driving blockchain technology during the Fourth Industrial Revolution (4IR) reveals a landscape rich with opportunities and challenges. Key findings indicate that entrepreneurs are crucial in identifying market gaps, innovating blockchain applications, and creating ventures that leverage this transformative technology. By developing decentralized solutions, they address pressing issues across various sectors, including finance, supply chain management, and healthcare. Furthermore, the entrepreneurial spirit fosters collaboration between businesses, academia, and governments, enhancing the overall ecosystem's resilience and adaptability.

The implications of these findings are significant for entrepreneurs, policymakers, and stakeholders. For entrepreneurs, understanding the technical complexities and regulatory landscape of blockchain is essential for success. Policymakers must create an environment conducive to innovation by implementing supportive regulations and incentivizing blockchain initiatives. Additionally, stakeholders—such as investors, educational institutions, and industry associations—must work together to cultivate an ecosystem that promotes knowledge sharing and resource allocation. This collaborative approach can accelerate the adoption of blockchain technology and ensure its benefits are widely accessible.

To harness the full potential of blockchain technology, there is an urgent call to action for fostering entrepreneurship in this field. This includes investing in educational programs that enhance blockchain literacy among entrepreneurs and facilitating access to funding and resources for startups. Creating incubators and accelerators focused on blockchain innovations can help nurture emerging ventures and provide the necessary support to navigate challenges. Furthermore, encouraging partnerships across industries can lead to innovative solutions and broaden the scope of blockchain applications. By actively promoting entrepreneurship in blockchain, stakeholders can drive meaningful change, positioning themselves at the forefront of technological advancements that promise to reshape industries and society in the 4IR.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest exists among the Authors.

References

- [1] Aamer, A., Eka Yani, L., & Alan Priyatna, I. (2020). Data analytics in the supply chain management: Review of machine learning applications in demand forecasting. *Operations and Supply Chain Management: An International Journal*, 14(1), 1-13.
- [2] Aamer, F. (2023). Water security: diplomacy, global cooperation, and effective management of shared rivers. *Konrad-Adenauer Foundation & Stimson Center*.

- [3] Aboelmaged, M. (2018). The drivers of sustainable manufacturing practices in Egyptian SMEs and their impact on competitive capabilities: A PLS-SEM model. *Journal of Cleaner Production*, 175, 207-221.
- [4] Adugna, D. (2023). Challenges of sanitation in developing counties-evidenced from a study of fourteen towns, Ethiopia. *Heliyon*, 9(1).
- [5] Ajayi, O., Bagula, A., & Maluleke, H. (2022). The fourth industrial revolution: A technological wave of change. In *Industry 4.0-Perspectives and Applications*. IntechOpen.
- [6] Aljohani, A. (2023). Predictive analytics and machine learning for real-time supply chain risk mitigation and agility. *Sustainability*, 15(20), 15088.
- [7] Allioui, H., & Mourdi, Y. (2023). Unleashing the potential of AI: Investigating cutting-edge technologies that are transforming businesses. *International Journal of Computer Engineering and Data Science (IJCEDs)*, 3(2), 1-12.
- [8] Asimwe, M. M. (2022). *Towards an integration of socio-technical transitions and the Fourth Industrial Revolution* (Doctoral dissertation, Stellenbosch: Stellenbosch University).
- [9] Bag, S., Dhamija, P., Bryde, D. J., & Singh, R. K. (2022). Effect of eco-innovation on green supply chain management, circular economy capability, and performance of small and medium enterprises. *Journal of Business Research*, 141, 60-72.
- [10] Bawack, R. E., Fosso Wamba, S., & Carillo, K. D. A. (2021). A framework for understanding artificial intelligence research: insights from practice. *Journal of Enterprise Information Management*, 34(2), 645-678.
- [11] Bayode, A., Van der Poll, J. A., & Ramphal, R. R. (2019, November). 4th industrial revolution: Challenges and opportunities in the South African context. In *Conference on Science, Engineering and Waste Management (SETWM-19)* (pp. 174-180).
- [12] Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital Business Strategy: Toward a Next Generation of Insights. *MIS Quarterly*, 37(2), 471-482.
- [13] Bhatia, R., Bansal, S., & Gupta, R. (2020). Blockchain Technology: The Future of Business in the 21st Century. *Journal of Business Research*, 116, 399-404.
- [14] Bock, D. E., Wolter, J. S., & Ferrell, O. C. (2020). Artificial intelligence: Disrupting what we know about services. *Journal of Services Marketing*, 34(3), 317-334.
- [15] Buterin, V. (2014). A Next-Generation Smart Contract and Decentralized Application Platform. Ethereum White Paper.
- [16] Cai, Y., Wang, H., & Zhang, L. (2020). Blockchain Talent Development: A Case Study of China's University Curriculum Development. *Journal of Education and Work*, 33(5), 396-408.
- [17] Caldera, H. T. S., Desha, C., & Dawes, L. (2017). Exploring the role of lean thinking in sustainable business practice: A systematic literature review. *Journal of cleaner production*, 167, 1546-1565.
- [18] Cantele, S., & Zardini, A. (2018). Is sustainability a competitive advantage for small businesses? An empirical analysis of possible mediators in the sustainability–financial performance relationship. *Journal of cleaner production*, 182, 166-176.
- [19] Catalini, C., & Gans, J. S. (2016). Some Simple Economics of the Blockchain. NBER Working Paper No. 22952.
- [20] CB Insights. (2020). The State of Blockchain 2020: Q2. <https://www.cbinsights.com/research/report/blockchain-trends-q2-2020/>
- [21] Chen, Y., Wu, Y., & Yan, X. (2022). Understanding the Factors Influencing the Adoption of Decentralized Finance. *Journal of Financial Technology*, 3(1), 20-35.
- [22] Crider, Y. S. (2021). *Pathways for progress toward universal access to safe drinking water*. University of California, Berkeley.
- [23] Croman, K., Decker, C., & Wattenhofer, R. (2016). On Scaling Decentralized Blockchains. In *Proceedings of the 3rd Workshop on Bitcoin and Blockchain Research*.
- [24] Crosman, P. (2017). How Blockchain Will Change Banking. American Banker. Retrieved from [American Banker](<https://www.americanbanker.com/news/how-blockchain-will-change-banking>).
- [25] De Filippi, P., & Wright, A. (2018). *Blockchain and the Law: The Rule of Code*. Harvard University Press.

- [26] Deloitte. (2021). 2021 Global Blockchain Survey. <https://www2.deloitte.com/global/en/pages/financial-services/articles/global-blockchain-survey.html>
- [27] Di Vaio, A., Palladino, R., Hassan, R., & Escobar, O. (2020). Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. *Journal of Business Research*, 121, 283-314.
- [28] Drescher, D. (2017). *Blockchain Basics: A Non-Technical Introduction in 25 Steps*. Apress.
- [29] Du, S., & Xie, C. (2021). Paradoxes of artificial intelligence in consumer markets: Ethical challenges and opportunities. *Journal of Business Research*, 129, 961-974.
- [30] Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., ... & Williams, M. D. (2021). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International journal of information management*, 57, 101994.
- [31] Dyer, J. H., Gregersen, H. B., & Christensen, C. M. (2019). Entrepreneurial Strategies for Disruptive Innovation. *Harvard Business Review*, 97(5), 72-79.
- [32] Enholm, I. M., Papagiannidis, E., Mikalef, P., & Krogstie, J. (2022). Artificial intelligence and business value: A literature review. *Information Systems Frontiers*, 24(5), 1709-1734.
- [33] Fanoro, M., Božanić, M., & Sinha, S. (2021). A Review of 4IR/5IR Enabling Technologies and Their Linkage to Manufacturing Supply Chain. *Technologies* 2021, 9, 77.
- [34] Fichter, K., & Tiemann, I. (2018). Factors influencing university support for sustainable entrepreneurship: Insights from explorative case studies. *Journal of Cleaner Production*, 175, 512-524.
- [35] Gans, J. S. (2019). The Case for an AI-Powered Future: What AI Can and Cannot Do. *Communications of the ACM*, 62(4), 26-28.
- [36] Gebhardt, M., Kopyto, M., Birkel, H., & Hartmann, E. (2022). Industry 4.0 technologies as enablers of collaboration in circular supply chains: A systematic literature review. *International Journal of Production Research*, 60(23), 6967-6995.
- [37] George, G., Corbishley, C., Khayesi, J. N., Haas, M. R., & Tihanyi, L. (2016). Bringing Africa in: Promising directions for management research. *Academy of management journal*, 59(2), 377-393.
- [38] Gikonyo, W. (2019). Blockchain Technology and Its Application in Governance: A Review. *Journal of Global Information Technology Management*, 22(3), 189-205.
- [39] Gorski, A. T., Gligorea, I., Gorski, H., & Oancea, R. (2022). Workforce and Workplace Ecosystem—Challenges and Opportunities in the Age of Digital Transformation and 4IR. In *International Conference Knowledge-Based Organization* (Vol. 28, No. 1, pp. 187-194).
- [40] Grey, D. (2023). *Global Water Resources Challenges: Achieving and Sustaining National Water Security and Sharing and Co-Managing International Water* (Doctoral dissertation, The University of Manchester (United Kingdom)).
- [41] Hassan, R., & Kaur, J. (2021). Blockchain Technology for Enhancing Transparency and Trust in Charitable Organizations. *Journal of Social Entrepreneurship*, 12(1), 65-85.
- [42] Hazen, B. T., Boone, C. A., Ezell, J. D., & Jones-Farmer, L. A. (2020). Data Quality for Data Science, Predictive Analytics, and Big Data in Supply Chain Management: An Introduction to the Problem and Suggestions for Research and Applications. *International Journal of Production Economics*, 207, 101-110.
- [43] Hughes, T., & Haseeb, M. (2020). Blockchain Adoption: A Review of the Literature. *International Journal of Business and Management*, 15(2), 1-10.
- [44] Ismail, M. H., Khairuddin, I., & Md Yusof, R. (2019). The Role of Entrepreneurial Competencies in Blockchain Technology Adoption. *Journal of Small Business and Enterprise Development*, 26(4), 523-540.
- [45] Jia, F., Zuluaga-Cardona, L., Bailey, A., & Rueda, X. (2018). Sustainable supply chain management in developing countries: An analysis of the literature. *Journal of cleaner production*, 189, 263-278.
- [46] Kamble, S. S., Gunasekaran, A., & Sharma, R. (2019). A Framework for Sustainable Industry 4.0 Supply Chain Management. *International Journal of Production Economics*, 210, 23-37.
- [47] Kamble, S. S., Gunasekaran, A., & Sharma, R. (2019). Blockchain Technology in Supply Chain Management: A Review of the Literature. *Computers & Industrial Engineering*, 142, 106264.

- [48] Kasza, J. (2019). Forth Industrial Revolution (4 IR): digital disruption of cyber-physical systems. *World Scientific News*, 134(2).
- [49] Khan, A., & Jalal, A. (2023). Supply Chain Optimization through Technology Integration: Riding the Digital Wave to Efficiency. *Abbottabad University Journal of Business and Management Sciences*, 1(01), 53-63.
- [50] Kouhizadeh, M., & Sarkis, J. (2021). Blockchain and the Circular Economy: A Review of the Literature. *Sustainability*, 13(3), 1337.
- [51] Krishnannair, A., Krishnannair, S., & Krishnannair, S. (2021). Learning environments in higher education: Their adaptability to the 4th industrial revolution and the 'social transformation' discourse. *South African journal of higher education*, 35(3), 65-82.
- [52] Kuo, T. T., Ohno-Machado, L., & Liu, F. (2021). Blockchain in Health Care: A Review. *Nursing Outlook*, 69(2), 170-178.
- [53] Lee, J., Suh, T., Roy, D., & Baucus, M. (2019). Emerging technology and business model innovation: the case of artificial intelligence. *Journal of Open Innovation: Technology, Market, and Complexity*, 5(3), 44.
- [54] Loureiro, S. M. C., Guerreiro, J., & Tussyadiah, I. (2021). Artificial intelligence in business: State of the art and future research agenda. *Journal of business research*, 129, 911-926.
- [55] Lüdeke-Freund, F. (2020). Sustainable entrepreneurship, innovation, and business models: Integrative framework and propositions for future research. *Business Strategy and the Environment*, 29(2), 665-681.
- [56] Mabotja, T. P. (2022). *An integrated supply chain management model for the South African steel manufacturing industry in the Fourth Industrial Revolution era* (Doctoral dissertation, University of Johannesburg).
- [57] Makarius, E. E., Mukherjee, D., Fox, J. D., & Fox, A. K. (2020). Rising with the machines: A sociotechnical framework for bringing artificial intelligence into the organization. *Journal of business research*, 120, 262-273.
- [58] Makhdoom, I., Hu, J., & Mehmood, R. (2019). Ripple: A Case Study on Blockchain Technology in Payment Systems. *International Journal of Information Systems and Change Management*, 12(1), 44-57.
- [59] Marr, B. (2018). Blockchain: The 5th Industrial Revolution. *Forbes*. Retrieved from [Forbes](<https://www.forbes.com/sites/bernardmarr/2018/02/20/blockchain-the-5th-industrial-revolution/?sh=34071be84372>).
- [60] Marr, B. (2018). The 7 Biggest Challenges of Blockchain Technology. *Forbes*. <https://www.forbes.com/sites/bernardmarr/2018/01/08/the-7-biggest-challenges-of-blockchain-technology/>
- [61] Moll, I. (2021). The myth of the fourth industrial revolution. *Theoria*, 68(167), 1-38.
- [62] Munoko, I., Brown-Liburud, H. L., & Vasarhelyi, M. (2020). The ethical implications of using artificial intelligence in auditing. *Journal of business ethics*, 167(2), 209-234.
- [63] Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved from (<https://bitcoin.org/bitcoin.pdf>).
- [64] Nwokolo, S. C., Eyime, E. E., Obiwulu, A. U., & Ogbulezie, J. C. (2023). Exploring cutting-edge approaches to reduce africa's carbon footprint through innovative technology dissemination. *Trends in Renewable Energy*, 10(1), 1-29.
- [65] O'Leary, D. E., Jabbour, C. J. C., & Jabbour, A. B. L. (2021). The Role of Social Enterprises in the Sustainable Development Goals: The Importance of Blockchain Technology. *Sustainability*, 13(12), 6583.
- [66] Okunlaya, R. O., Syed Abdullah, N., & Alias, R. A. (2022). Artificial intelligence (AI) library services innovative conceptual framework for the digital transformation of university education. *Library Hi Tech*, 40(6), 1869-1892.
- [67] Păvăloaia, V. D., & Necula, S. C. (2023). Artificial intelligence as a disruptive technology—a systematic literature review. *Electronics*, 12(5), 1102.
- [68] Puntoni, S., Reczek, R. W., Giesler, M., & Botti, S. (2021). Consumers and artificial intelligence: An experiential perspective. *Journal of Marketing*, 85(1), 131-151.
- [69] Ramakgolo, M. A., & Ukwandu, D. C. (2020). The Fourth Industrial Revolution and its Implications for World Order. *Administratio Publica*, 28(4), 115-125.
- [70] Ramakrishna, S., Ngowi, A., Jager, H. D., & Awuzie, B. O. (2020). Emerging industrial revolution: Symbiosis of industry 4.0 and circular economy: The role of universities. *Science, Technology and Society*, 25(3), 505-525.

- [71] Russ, M. (2021). Knowledge management for sustainable development in the era of continuously accelerating technological revolutions: A framework and models. *Sustainability*, 13(6), 3353.
- [72] Schwab, K. (2016). *The Fourth Industrial Revolution*. Crown Business.
- [73] Serumaga-Zake, J. M., & van der Poll, J. A. (2021). Addressing the impact of fourth industrial revolution on South African manufacturing small and medium enterprises (SMEs). *Sustainability*, 13(21), 11703.
- [74] Singh, P. K. (2023). Digital transformation in supply chain management: Artificial Intelligence (AI) and Machine Learning (ML) as Catalysts for Value Creation. *International Journal of Supply Chain Management*, 12(6), 57-63.
- [75] Stahl, B. C. (2021). *Artificial intelligence for a better future: an ecosystem perspective on the ethics of AI and emerging digital technologies* (p. 124). Springer Nature.
- [76] Tapscott, D., & Tapscott, A. (2016). *Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World*. Penguin.
- [77] Turktarhan, G., Aleong, D. S., & Aleong, C. (2022). Re-architecting the firm for increased value: How business models are adapting to the new AI environment. *Journal of Global Business Insights*, 7(1), 33-49.
- [78] Turner, P., & Turner, P. (2021). The Fourth Industrial Revolution. *The Making of the Modern Manager: Mapping Management Competencies from the First to the Fourth Industrial Revolution*, 131-161.
- [79] Vasilescu, L., Gadea, C., & Bădescu, M. (2022). Non-Fungible Tokens: A New Paradigm for the Art Industry. *Journal of Cultural Heritage Management and Sustainable Development*, 12(3), 320-334.
- [80] Wang, Y., Wang, F., & Liu, Y. (2022). The Evolution of Blockchain Technology and Its Applications in the Supply Chain. *IEEE Transactions on Engineering Management*, 69(4), 1080-1093.
- [81] Wang, Z., Li, M., Lu, J., & Cheng, X. (2022). Business Innovation based on artificial intelligence and Blockchain technology. *Information Processing & Management*, 59(1), 102759.
- [82] Weldetsion, G. G. (2023). *Eritrea's Self-reliance policy and the Road to Sustainable Food and Water Security* (Doctoral dissertation, SOAS University of London).
- [83] Wright, S. A., & Schultz, A. E. (2018). The rising tide of artificial intelligence and business automation: Developing an ethical framework. *Business Horizons*, 61(6), 823-832.
- [84] Yli-Huumo, J., Ko, D., Choi, S., & Park, S. (2016). Where Is Current Research on Blockchain Technology?—A Systematic Review. *PloS One*, 11(10), e0163477.
- [85] Zeufack, A. G., Calderon, C., Kubota, M., Kabundi, A. N., Korman, V., & Canales, C. C. (2021). *Africa's Pulse, No. 23, October 2021*. World Bank Publications.
- [86] Zhang, P., et al. (2018). Blockchain Technology in Health Care: A Systematic Review. *Health Policy and Technology*, 7(4), 491-500.
- [87] Zhang, P., et al. (2020). Decentralized Finance: The Role of Blockchain in Financial Services. *International Journal of Financial Studies*, 8(1), 1-24.
- [88] Zhang, Y., Xie, J., & Wang, Y. (2020). Decentralized Finance: A New Era of Financial Innovation. *Journal of Finance and Economics*, 8(4), 333-343.
- [89] Zhao, J. L., Fan, S., & Yan, J. (2019). Blockchain Technology in the FinTech Industry: A Review. *Financial Innovation*, 5(1), 1-21.
- [90] Zhao, X., Huang, Y., & Zhang, X. (2021). The Role of Blockchain in the Financial Services Industry: A Systematic Review and Future Research Agenda. *International Journal of Financial Studies*, 9(3), 49.
- [91] Zohar, A. (2015). Bitcoin: A Technical Overview. *Communications of the ACM*, 58(9), 36-44.