Decentralized Finance (DeFi) on Blockchain: Current Landscape and Future Trends

Muhammad Salah and Sofia Gonzalez
Nile Valley College, Egypt

Abstract

Decentralized Finance (DeFi) represents a paradigm shift in the traditional financial landscape, leveraging blockchain technology to provide financial services without intermediaries. This paper presents an overview of the current landscape of DeFi applications built on blockchain platforms, highlighting their key features, benefits, and challenges. This paper analyzes the current landscape and future trends of DeFi on blockchain. It examines various DeFi protocols, including decentralized exchanges (DEXs), lending and borrowing platforms, liquidity pools, and synthetic asset platforms. Additionally, it discusses the growth and adoption of DeFi, evidenced by the increase in total value locked (TVL) and user participation across different protocols. Regulatory challenges and security considerations are explored, emphasizing the need for regulatory clarity and robust security measures. Finally, future trends such as scalability solutions, interoperability, and decentralized governance mechanisms are analyzed.

Keywords: Decentralized Finance, DeFi, Blockchain, Landscape, Trends, Protocols, Decentralized Exchanges, DEXs

Introduction

Decentralized Finance, often abbreviated as DeFi, refers to a fast-growing sector within the cryptocurrency and blockchain space[1]. Unlike traditional finance, which relies on centralized institutions like banks and exchanges to facilitate transactions and lending, DeFi aims to create a more open, transparent, and accessible financial system using blockchain technology. Decentralized Finance (DeFi) has emerged as a transformative force within the financial industry, leveraging blockchain technology to redefine traditional financial services. By eliminating the need for intermediaries, DeFi protocols enable peer-to-peer transactions and provide greater accessibility, transparency, and efficiency to users worldwide. This introduction provides an overview of the current landscape and future trends of DeFi on blockchain. The rapid proliferation of DeFi applications has created a diverse ecosystem of

decentralized protocols, offering a wide range of financial services, including decentralized exchanges (DEXs), lending and borrowing platforms, liquidity pools, and synthetic asset platforms, among others. These protocols enable users to trade digital assets, lend or borrow cryptocurrencies, earn interest on deposits, and access a variety of financial products and services, all without relying on traditional financial institutions. One of the defining features of DeFi is its composability, allowing different protocols to interact and integrate seamlessly with one another. This interoperability fosters innovation and enables the creation of complex financial instruments and decentralized applications (DApps) that were previously inaccessible or impractical within traditional finance. Despite the exponential growth and potential of DeFi, the ecosystem faces several challenges, including regulatory uncertainty, security vulnerabilities, and scalability limitations[2]. Regulatory frameworks vary significantly across jurisdictions, creating compliance challenges for DeFi projects and uncertainty for users and investors. Moreover, security incidents and exploits have highlighted the importance of robust security measures and risk management practices within DeFi protocols. The rise of DeFi can be attributed to several factors, including the growing demand for financial inclusion, transparency, and censorship resistance. By eliminating intermediaries, DeFi platforms offer users greater control over their assets and financial activities, as well as access to a wide range of financial services, including lending, borrowing, trading, and asset management. This paper aims to provide an overview of the current landscape of DeFi on blockchain, exploring the various protocols, applications, and use cases that have emerged in this rapidly evolving space. Additionally, it examines the challenges and opportunities facing DeFi, including regulatory uncertainty, security risks, and scalability limitations. Looking ahead, the future of DeFi holds immense promise and potential. Scalability solutions, such as layer 2 solutions and blockchain interoperability, aim to address the scalability challenges facing DeFi networks, enabling greater transaction throughput and lower fees. Additionally, advancements in decentralized governance mechanisms seek to enhance the transparency, resilience, and inclusivity of DeFi protocols, empowering users to participate in protocol decision-making and governance processes. Decentralized finance or DeFi is a monetary system that is built on public blockchains. The components of open finance consist of protocols, digital assets, dApps (decentralized applications), and smart contracts, which are built on blockchain, as shown in Figure 1:
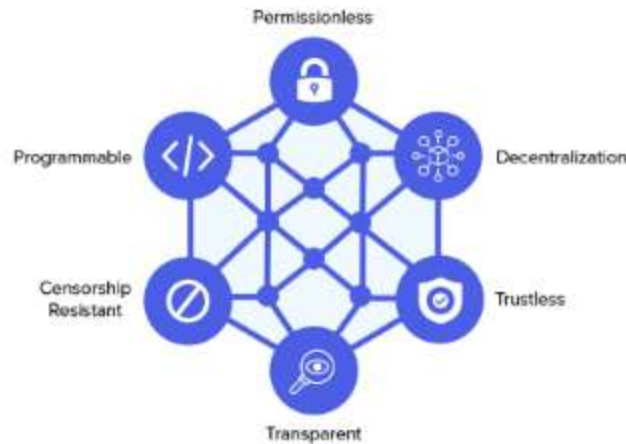
Figure 1: Decentralized Finance (DeFi)

Furthermore, this paper discusses the future trends and potential developments in DeFi, such as scalability solutions, interoperability between different blockchain networks, and the integration of decentralized governance mechanisms. By analyzing these trends, we aim to offer insights into the future trajectory of DeFi and its potential impact on the broader financial ecosystem. Overall, this paper seeks to contribute to the growing body of research on DeFi by providing a comprehensive overview of its current state and prospects. Through this analysis, we hope to deepen our understanding of the opportunities and challenges associated with decentralized finance and its role in shaping the future of finance.

Key Components of Decentralized Finance (DeFi)

Decentralized finance (DeFi) encompasses a range of components that collectively aim to recreate and improve traditional financial services in a decentralized manner[3]. DeFi relies on blockchain technology, particularly smart contracts, to automate and execute financial transactions without the need for intermediaries. These are self-executing contracts where the terms of the agreement between buyer and seller are directly written into code. They automatically execute and enforce once the conditions are met. Ethereum is a popular platform for deploying smart contracts. Smart contracts enable automation and trustless execution of transactions within the DeFi ecosystem. DEXs facilitate peer-to-peer cryptocurrency trading without the need for a central authority to facilitate transactions. They operate using smart contracts and provide users with greater control over their funds. DEXs allow users to trade cryptocurrencies directly with each other without the need for intermediaries. They provide liquidity pools and rely on automated market-

making algorithms. DeFi lending platforms allow users to lend out their cryptocurrencies and earn interest, or borrow assets against collateral. These protocols operate autonomously through smart contracts, enabling borderless lending and borrowing. DeFi lending platforms enable users to lend out their crypto assets and earn interest or borrow assets against collateral. These protocols are automated, transparent, and accessible to anyone with an internet connection[4]. These are cryptocurrencies designed to minimize price volatility by pegging their value to a stable asset like fiat currency or commodities. They provide a reliable medium of exchange and a store of value within the volatile cryptocurrency market. Stablecoins are cryptocurrencies designed to maintain a stable value by pegging them to fiat currencies, commodities, or algorithmic mechanisms. They provide stability and facilitate trading and transactions within the DeFi ecosystem. These are mechanisms used by DeFi protocols to incentivize liquidity provision and participation. Yield farmers provide liquidity to decentralized exchanges or lending protocols and earn rewards, often in the form of additional tokens. These mechanisms incentivize users to provide liquidity to DeFi platforms by offering rewards in the form of additional tokens. Yield farmers and liquidity providers contribute to the liquidity and stability of DeFi protocols. DAOs are organizations governed by smart contracts and run by their members, who vote on proposals and decisions related to the organization's operations. They aim to create decentralized, community-driven entities without centralized control. DAOs are organizations governed by smart contracts and run by their members. They enable decentralized decision-making, allowing participants to vote on proposals and manage the organization's resources[5].

Current Landscape and Opportunities of DeFi

The decentralized finance (DeFi) market has experienced exponential growth since its inception, driven by factors such as increasing adoption, technological advancements, and growing interest from both retail and institutional investors[6]. However, it's important to note that the market size and growth can vary depending on the metrics and timeframes considered, as the DeFi space is still relatively young and evolving rapidly. As of my last update in January 2022, the total value locked (TVL) in DeFi protocols had surpassed tens of billions of dollars, indicating significant capital inflows into the ecosystem. TVL refers to the total value of assets locked in DeFi smart contracts and is often used as a key metric to gauge the overall activity and growth of the DeFi market. Moreover, the number of users, transactions, and new DeFi projects continue to increase, indicating a vibrant and expanding ecosystem. Institutional involvement and mainstream adoption have also been

on the rise, with traditional financial institutions, venture capital firms, and corporations exploring DeFi opportunities. It's worth noting that while the DeFi market has experienced impressive growth, it also faces challenges and risks, including regulatory uncertainties, security vulnerabilities, and scalability issues. These factors can impact the market's growth trajectory and require careful consideration by stakeholders. Looking ahead, the DeFi market is expected to continue growing as developers innovate, new use cases emerge, and the technology matures. However, it's essential to monitor developments closely and ensure that the ecosystem evolves sustainably while addressing regulatory concerns and mitigating risks. Uniswap is a decentralized exchange (DEX) protocol built on Ethereum, renowned for its automated market-making mechanism and permissionless trading. Compound offers a decentralized lending protocol that enables users to lend and borrow cryptocurrencies without intermediaries, with interest rates algorithmically set based on supply and demand dynamics. Aave, another decentralized lending and borrowing platform on Ethereum, provides features such as flash loans, variable interest rates, and collateral swapping. MakerDAO operates as a decentralized autonomous organization (DAO), issuing the stablecoin Dai pegged to the US dollar through collateralized debt positions (CDPs) on Ethereum[7]. Yearn. finance (YFI) is a DeFi platform optimizing yield farming strategies by automatically reallocating funds between different lending protocols, utilizing the YFI token for governance and incentives. Synthetix functions as a derivatives platform on Ethereum, allowing users to mint and trade synthetic assets mirroring real-world assets. Balancer operates as a decentralized liquidity protocol, enabling users to create liquidity pools with customizable asset ratios to facilitate efficient trading and portfolio management. Curve Finance specializes in DEX optimized for stablecoin trading, offering low slippage and fees for swapping between different stablecoin assets. SushiSwap, a decentralized exchange and automated market maker protocol forked from Uniswap, introduces features like yield farming and community governance. Chainlink serves as a decentralized oracle network providing reliable data feeds to smart contracts, aiding the integration of off-chain data into DeFi applications. As of the last update in January 2022, the Total Value Locked (TVL) in decentralized finance (DeFi) protocols had surpassed tens of billions of dollars. TVL refers to the total value of assets locked in DeFi smart contracts, serving as a key metric to gauge the overall activity and growth of the DeFi market. However, it's important to note that TVL can fluctuate over time due to factors such as market conditions, protocol upgrades, and shifts in user behavior. For the most current TVL data, it's recommended to refer to specialized DeFi analytics platforms or aggregator websites that track and

provide real-time updates on DeFi protocols and their respective TVLs. DeFi is not only the largest crypto vertical but also the one that has experienced the highest level of innovation in the last two years. Using smart contract platforms as a base, DeFi has leveraged blockchain's technical characteristics to develop a network of interconnected layers that provide decentralized financial services to users. DeFi not only represents the market vertical with the highest valuation, but it is also the one with the highest TVL. In constructing the BNB ecosystem growth strategy we have identified opportunities for specific categories that can boost the overall DeFi landscape of BNB Chain, as illustrated in Figure 2:

Figure 2: DeFi Landscape with their Strengths and Opportunities on BNB Chain

Financial inclusion and access to banking services are critical aspects of global economic development, and decentralized finance (DeFi) has the potential to significantly enhance both. These protocols operate on blockchain technology, which is accessible to anyone with an internet connection and a compatible device. This accessibility can benefit individuals in underserved regions who lack traditional banking infrastructure, enabling them to participate in financial activities like lending, borrowing, and trading using decentralized platforms. Additionally, DeFi typically has lower barriers to entry compared to traditional banking systems, allowing individuals to participate with minimal requirements. Moreover, DeFi protocols often offer lower costs, such as reduced interest rates and fees, compared to traditional banks, making financial services more affordable and accessible to a broader range of users. By providing individuals with greater control over their finances, facilitating borderless transactions, and promoting financial empowerment, DeFi has the potential to improve the economic well-being of individuals and communities

worldwide, particularly those who have been historically underserved by traditional banking systems. However, challenges such as regulatory compliance, user education, and security must be addressed to ensure the sustainable growth and adoption of decentralized finance on a global scale. Firstly, DeFi operates on blockchain technology, which is accessible to anyone with internet connectivity, thereby enabling individuals worldwide to participate in financial activities. Additionally, DeFi protocols facilitate peer-to-peer transactions without geographical borders, allowing users from different regions to interact directly[8]. The growing adoption of cryptocurrencies further supports DeFi's global expansion, as cryptocurrencies offer a borderless and censorship-resistant form of money. Moreover, DeFi can empower individuals who lack access to traditional banking services, promoting financial inclusion on a global scale. The diverse range of financial services offered by DeFi, including lending, borrowing, trading, and asset management, cater to varied needs and preferences across different demographics and regions. While regulatory uncertainty remains a challenge, favorable regulations in certain jurisdictions can foster growth and investment in DeFi projects, attracting users and capital from around the world. Overall, the accessible, borderless nature of DeFi, combined with increasing cryptocurrency adoption and demand for financial inclusion, positions it as a transformative force with a truly global market reach.

Case Studies

Decentralized insurance, a burgeoning sector within decentralized finance (DeFi), harnesses blockchain technology and smart contracts to revolutionize traditional insurance models[9]. Unlike centralized counterparts, decentralized insurance operates autonomously, executing policy issuance, premium payments, and claims settlements through transparent and immutable smart contracts. This transparency enhances trust among users, as all transactions are recorded on a public ledger, reducing fraud and ensuring fair claims processing. Accessibility is a key advantage of decentralized insurance. Utilizing blockchain technology, decentralized insurance protocols offer inclusive access to insurance services, catering to individuals globally, including those in underserved regions. Moreover, the elimination of intermediaries streamlines processes, potentially reducing administrative costs and making insurance more affordable. Despite its promise, decentralized insurance faces challenges such as regulatory compliance and scalability. However, its potential to disrupt traditional insurance models by offering transparent, accessible, and efficient insurance solutions is significant. As the DeFi ecosystem evolves and matures, decentralized insurance is poised to play

a pivotal role in democratizing access to insurance services and fostering financial inclusion on a global scale[10]. Asset tokenization involves representing ownership of real-world assets, such as real estate, art, or stocks, as digital tokens on a blockchain. These tokens, often referred to as security tokens, are programmable and can be traded peer-to-peer, providing liquidity and fractional ownership of traditionally illiquid assets. One of the key benefits of asset tokenization is increased liquidity. By digitizing assets and enabling fractional ownership, tokenization opens up investment opportunities to a wider pool of investors. Moreover, trading can occur 24/7 on global markets, enhancing liquidity compared to traditional markets. Another advantage is the reduction of barriers to entry. Fractional ownership allows investors to access high-value assets with smaller investments, democratizing access to previously exclusive markets. Additionally, tokenization streamlines the investment process, with transactions executed digitally, reducing paperwork and administrative costs. Asset tokenization also enhances transparency and security. Blockchain technology provides an immutable record of ownership and transactions, reducing the risk of fraud and ensuring transparency throughout the asset lifecycle. Smart contracts can automate compliance requirements, such as regulatory filings and dividend distributions, further enhancing security and efficiency. Decentralized identity management (DID) is a concept that aims to give individuals control over their digital identities while ensuring privacy, security, and interoperability across various systems and applications. Unlike traditional identity management systems, which are often centralized and controlled by third-party entities, DID relies on blockchain technology and cryptographic principles to enable self-sovereign identity. In a decentralized identity management system, individuals create and manage their digital identities using cryptographic keys stored in a digital wallet. These identities are verified and attested by trusted parties, such as government agencies, educational institutions, or financial institutions, through the issuance of verifiable credentials. One of the key benefits of DID is privacy. Users have full control over their data and can choose what information to share and with whom, reducing the risk of data breaches and identity theft. Additionally, DID enables selective disclosure, allowing users to provide only relevant information to different service providers without revealing unnecessary details. Security is another advantage of decentralized identity management. By leveraging blockchain technology and cryptographic techniques, DID ensures the integrity and authenticity of identity information, mitigating the risk of identity fraud and unauthorized access. Decentralized derivatives trading refers to the exchange of derivative contracts, such as options, futures, and swaps, on decentralized platforms without the need for

intermediaries. These platforms utilize blockchain technology and smart contracts to facilitate peer-to-peer trading, offering benefits such as transparency, security, and accessibility. Security is another benefit of decentralized derivatives trading[11]. Smart contracts automate the execution and settlement of trades, eliminating the need for centralized clearinghouses or custodians. As a result, counterparty risk is minimized, and funds are held securely in users' digital wallets. Accessibility is also a significant advantage. Decentralized derivatives trading platforms are accessible to anyone with an internet connection and a compatible wallet, democratizing access to derivative markets. Moreover, these platforms typically have lower barriers to entry compared to traditional derivatives exchanges, allowing users to participate with smaller investments. Decentralized derivatives trading also offers potential cost savings. By eliminating intermediaries and automating processes through smart contracts, transaction fees can be reduced, making trading more affordable for users.

Challenges and Future Trends in DeFi

Security risks and smart contract vulnerabilities are significant concerns within the decentralized finance (DeFi) ecosystem[12]. Smart contracts, which are self-executing contracts with the terms of the agreement directly written into code, are susceptible to various vulnerabilities that can be exploited by attackers. In a reentrancy attack, an attacker exploits a flaw in a smart contract to repeatedly call back into the contract before the initial function call completes. This can result in unintended behavior and allow the attacker to drain funds from the contract. Front-running occurs when an attacker exploits the time delay between the submission and execution of a transaction on the blockchain. By monitoring pending transactions and inserting their transaction with higher gas fees, attackers can profit from price discrepancies. DeFi protocols often have governance mechanisms allowing token holders to vote on protocol upgrades and changes. However, if governance tokens are concentrated in the hands of a few large holders or if voting is vulnerable to manipulation, attackers can control the protocol and exploit it for their gain. Oracles provide external data to smart contracts, and if compromised or manipulated, can provide inaccurate or malicious data, leading to incorrect contract execution and potential loss of funds. Scalability is a critical challenge within the decentralized finance (DeFi) ecosystem, stemming primarily from limitations in blockchain technology. As DeFi applications continue to gain popularity, they face increasing demand for transaction throughput, efficiency, and responsiveness[13]. However, existing blockchain networks, particularly Ethereum, have struggled to keep pace with this demand due to inherent

scalability limitations. One of the primary scalability issues is network congestion. As more users interact with DeFi protocols, transaction backlogs can occur, leading to delays and higher fees. Ethereum's network congestion during periods of high activity, such as during token launches or major DeFi events, has resulted in significantly increased gas fees and slower transaction processing times. Another scalability challenge is the throughput bottleneck. Ethereum's current transaction throughput is limited, with a maximum capacity of around 15-30 transactions per second (TPS). This limitation restricts the number of transactions that can be processed simultaneously, causing congestion during peak usage periods. User experience (UX) and accessibility are critical considerations for the widespread adoption and success of decentralized finance (DeFi) applications. Despite the promising potential of DeFi to revolutionize financial services, challenges related to UX and accessibility can hinder user adoption and usability. By prioritizing user experience and accessibility, DeFi platforms can attract a broader user base and drive greater adoption of decentralized finance. Investing in usability testing, user feedback, and continuous improvement can help ensure that DeFi applications meet the needs and preferences of their diverse user communities.

Table 1: Challenges facing DeFi in Blockchain

Security Risks	*Scalability Issues*	*User Experience and Accessibility*
• *Reentrancy Attacks*	• *Transaction Throughput*	• *Complexity of Wallets and Interfaces*
o *Unchecked External Calls*	• *Network Congestion*	• *Private Key Management*
• *Integer Overflow and Underflow*	• *Smart Contract Complexity*	• *Lack of User Education*
• *Front-Running*	• *Interoperability*	• *Regulatory Uncertainty*
o *Oracle Manipulation*	• *Gas Fees*	• *Language and Localization*

Integration with traditional finance is crucial for the broader adoption and long-term sustainability of decentralized finance (DeFi). While DeFi offers

innovative solutions and advantages over traditional finance, bridging the gap between the two ecosystems is essential to unlock synergies and overcome existing barriers. Integrating fiat on-ramps and off-ramps allows users to seamlessly convert fiat currency into cryptocurrencies and vice versa, simplifying the process of entering and exiting the DeFi ecosystem. Collaborating with regulatory authorities and complying with regulatory requirements is essential for building trust and legitimacy in the DeFi space, attracting institutional investors and mainstream users who prioritize regulatory compliance. Establishing interoperability between DeFi and traditional finance systems enables seamless transfer of assets and data between the two ecosystems, driving innovation and growth. Offering financial products and services that bridge the gap between DeFi and traditional finance, such as tokenized securities and decentralized lending platforms, attracts users from both ecosystems, providing access to new investment opportunities. Educating stakeholders in both DeFi and traditional finance about the benefits, risks, and potential of decentralized finance fosters understanding and collaboration, facilitating integration and cooperation[14]. Cross-chain compatibility is a critical aspect of decentralized finance (DeFi) that enables interoperability between different blockchain networks, allowing assets and data to move seamlessly between them. Achieving cross-chain compatibility is essential for addressing scalability limitations, improving liquidity, and unlocking new opportunities for innovation within the DeFi ecosystem. By enabling interoperability, cross-chain compatibility facilitates the transfer of assets and data between different blockchain networks, enabling users to access a broader range of financial products and services. For example, users can leverage assets from one blockchain network to participate in liquidity pools, yield farming, or lending protocols on another blockchain network, expanding their investment opportunities and diversifying their portfolios. Layer 2 solutions are scalability solutions built on top of existing blockchain networks, aiming to increase transaction throughput and reduce fees without compromising on security or decentralization. These solutions operate "off-chain," meaning transactions are conducted on separate, parallel networks or protocols that are anchored to the main blockchain network, providing scalability benefits while still maintaining the security and trustlessness of the underlying blockchain. One prominent type of Layer 2 solution is rollups, which bundle multiple transactions together off-chain and submit a single aggregated transaction to the main blockchain network, reducing congestion and fees. There are two main types of rollups: optimistic rollups and zk-rollups. Optimistic rollups rely on fraud proofs to ensure transaction validity, while zk-rollups use zero-knowledge proofs for enhanced

privacy and efficiency. Another type of Layer 2 solution is sidechains, which are independent blockchain networks that are interoperable with the main blockchain. Sidechains can process transactions more quickly and at a lower cost than the main blockchain, allowing users to perform transactions off-chain and settle periodically on the main blockchain for security. The evolution of governance models within decentralized finance (DeFi) has been marked by experimentation, iteration, and adaptation to address the evolving needs and challenges of decentralized protocols and communities. Initially, many DeFi projects relied on simple token-based governance models, where holders of governance tokens could vote on proposals related to protocol upgrades, parameter adjustments, and fund allocations. However, as the DeFi ecosystem has matured, governance models have become more sophisticated and diverse, incorporating a range of mechanisms to promote decentralization, transparency, and community participation[15].

Conclusion

In conclusion, decentralized finance on blockchain represents a paradigm shift in the financial industry, offering unprecedented opportunities for innovation, inclusion, and empowerment. While the current landscape of DeFi is marked by growth, experimentation, and challenges, future trends are likely to focus on scalability, regulation, institutional adoption, decentralized governance, and cross-chain interoperability. By addressing these trends and challenges, the future of DeFi holds immense potential to revolutionize finance and democratize access to financial services on a global scale. Efforts to address these challenges include the development of Layer 2 scaling solutions and interoperability protocols to improve transaction throughput and reduce costs. Looking ahead, future trends in DeFi are likely to focus on scalability, regulation, institutional adoption, decentralized governance, and cross-chain interoperability. By addressing these trends and challenges, DeFi has the potential to revolutionize finance and empower individuals worldwide with greater financial access and control.

References

[1]   X. Li, X. Wang, X. Chen, Y. Lu, H. Fu, and Y. C. Wu, "Unlabeled data selection for active learning in image classification," *Scientific Reports,* vol. 14, no. 1, p. 424, 2024.

[2]   S. Werner, D. Perez, L. Gudgeon, A. Klages-Mundt, D. Harz, and W. Knottenbelt, "Sok: Decentralized finance (defi)," in *Proceedings of the 4th ACM Conference on Advances in Financial Technologies*, 2022, pp. 30-46.

[3]   Y. Liang, X. Wang, Y. C. Wu, H. Fu, and M. Zhou, "A Study on Blockchain Sandwich Attack Strategies Based on Mechanism Design Game Theory," *Electronics,* vol. 12, no. 21, p. 4417, 2023.

[4]   J. R. Jensen, V. von Wachter, and O. Ross, "An introduction to decentralized finance (defi)," *Complex Systems Informatics and Modeling Quarterly,* no. 26, pp. 46-54, 2021.

[5]   D. Lau *et al.*, *How to DeFi: Beginner.* CoinGecko, 2021.

[6]   Z. Lee, Y. C. Wu, and X. Wang, "Automated Machine Learning in Waste Classification: A Revolutionary Approach to Efficiency and Accuracy," in *Proceedings of the 2023 12th International Conference on Computing and Pattern Recognition*, 2023, pp. 299-303.

[7]   S. Aramonte, W. Huang, and A. Schrimpf, "DeFi risks and the decentralisation illusion," *BIS Quarterly Review,* vol. 21, 2021.

[8]   L. Gudgeon, S. Werner, D. Perez, and W. J. Knottenbelt, "Defi protocols for loanable funds: Interest rates, liquidity and market efficiency," in *Proceedings of the 2nd ACM Conference on Advances in Financial Technologies*, 2020, pp. 92-112.

[9]   H. Guo, Z. Ma, X. Chen, X. Wang, J. Xu, and Y. Zheng, "Generating Artistic Portraits from Face Photos with Feature Disentanglement and Reconstruction," *Electronics,* vol. 13, no. 5, p. 955, 2024.

[10]   L. Fang, E. Azmi, B. Hor, and K. W. Win, *How to DeFi: Advanced.* CoinGecko, 2021.

[11]   M. Aquilina, J. Frost, and A. Schrimpf, "Decentralized finance (DeFi): A functional approach," *Journal of Financial Regulation,* vol. 10, no. 1, pp. 1-27, 2024.

[12]   X. Wang, Y. C. Wu, and Z. Ma, "Blockchain in the courtroom: exploring its evidentiary significance and procedural implications in US judicial processes," *Frontiers in Blockchain,* vol. 7, p. 1306058, 2024.

[13]   D. A. Zetzsche, D. W. Arner, and R. P. Buckley, "Decentralized finance (defi)," *Journal of Financial Regulation,* vol. 6, pp. 172-203, 2020.

[14]   K. Qin, L. Zhou, Y. Afonin, L. Lazzaretti, and A. Gervais, "CeFi vs. DeFi--Comparing Centralized to Decentralized Finance," *arXiv preprint arXiv:2106.08157,* 2021.

[15]   V. Mohan, "Automated market makers and decentralized exchanges: a DeFi primer," *Financial Innovation,* vol. 8, no. 1, p. 20, 2022.