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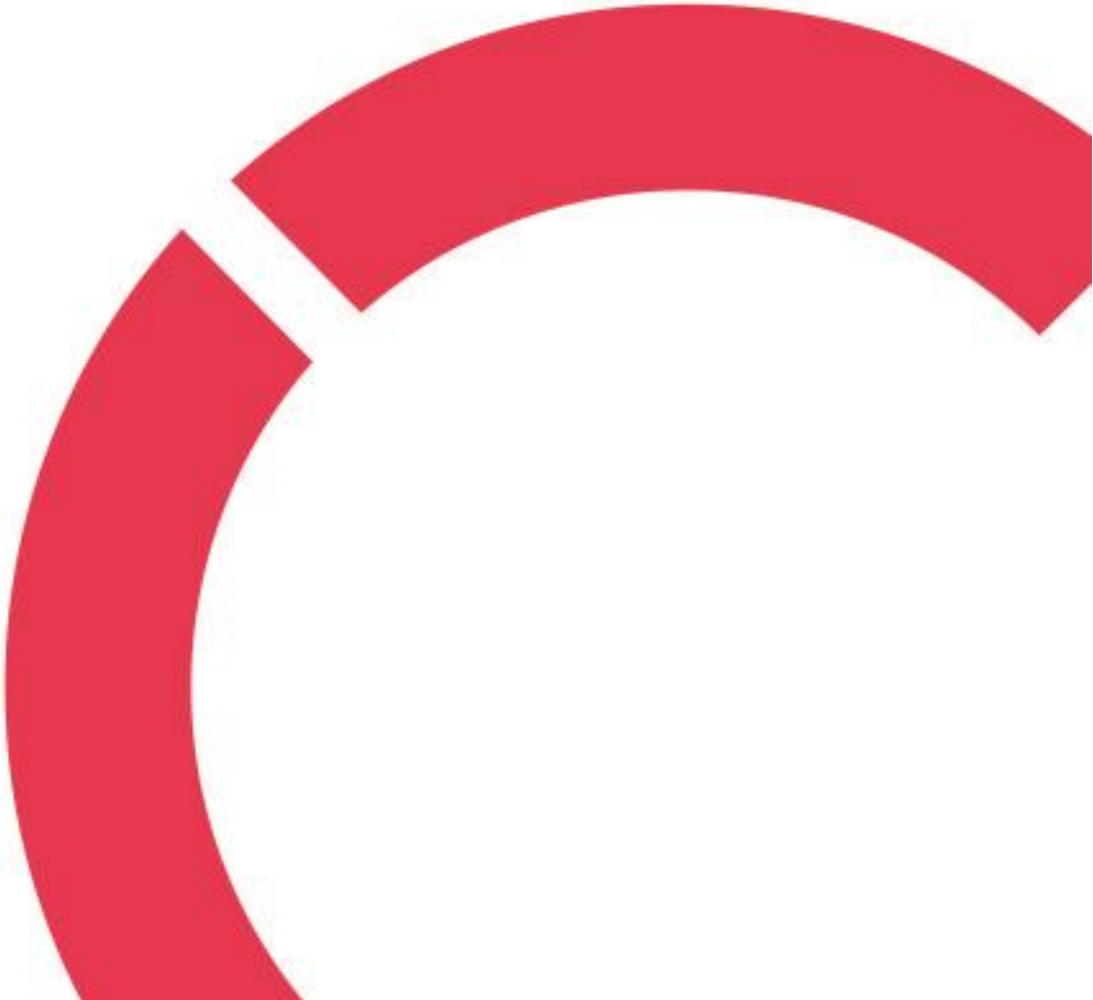
BLOCKCHAIN AND REAL-WORLD ASSETS

Will blockchain disrupt the trading of real-world assets?

Thesis
CENTRIA UNIVERSITY OF APPLIED SCIENCES
Master of Business Administration, International Business Management
November 2023



ABSTRACT

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Degree programme Master of Business Administration, International Business Management		
Name of thesis BLOCKCHAIN AND REAL-WORLD ASSETS. Will blockchain disrupt the trading of real-world assets?		
Centria supervisor Jari Isohanni		**Pages** 29 + 8
Instructor representing commissioning institution or company Not Applicable		

The purpose of this thesis was to explore the potential of blockchain technology and how it will streamline the process of real-world asset management. In particular, this thesis focused on the feasibility of using blockchain technology and blockchain-based smart contracts to track and manage ownership of real-world assets. The first part of this thesis provided an overview of blockchain technology and its potential applications in asset management. Next, the thesis discussed the challenges associated with managing real-world assets on a blockchain. Finally, the thesis concluded with a case study demonstrating how blockchain-based smart contracts can be used to manage ownership of real-world assets.

Blockchain technology has the potential to revolutionize the way we manage and transfer real-world assets. By creating a secure, decentralized ledger of all asset transactions, blockchain could streamline the management of complex supply chains, reduce the costs and risks of buying and selling assets, and create new opportunities for fractional ownership and peer-to-peer lending. Additionally, by making assets more liquid and easier to exchange, blockchain could potentially unlock billions of dollars in value that is currently locked up in illiquid assets such as real estate and art. Ultimately, blockchain could help build a more efficient, transparent, and equitable economy.

Key words
Asset tokenization on blockchain, Blockchain, Non-fungible tokens, Real-world assets on blockchain, Security tokens, Tokenization

CONCEPT DEFINITIONS

DISTRIBUTED LEDGER (DLT)

A distributed ledger also known as distributed ledger technology is a database spread across a network of computers called nodes. Each node holds a copy of the ledger and updates it independently.

DECENTRALIZED FINANCE (DeFi)

DeFi, short for "Decentralized Finance," refers to a set of financial services and applications that are built on blockchain technology, primarily on the any of the blockchain network, and aim to recreate and enhance traditional financial systems in a more open, accessible, and decentralized manner.

EBA

European Banking Authority.

FCA

Financial Conduct Authority. A regulatory body in the United Kingdom.

NFTs

Non-Fungible Assets. This means that the value of one asset is not equal to the value of another, unlike Fungible Assets. For example, in a fungible asset like the Euro currency, 1 Euro is equal to 1 Euro, if the Euro is considered a non-fungible asset, then 1 Euro is not in value as other Euro. Consider it like a piece of art where one piece of art identical to other may differ in value.

RWAs

Real-World Assets. It can be considered a piece of art or real estate property, or anything that proves to have value.

ABSTRACT
CONCEPT DEFINITIONS
CONTENTS

List of Pictures

1 INTRODUCTION

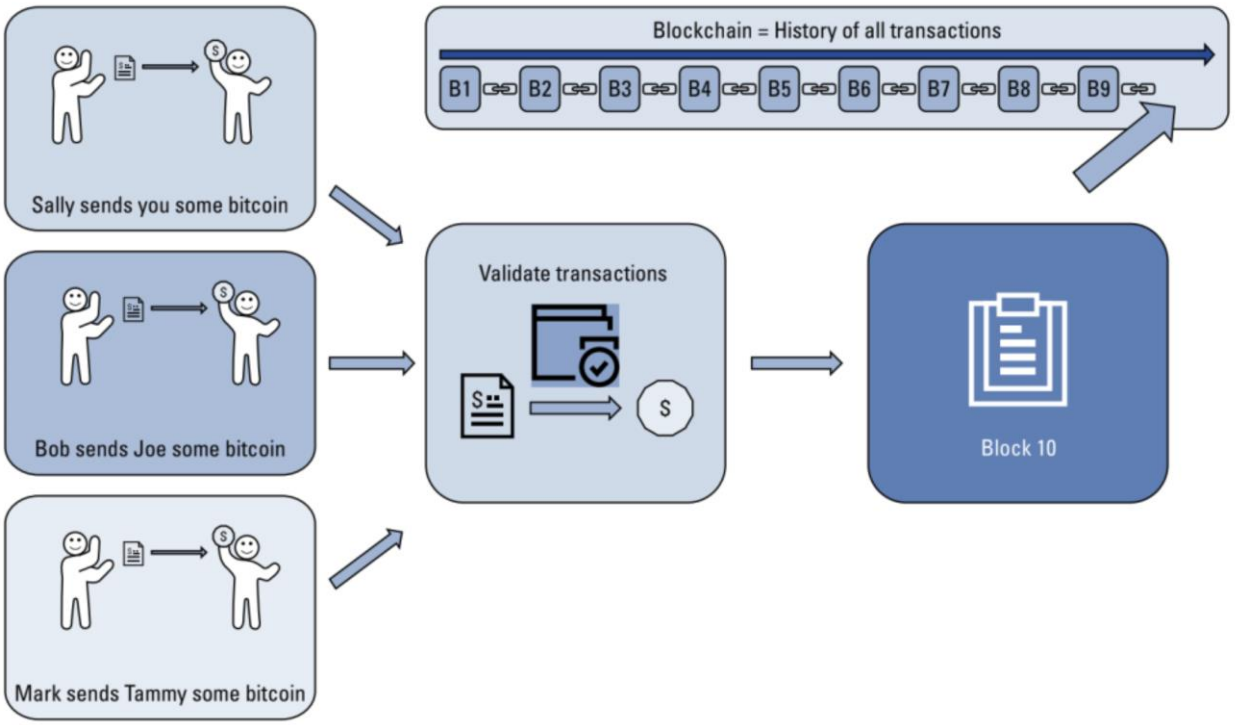
Blockchain is often described as a digital ledger, as it keeps a record of all transactions that have taken place on the network. It is constantly growing as completed blocks are added to the chain of previous blocks. Each block contains a unique cryptographic hash of the previous block, a timestamp, and transaction data. The past decade has seen a dramatic increase in the use of digital technologies in our everyday lives. We now rely on digital devices for everything from communicating with friends and family to managing our finances to hailing a taxi. It's no surprise then that the past few years have also seen a surge in interest in digital currency assets, also known as cryptocurrencies. The underlying technology of cryptocurrencies is blockchain. These digital currencies are often traded on decentralized exchanges and can also be used to purchase goods and services. However, their most common use currently is purely for speculation purposes rather than watching the technology build something, but this could change over time.

A real-world asset is an asset with physical existence, such as land, buildings, and machinery. Real-world assets are usually traded through intermediaries, such as banks and stock exchanges. However today, the management of real-world assets is complex and often inefficient. This technology can help to reduce costs, speed up transactions, and increase transparency in the management of real-world assets. In addition, blockchain technology can help to reduce fraudulent activities associated with the management of these assets. Furthermore, the adoption of blockchain technology for the management of real-world assets is still in its early stages. However, there are already several pilot projects and initiatives underway that are exploring the potential of this technology. With its potential to revolutionize the management of real-world assets, blockchain technology is an exciting and emerging area of development and one of these projects will be discussed in a case study.

The thesis will conclude based on blockchain literature and a case study whether it is feasible to build on this technology to manage ownership of real-world assets. Blockchain technology its advantages and disadvantages, its current implementations, and their results will be discussed. Furthermore, the potential challenges associated with managing real-world assets on a blockchain will be discussed including but not limited to regulatory issues, security issues, etc. Moreover, smart contracts will be discussed in detail and how they could support the trading of real-world assets autonomously. To support the research topics a case study of a blockchain project will be discussed to demonstrate blockchain capabilities and if it is feasible to manage real-world assets on blockchain or not.

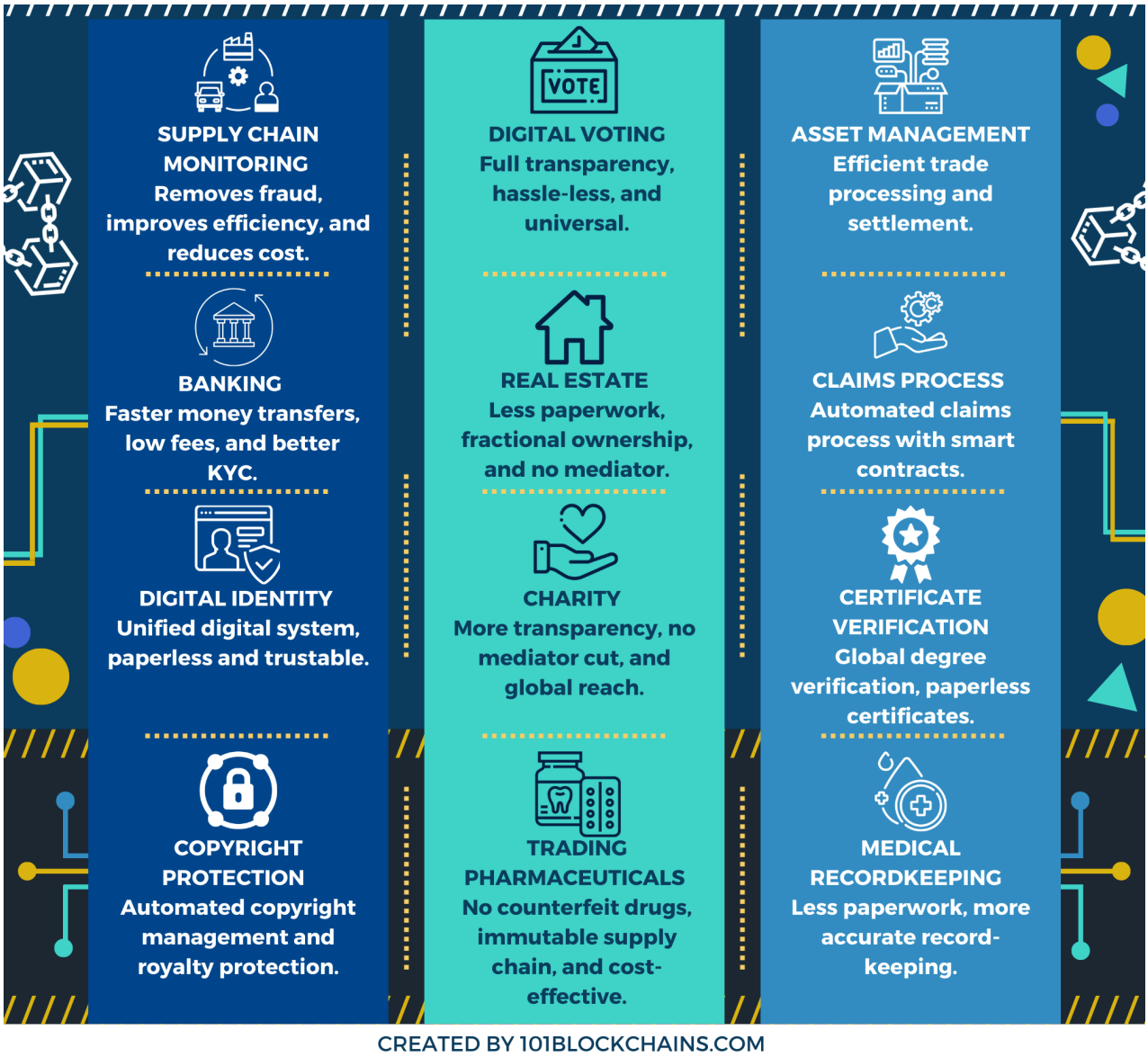
2 BLOCKCHAIN

Blockchain is an immutable, distributed ledger that creates a tamper-proof record of transactions (Schapkohl 2020). At its core, a blockchain is a digital ledger of transactions. Once a transaction is recorded, its authenticity can be verified by the entire community using the public ledger. Blockchain is an immutable ledger of transactions, and its use case is not limited to just financial transactions but usually, anything of value. (Tapscott & Tapscott 2016.) Blockchain technology has the potential to revolutionize business processes. The main advantage of blockchain is that it is secure and tamper-proof. The decentralized nature of blockchain makes it resistant to hacks. The immutability feature ensures that the data cannot be changed once it is recorded on the blockchain. This makes it an ideal platform for storing sensitive data. Another advantage is that it is fast and efficient. The peer-to-peer nature of blockchain eliminates the need for third parties, which makes the process faster. Blockchain is also transparent, meaning that all the parties involved in a transaction can view the details of the transaction although it can be controlled. This makes it easy to track the movement of goods and ensure their authenticity. (Attaran & Gunasekaran 2019, 13.)



PICTURE 1. How Blockchain Works? (Laurence 2019)

Blockchain, as the term says, has blocks tied to a chain. A block can be referred to as a block of transactions. These transactions can be of any nature, not just financial assets but they can be about any asset that has value. Each new block created is added to a chain of the previous blocks with a unique hash. A blockchain can be termed as a distributed database that enables secure, transparent, and tamper-proof record-keeping of transactions. By design, a blockchain is resistant to modification of the data due to its immutable nature. Once transactions are recorded, the data in any given block cannot be altered retroactively without the alteration of all subsequent blocks, which requires the validation of the network majority. Since all network nodes had the same copy of transactions in a block, if any transactions are found tampered with, the block is rejected by the whole network and no changes will be made on the blockchain. Automatic transactions can also be programmed on blockchain. A blockchain is managed autonomously using a peer-to-peer network and a distributed timestamping server. They are authenticated by a mass collaboration of collective network nodes. The use of a blockchain removes the characteristic of infinite reproducibility from a digital asset. It confirms that each unit of value was transferred only once, solving the double-spending problem. It is used for a growing variety of purposes today. Financial institutions are investigating how they can use this technology to reduce the cost of infrastructure and increase transparency and auditability. In the healthcare sector, blockchains are being explored to securely store and share patient health records. The potential applications of blockchain technology are growing as research is pursued on this emerging technology.



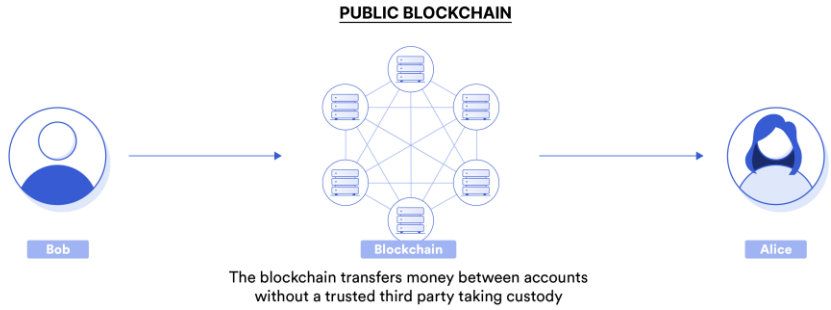
PICTURE 2 Use Cases of Blockchain (101blockchain 2021)

According to a report by the World Economic Forum, the global economy is on the edge of a Fourth Industrial Revolution, in which blockchain technology is poised to play a major role. With the ability to provide a secure, tamper-proof digital ledger for everything from financial transactions to medical records and supply chain management, the potential applications of blockchain are virtually limitless. The global banking sector also began to explore the use of blockchain to streamline processes and reduce costs. Banks such as Credit Suisse, UBS, and Barclays have all been experimenting with blockchain-based systems for things like cross-border payments, trade finance, and identity verification. In the healthcare sector, blockchain is being used to create secure, tamper-proof medical records. The use of blockchain could potentially eliminate the need for paper records and make it easier for patients to control access to their own data. The supply chain is another area where blockchain is being piloted.

By creating a digital ledger of every step in the supply chain, from manufacture to delivery, blockchain could help to improve transparency and accountability and reduce the incidence of fraud. These are a few examples of the use-cases that are being powered by blockchain technology.

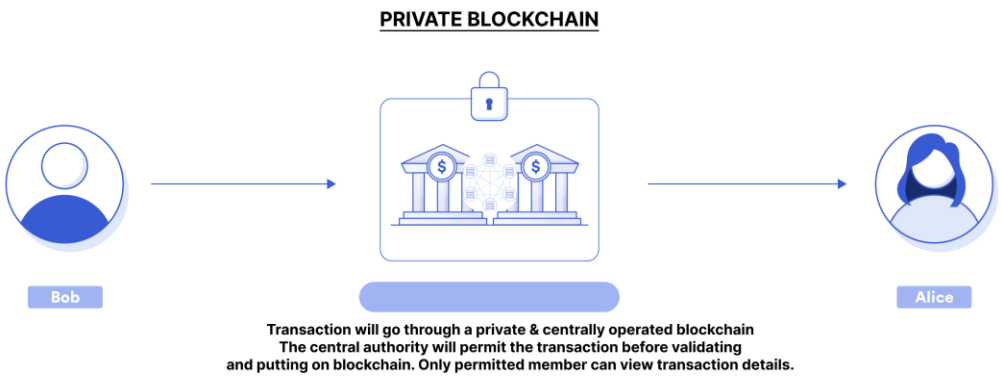
2.1 Types of Blockchain

There are majorly three types of blockchain terminologies widely discussed: public, private, and consortium. A public blockchain is a public decentralized ledger that anybody can access and make use of with minimal resources. Its goal is to remove the need for intermediaries and enable peer-to-peer transactions. Bitcoin, Ethereum, Solana, Cardano, Polkadot, and other blockchains are some of the most well-known examples of public blockchains. Anybody can verify the transaction by going through on-chain data. The network verifies each transaction, making them highly secure. Although they are more expensive and slower than private blockchains, they still perform better than the current systems used for recording transactions on ledgers. (Thompson 2016.)



PICTURE 3 Public Blockchain (Chainlink 2023)

A private blockchain requires permission to access and add transactions to the blockchain. It is not decentralized but is instead managed by a controlled number of nodes who have authority over the transactions made. It is usually faster and more cost effective than a public blockchain, making it suitable for corporate use cases. Potential benefits of private blockchains include increased efficiency and reduced operational costs. Examples of its use include online voting systems. (Dragonchain 2019.)



PICTURE 4 Private Blockchain (Chainlink 2023)

A consortium blockchain is a combination of private and public blockchains that allows for a decentralized environment within a private network. It offers organizations great flexibility and control over their data, which makes it suitable for highly regulated companies. Consortium blockchains are like private blockchains instead they require permission to access and make changes, but are owned by a group of entities, rather than one. An example of a hybrid blockchain is XinFin, which is built by combining Ethereum (public) and Quorum (private) to provide solutions for global trade, finance, and supply chain management. (Freuden 2018.) Further, it can be used in the healthcare sector where all medical institutions based on mutual consensus deploy their own network and manage data across themselves for better sharing of data.

2.1 Blockchain Disrupting Traditional Implementations

Blockchain's impact lies in its ability to reshape traditional models by providing decentralized, secure, transparent, and efficient solutions across a wide range of applications. It introduces a paradigm shift in how transactions can be conducted in a trustless manner, and how data is managed, with the potential to revolutionize businesses and improve the way we interact with technology and each other in our day-to-day lives. Below are some of the major factors of blockchain compared with traditional ways of implementation.

2.1.1 Decentralization and Trust

Decentralization is one of the key ideas in blockchain. It means we don't need a middle person to check transactions; instead, a group of computers decides if a transaction is okay. Since everyone can see what is on the blockchain, it is open to everyone, which makes it trustworthy. This is important for things like giving out money or benefits where we want to limit personal choices. (Bashir 2017, 1.) Many systems rely on a central authority to validate and manage transactions, which are central hence leading to single points of failure, allowing data manipulation, and a lack of transparency. In blockchain more specifically public blockchains, transactions are validated by a network of decentralized participants also known as nodes, through consensus mechanisms. This eliminates the need for intermediaries and central control, enhancing trust and transparency as all participants can verify the validity of transactions.

2.1.2 Immutability

Once information is put on the blockchain, it's hard to change. It's not completely unchangeable, but because it is extremely tough and almost impossible to do. This is seen as a good aspect for keeping a solid record of transactions. (Bashir 2017, 1.) Data stored in centralized databases can be altered or deleted by authorized users or hackers. In blockchain, once a transaction is added to a block and confirmed by the network, then due to its immutable nature it becomes nearly impossible to alter data because of its cryptographic hashing and the structure of the chain. This ensures the integrity of historical records.

2.1.3 Security

All transactions on the blockchain are stored with high integrity and by applying cryptography for enhanced security (Bashir 2017, 1). Centralized systems are much more vulnerable to attacks as a single breach can compromise the entire system even if they are physically dispersed and backed up, still, there will always be a single point of attack and failure. In blockchain, security is enhanced through cryptography, consensus algorithms, and its decentralized nature. Hacking one node doesn't affect the entire network. Attackers must take over more than half of the network nodes also known as a 51% attack which makes attacks more difficult and makes the system more robust.

2.1.4 Smart Contracts

Traditional contracts often involve intermediaries and manual processes to enforce agreements. A lot of time is required to follow through manual processes. Smart contracts on the blockchain are self-executing chunks of codes that automatically execute contract terms when predefined conditions are met. This reduces the need for intermediaries or authorities to approve anything, automates processes, and ensures accurate execution strictly based on conditions mentioned in the contract. This is discussed in more detail in chapter three of this thesis.

2.1.5 Efficiency and Intermediaries

Blockchain can enable efficient and faster dealings as it does not require lengthy validation processes, as a result removing extra intermediaries required in these extra processes (Bashir 2017, 1). In traditional systems many transactions involve intermediaries like banks, and brokers leading to delays and incurring extra transactional costs. In blockchain transactions are verified and executed automatically by the network, which handles the need for intermediaries hence leading to faster and effective transactions.

2.1.6 Global Accessibility

In traditional systems cross-border transactions can be complex, involving multiple financial institutions and regulatory hurdles (Bashir 2017, 1). The global nature of blockchain networks allows participants from different parts of the world to transact directly, removing the need for intermediaries and simplifying and speeding up cross-border interactions.

3 SMART CONTRACTS

Smart contracts are programmable self-executing contracts that hold the terms of the agreement written into lines of codes that are agreed to be executed between seller and buyer. Smart contracts are computer protocols that facilitate, verify, and enforce the performance of agreements or transactions without the need for a central authority. They are created on distributed ledger systems, such as blockchain, and are typically written in a programming language such as Solidity. (Levi & Lipton, 2018.)

Smart contracts are like computer instructions that sit on a special kind of digital platform called a blockchain. They are executed automatically when certain conditions are met. Think of them as digital agreements that work by themselves. This can help everyone involved in a deal feel sure about what will happen, even without someone else watching over it. When lots of people are part of a deal, these smart contracts can make everything smoother and more trustworthy, even without a middleman. (Gopie, 2018.)

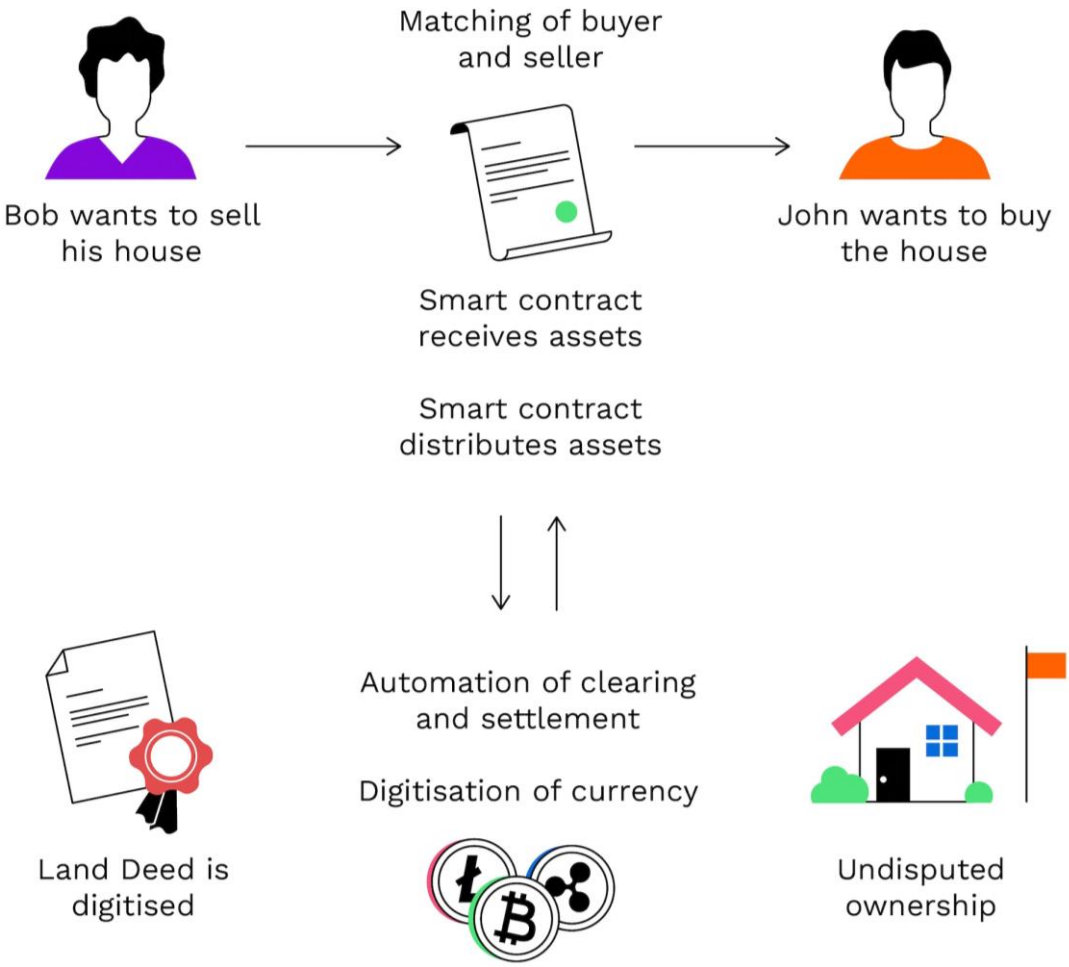
Smart contracts work like computer instructions that follow a pattern of "if ... then ..." statements. They are written in a special code on a blockchain. Below mentioned are the basic components of a smart contract:

1. Conditions: Smart contracts have conditions, like "if certain things happen..."
2. Execution: When those conditions are met, a network of computers commands automatically. For instance, if the right conditions are satisfied, the smart contract will exchange money or desired assets between the people involved in the deal.
3. Update: Once everything is done, the blockchain gets updated to show that the smart contract's job is finished.

To make it clear, imagine a regular stock deal. Normally it happens quickly, in a fraction of a second. Although the trade is quick, the people involved don't have access to each other's stock records. So, they cannot easily check that they both own what they're trading. This means that sometimes transferring ownership of those stocks could take a week. The reason for the delay is that there are a bunch of middlemen who make sure everything is legit. As the record of the trade moves through different organizations, each of them updates its own records. These middlemen vouch for the assets while the process goes on. This is the step where smart contracts come in. They can speed up this whole process

and make it more trustworthy by automating those middlemen's work. This way, the trade could be fast, and secure, and everyone would know what was going on. (Iansiti & Lakhani 2017.)

Smart contracts are designed to automate the transfer of digital assets, such as cryptocurrency or tokens, or any other digital or physical assets decided between two parties. By automating the exchange, these contracts reduce the need for human interference, making transactions faster, more secure, and more cost-efficient. Smart contracts offer several benefits when compared to traditional methods of conducting transactions. Below is the basic depiction of how a smart contract works.

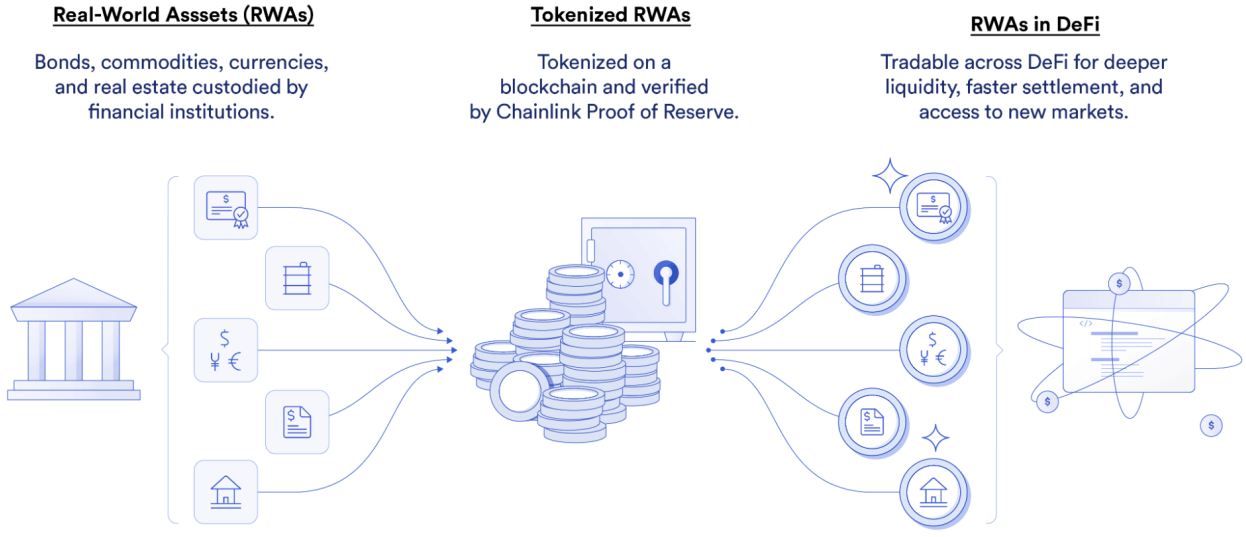


PICTURE 5 Smart Contracts for Managing Digital Assets (Bitpanda 2023)

Furthermore, smart contracts are more transparent than traditional contracts, as all parties involved can view the terms and conditions in real time. Additionally, smart contracts are fully automated, so there is no need for a central authority to oversee the transaction. Smart contracts can be used to facilitate the exchange of goods or services, such as when a buyer sends money to the seller in exchange for a product. They are more cost-efficient, as they eliminate the need for intermediaries and other third-party dependencies. (Gopie 2018.)

4 FROM REAL-WORLD ASSETS TO DIGITAL ASSETS

Digital assets are things having value that exist only on computers in digital form, not as physical or tangible objects. They can be represented in terms of real money like PayPal. For example, virtual currencies work like money in some places, but they don't have all the features of real money. This means they aren't officially recognized as money in any specific region. (Dibrova 2016.) The European Banking Authority (EBA) describes virtual currency assets as digital tokens that are not issued by a government or official body. These assets are not directly linked to regular money but are accepted by regular people or organizations to trade and can be moved, stored, or exchanged electronically. (EBA 2014.) According to a study by the World Bank, real-world assets are things that people value and that can be used to produce other valuable things. This includes land, buildings, infrastructure, and natural resources. Real-world assets are items with economic value that can be owned and exchanged. Commodities, land, and precious metals are all examples of real-world assets. Blockchain technology can be used to create digital representations of these assets, which can be bought, sold, or traded on a blockchain-based marketplace. This allows for the easy and secure transfer of ownership of these assets without needing a central authority.



PICTURE 6 How Asset Tokenization Works? (Chainlink 2023)

Over the years, blockchain has transformed from a simple payment system into a versatile technology that serves as a foundation for various industries. Initially designed for processing transactions, it has expanded its applications to become a fundamental platform for different sectors. This means that blockchain is not only used for making payments but also provides a secure and transparent framework for a wide range of business processes and activities in different industries. (Swan 2015.) Blockchain technology has a lot of chances to be useful for example in real estate. The fact that it's hard to change things once they're on the blockchain, and everyone can see everything, which makes it a good choice. Because of this, people are thinking about using blockchain to do things in real estate. One big idea is to test if it can track who owns land or give permission to use it. This could work by letting people do deals with each other directly, without the intervention of larger institutions. Many people are already looking into this idea and studying it closely (Daniel & Speranza 2020). Blockchain finds applications in tasks such as data management, property ownership transfers, rental and lease agreement management, and real estate investment tracking. However, the full integration of blockchain into real estate processes has not been realized so far. (Garcia-Teruel 2020.)

The idea of dividing and sharing ownership of assets is not a new concept. In the past, this practice was mostly limited to bigger institutions and very wealthy individuals in advanced countries. These investors typically knew each other well and felt confident working together to manage the risks associated with such investments. (Pasimeni 2020.) Tokenization can mean different things. It might be any asset for example a real estate property fractionalized into one million smaller tokens. These tokens will show debts tied to that asset and can be used to show percentage ownership in the property. The term "digitalization of assets" could be used to refer to all these strategies for tokenizing any digital asset.

There are two primary types of tokens: security tokens and utility tokens. Security tokens are like digital versions of real-world investments, such as real estate or commodities, recorded on the blockchain. They can be further categorized into equity tokens, like traditional shares, and debt tokens, which resemble bonds or fractional property ownership on the blockchain. On the other hand, utility tokens provide access to specific services, like cloud storage or conference room usage, rather than financial returns. This report primarily focuses on security tokens, which are akin to digital investments in assets, making them a key area of interest. Below is an overview of the tokenization process and its significance. (Sean Stein Smith 2019.) A token is a digital share of an asset and real estate, works of art, intellectual property are all examples of digital assets also referred to as non-fungible tokens or NFT.

Asset tokenization is the process of converting ownership rights or rights to an asset into digital tokens that are then recorded and managed on a blockchain. This allows real-world assets, which traditionally have been physical and illiquid, to be represented digitally and traded on digital platforms.

The tokenization process consists of four stages, at the identification stage an asset to be tokenized is identified, and its ownership and rights are legally confirmed. Then comes smart contract creation where a smart contract is created on a blockchain, outlining the terms and conditions of the asset ownership. This could include details such as dividend distribution, voting rights, or any other contractual obligations. Then at the token generation stage, digital tokens are generated to represent ownership or rights to the asset. These tokens are then linked to the smart contract, ensuring that the tokens' value and attributes are determined by the asset's real-world characteristics. Then at the distribution and trading stage tokens can be distributed to investors through Initial Coin Offerings (ICOs) or Security Token Offerings (STOs). Investors can then trade these tokens on blockchain-based exchanges, enabling liquidity and access to a broader investor base.

The Significance of asset tokenization will be fractional ownership and accessibility. Asset tokenization allows fractional ownership, enabling multiple investors to own fractions of a high-value asset. This lowers the barrier to entry for investments that were traditionally reserved for high-net-worth individuals or large institutions. Further, traditional assets, like real estate, often suffer from limited liquidity due to their high value and illiquid nature. Tokenization enhances liquidity by enabling investors to buy and sell fractional ownership stakes more easily. Furthermore, as every transaction involving asset tokens is recorded on the blockchain, providing an immutable and transparent record of ownership changes and transactions. This increases accountability and reduces fraud. Moreover, smart contracts embedded in tokens can automate various processes, such as dividend distributions, rental payments, and compliance checks. This streamlines administrative processes and reduces the need for intermediaries.

5 CHALLENGES ASSOCIATED WITH REAL-WORLD ASSETS MANAGEMENT ON BLOCKCHAIN

Tokenizing real-world assets on blockchain presents numerous opportunities to enhance liquidity, transparency, and accessibility. However, these opportunities come with a set of challenges that must be carefully addressed to ensure successful implementation. Overcoming regulatory hurdles, fostering technological literacy, selecting appropriate blockchain platforms, ensuring security and privacy, and assessing the risk of smart contracts during implementation are key steps toward realizing the transformative potential of asset tokenization to real-world assets.

5.1 Regulatory Authorities

Integrating real-world assets into blockchain platforms faces significant regulatory complexities. Traditional assets like real estate, securities, and commodities are subject to established regulatory frameworks that may not have been designed with blockchain technology in mind. This presents several challenges. When a decentralized system spreads across the globe, it's tricky to figure out which rules apply to it. If a company's blockchain operates in many different countries, it could be subject to the laws of all those places. This can make things really complex for transactions in the blockchain. (Salmon & Myers 2019.) Regulatory requirements can differ significantly from one location to another. When tokenizing assets, it's crucial to understand and comply with the specific laws and regulations of each jurisdiction involved in the transaction.

The technology behind digital ledgers (DLT) isn't tied to any specific country due to decentralization. So, even if we can figure out who's who in the digital world, it doesn't solve the problem that no one place is really in charge of this technology. This gets even more complicated because different countries have different laws and rules about cryptocurrencies and crypto assets. For example, Japan doesn't have a single set of rules, and in the UK, the Financial Conduct Authority (FCA) has banned certain blockchain applications, showing a conflict between traditional legal control and the free, automated nature of decentralized markets. So, international law will need to deal with the fact that the rules in this area are all over the place and try to make some common ground about how digital assets are treated under property and contract law. (Lehmann 2019.) Determining the legal status of tokenized assets is complex whether they are considered securities, digital assets, or something else. This classification affects how they are regulated and traded. Securities laws can also be particularly challenging.

If an asset is considered a security, it must comply with securities regulations, including registration, disclosure, and investor protection requirements.

There is an urgent need for countries to collaboratively address digital currency tax compliance, given the unique characteristics of digital assets. One major concern is the taxation of cryptocurrency transactions, which, due to their borderless and pseudonymous nature, pose difficulties for tax authorities in terms of monitoring and regulating them. There is a necessity to adapt national tax systems to ensure proper tax collection and mitigate risks related to illicit digital-assets-related activities with international cooperation and the establishment of standardized reporting mechanisms as essential tools for effectively addressing tax issues in the cryptocurrency landscape. (Baer, Mooij, Hebous, & Keen 2023.) Taxation rules for digital assets may vary from those for traditional assets. Clear guidance on how taxes should be applied to blockchain-based assets is often lacking.

Anti-money laundering (AML) and know-your-customer (KYC) regulations are crucial in financial transactions. Implementing these processes in a decentralized and pseudonymous blockchain environment can be challenging. Many companies are exploring computer systems to enhance the security and compliance of customer data. For instance, in 2017, Bluzelle, a start-up, teamed up with major banks like HSBC, Mitsubishi UFJ Financial Group, and OCBC bank to test a platform for Know Your Customer (KYC) regulations. The results showed potential cost reductions of 25% to 50% and improved monitoring of fraud and money laundering. In another example, SecureKey, a Canadian fintech startup, partnered with IBM and Canadian banks like the National Bank of Canada, and Scotiabank to create a digital identity and verification service. Even Mastercard is experimenting with blockchain technology to securely record and verify transaction ownership. Other innovators in the KYC field include Norbloc, Cambridge Blockchain, Spring Labs, and Blockstack, all working to improve the security and efficiency of personal information handling and transactions – like a team of digital guardians looking out for your data. (Higginson, Halil, & Yugac 2019.)

Addressing regulatory challenges is a key step in realizing the potential of real-world asset tokenization on the blockchain. While it can be complex and time-consuming, compliance with existing and emerging regulations is essential for ensuring the legality and viability of blockchain-based asset management. Collaboration with legal experts who specialize in blockchain and financial regulations is essential. They can help navigate the legal landscape and ensure compliance. For cross-border transac-

tions, understanding and adhering to regulatory requirements in multiple jurisdictions is vital. Furthermore, educating stakeholders, regulators, and policymakers about the benefits and challenges of blockchain technology could lead to more favorable regulatory developments.

5.2 Technology Understanding

Implementing blockchain solutions for real-world assets often involves multiple stakeholders, including asset owners, issuers, investors, regulators, and service providers. However, not all of these parties may have a deep understanding of blockchain technology, smart contracts, and token standards. This lack of technological literacy can pose several challenges. Blockchain technology is still considered emerging, and there's a shortage of skilled individuals who can develop and utilize it effectively. In a 2020 survey, 49% of respondents highlighted the skills gap as a significant challenge. Competition for blockchain expertise is high, making it challenging and costly for organizations to acquire the necessary talent for blockchain adoption. Data reaffirms the issue of limited tech experience, impacting product development and user-friendly interfaces for blockchain applications. One solution to address this skills gap is utilizing Blockchain as a Service (BaaS). BaaS offerings from providers like IBM, Amazon Web Services, and Oracle allow organizations to harness blockchain's advantages without heavy investments in technical talent. This approach has successfully bridged skills gaps in other technologies, such as robotic process automation (RPA), by enabling users to leverage the technology without extensive coding knowledge. Similarly, BaaS can simplify blockchain adoption by eliminating the need for specialized expertise, potentially overcoming the blockchain skills barrier. (Brown & Melchionna 2023.) Blockchain is emerging exponentially, and this has created a gap in skilled talent due to factors like a lack of adoption of newer technologies. This leads to slower developments due to the complexity of new emerging problems. A valid solution requires in-depth research from the most skilled resources to overcome these challenges.

Furthermore, it all comes down to the initial costs. For some companies, the expenses involved in implementing blockchain technology can be too high. Even though many of the current blockchain solutions are free, a substantial investment is needed for hiring skilled software engineers specialized in blockchain development, licensing fees in case a paid software version is preferred, managing the overall administrative aspects, and more. This financial aspect stands out as one of the most significant challenges in adopting blockchain. If businesses are not prepared to allocate a considerable amount of money, it might be more practical to delay the implementation of blockchain technology for the time

being. (Eliaçık 2022.) Without a clear understanding of the technology, stakeholders may struggle to effectively implement blockchain solutions, leading to delays and suboptimal outcomes.

There is also the challenge of integrating blockchain with existing legacy systems. In most cases, organizations need to undergo an in-depth analysis of their outdated systems or formulate a strategy to effectively connect these two technologies when opting for blockchain implementation. Furthermore, organizations that do not have in-house blockchain developers face difficulties in accessing the necessary talent pool to engage in this integration process. Dependence on external sources can exacerbate this issue. Nonetheless, many available solutions in the market demand a substantial commitment of time and resources from the company to successfully carry out this transition. (Eliaçık 2022.)

Addressing the challenge of technological literacy requires proactive measures which include developing educational programs, workshops, and resources tailored to different stakeholder groups. These should cover the basics of blockchain technology, smart contracts, and how they apply to real-world asset management. Accessible materials provide easily digestible materials that explain complex concepts in simple terms. Infographics, videos, and user-friendly documentation can help bridge the knowledge gap. Further clear communication could encourage open and clear communication between technical experts and non-technical stakeholders. Avoiding technical jargon and using analogies can also facilitate understanding. Overcoming the challenge of technological literacy is essential for the successful adoption of blockchain technology in real-world asset management. By empowering all parties with the knowledge and confidence to engage with blockchain systems effectively, organizations can maximize the benefits of blockchain while minimizing potential roadblocks and misunderstandings.

5.3 Choosing the Right Blockchain

Selecting the most suitable blockchain platform for tokenizing real-world assets is a critical decision. Blockchain technology is not one-size-fits-all, and various platforms offer different features, consensus mechanisms, scalability options, and token standards. This complexity can make the choice challenging. One of the primary technological challenges associated with blockchain is its technical scalability, which can potentially hinder widespread adoption, particularly in the case of public blockchains. The capacity to handle a high volume of transactions per second is a distinguishing feature of traditional transaction networks. For instance, Visa can process over 2000 transactions per second. In contrast,

leading blockchain networks like Bitcoin and Ethereum fall significantly short in terms of transaction speed. Bitcoin, for instance, can manage just three to seven transactions per second, while Ethereum can handle up to 20 transactions per second. This limitation in scalability is not a significant issue for private blockchain networks since their nodes are specifically designed to process transactions within a trusted party environment. (Fardian 2022.) Scalability refers to a blockchain's capacity to handle a large number of transactions per second. Choosing a blockchain that can scale to accommodate the expected transaction volume is vital.

While cryptocurrencies offer a level of anonymity, many potential blockchain applications demand that smart transactions and contracts are unquestionably tied to real identities, giving rise to significant concerns regarding privacy and data security. Today, many businesses function under the constraints of regulatory frameworks, and they are entrusted with sensitive information by their customers. However, if all this data is stored on a public ledger, genuine privacy may become an issue. This is where private or consortium blockchain technology can come into play. With this technology, you would have just the necessary level of access, ensuring the confidentiality of your information. (Eliaçık 2022.) Security is paramount when dealing with valuable real-world assets. Assessing the security features of potential blockchain platforms, such as encryption and consensus mechanisms, is crucial.

Another notable problem pertains to the absence of compatibility among the diverse blockchain networks. Multiple projects make use of various, often isolated, blockchain platforms and solutions, each equipped with its distinct protocol, coding language, consensus mechanism, and privacy measures. The embarrassing situation lies in the blockchain industry's current chaotic state due to the absence of universal standards that would facilitate the interconnection of various networks. This lack of uniformity among blockchain protocols adversely affects crucial processes like security, thereby rendering widespread adoption a nearly unattainable goal. (Fardian 2022.) Real-world asset management often involves multiple systems and platforms. Ensuring that the chosen blockchain can interoperate with existing systems is essential for seamless integration.

Because public blockchains are accessible to anyone, and all participants can freely join the network and access its data, they face scalability challenges related to network expansion and the substantial computational power consumption associated with the Proof of Work (PoW) consensus mechanism. (Swan 2015.) To address the challenge of selecting the right blockchain platform in the near future, blockchain solutions like Polygon, Polkadot or Solana, which introduce a secondary layer for faster transactions, dividing nodes into smaller groups for scalability, offer promise to address blockchain's

scalability issue. For example, Solana claims to provide 50,000 transactions per second making it one of the fastest blockchains getting the number way above Visa, which is 2000 transactions per second. However, decentralized networks need to operate within existing regulatory frameworks to ensure resilience to potential disruptions. This requires government and regulated industries to embrace blockchain-specific legislation and regulators to grasp the technology's implications. Establishing industry-wide standards for blockchain protocols can foster collaboration, proofs of concept validation, and seamless integration with existing systems. Choosing the right blockchain platform is a crucial step in ensuring the success of real-world asset tokenization. It requires a comprehensive evaluation process that considers the specific needs of the project and the long-term goals of the organization.

5.4 Security & Privacy Concerns

Security and privacy challenges in managing real-world assets on the blockchain encompass various aspects, including asset custody, regulatory compliance, data privacy, asset provenance, and network scalability. Overcoming these challenges requires a comprehensive approach that balances the unique requirements of real-world assets with the benefits of blockchain technology. Several challenges must be addressed to ensure the protection of assets and sensitive information. Real-world assets often require a secure custody and ownership framework within a blockchain ecosystem. Ensuring that the blockchain can accurately represent the ownership of assets like real estate properties, art, or even intellectual property is a significant challenge. Unauthorized or fraudulent changes to asset ownership records could have severe legal and financial consequences. (Mohanta, Jena, Ramasubbareddy, Daneshmand, & Gandomi 2020.)

Real-world assets often come with confidential data, such as property addresses, transaction histories, or intellectual property details. Protecting this sensitive information from unauthorized access and disclosure is vital. Provenance, or the history and origin of an asset, is crucial for certain asset classes like art and collectibles. Maintaining an immutable record of an asset’s journey is a challenge that blockchain can address.

To address security and privacy concerns, implementing secure custody solutions, such as multi-signature wallets or hardware-based storage, is essential to safeguard the ownership records of real-world assets. These measures ensure that only authorized entities can make changes to asset ownership, enhancing the security of the blockchain system. Utilizing strong data encryption techniques and access

control mechanisms within the blockchain ensures that sensitive data remains confidential. This way, only authorized parties can access specific details associated with real-world assets. Further, blockchain's immutability feature ensures that once information is recorded, it cannot be altered or deleted. This capability aids in preserving the provenance of real-world assets, enhancing their authenticity and value. Addressing security and privacy concerns is essential to build trust in blockchain-based asset management systems. It involves a combination of technical measures, compliance with regulations, and ongoing vigilance to protect both assets and sensitive information from potential threats.

5.5 Smart Contract Risks

Smart contracts are self-executing agreements with the terms of the contract directly written into code. They automatically execute predefined actions when specific conditions or criteria are met. In the context of real-world asset trading on the blockchain, smart contracts are fundamental. They facilitate, automate, and secure the transfer of digital tokens representing real-world assets between parties.

Smart contracts, while powerful, are not immune to bugs or vulnerabilities in the code. These issues can be exploited by malicious actors, leading to unauthorized access, manipulation, or theft of assets. Security audits and code reviews are essential to identify and rectify vulnerabilities. Mistakes made during the development or deployment of smart contracts can result in irreversible consequences. Errors can lead to the loss of assets or funds, negatively affecting users' trust and platform reputation. (Hewa, Ylianttila, & Liyanage 2021.) Ensuring that smart contracts comply with local and international regulations is crucial. Failing to do so can result in legal issues and fines. Implementing Know Your Customer (KYC) and Anti-Money Laundering (AML) procedures within smart contracts can be challenging. The immutability of blockchain transactions means that once a smart contract is deployed, it cannot be easily changed or updated. This can be problematic if issues are discovered after deployment, requiring a new contract to be created. Ensuring that smart contracts accurately represent real-world assets and that these assets can be seamlessly converted to and from digital tokens is complex.

To mitigate risks for smart contracts some measures can be taken like regular code audits by security experts can help identify and resolve vulnerabilities. There are also many code auditing companies that offer these services and are acting standard audit firms namely Hacken and Certik. This is a proactive measure to prevent exploitation. Developers should utilize testing environments to identify and address issues before deploying smart contracts to the main network. Following secure coding practices and

using standardized libraries can reduce vulnerabilities and errors. Where possible, design contracts to allow for updates while maintaining security. However, these updates should be subject to strict governance and approval processes. Work closely with legal experts to ensure smart contracts meet regulatory requirements. Addressing these smart contract risks requires a combination of technical expertise, robust governance, and a commitment to user protection and asset security in real-world asset trading on the blockchain.

6 CASE STUDY – CENTRIFUGE

The Centrifuge Protocol is a pioneering blockchain-based project with a unique mission: to bridge the gap between the real world and the world of decentralized finance (DeFi). In simple terms, it's all about making traditional finance more accessible and efficient using blockchain technology. It is a blockchain project built on the Polkadot blockchain ecosystem. Using Centrifuge almost anyone can borrow money or lend your money directly to others without relying on banks or financial middlemen. Centrifuge makes this vision a reality. At its core, Centrifuge allows real-world assets, which can be tangible things like properties or intangible assets like invoices or other things having value, to be transformed into digital tokens on the blockchain. Here's how it works. Let's say you own a valuable property, and you want to borrow some money against it. Instead of going through a traditional bank, you can use Centrifuge to turn your property's value into a digital token. This token represents a share of your property's worth. Other people, like investors, can then buy these tokens, essentially providing the funds you need. If you repay the borrowed money, you get your property token back. If not, the investors have a claim on your property. (Centrifuge-Docs 2023.)

This approach revolutionizes the way we think about assets and lending. It brings the benefits of blockchain, such as transparency and security, to the traditional financial world, making it more accessible to everyone, from large institutions to individual investors. Essentially, Centrifuge opens up new possibilities for borrowing, lending, and investing in real-world assets, and it's all done on the blockchain.

6.1 Implementation

Think of real assets like houses, cars, or invoices. Centrifuge starts by creating digital certificates for these real assets. These certificates contain critical information about the asset, such as its value, ownership, and perhaps even its payment history. These digital certificates (Smart Contracts) act as proof of ownership and value. When someone wants to borrow money, they can provide this certificate as evidence of their asset's value. It's like saying, "I promise to pay you back, and here's proof that I own this valuable asset." This is achieved by validating smart contracts.

However, not all the information on these contracts should be visible to everyone, especially when dealing with significant investors. This is where Centrifuge's Private Data Layer comes into play. It's like a secure vault where sensitive information is kept hidden. Instead of revealing all the details, Centrifuge uses advanced proofing mechanisms. These mechanisms can include technologies like zero-knowledge proofs or fraud-proof methods. They ensure that the information is both real and secure without revealing any sensitive data. Further, there is a private data layer that operates like a private club of trusted friends who can communicate in secret. They decide who gets to see the confidential information and how much they get to see. Some people might have full access, while others might only see limited details. For instance, large investors might need complete access, while someone else might only need to see a tiny bit. In essence, this Private Data Layer maintains confidentiality and security while still allowing users to leverage their valuable assets as collateral for loans.

The above implementation describes the creation of Smart Contracts for real assets, using these contracts as proof of value and ownership, and ensuring that sensitive asset information remains private through advanced proofing mechanisms and the Private Data Layer. This unique approach brings transparency and security to traditional asset-backed lending in the world of blockchain and DeFi.

6.2 Benefits

Centrifuge offers a range of compelling benefits, both for individuals and businesses, as well as for the broader financial system. The Centrifuge Protocol introduces a level of transparency that is often lacking in traditional financial systems. By operating on a blockchain, it allows participants to see every transaction and movement of assets. This transparency provides a clear window into how financial assets move, how loans are managed, and how investments are secured. In essence, it makes the financial system more open and understandable for everyone involved.

Traditional financial systems can be burdened by high fees and costs, particularly when it comes to intermediaries like banks. Centrifuge leverages blockchain technology to streamline and automate many financial processes, reducing the associated costs. This means that managing loans, transferring assets, and conducting financial operations can be more affordable, benefiting both borrowers and lenders. Centrifuge manages security by implementing Know Your Customer (KYC) and other security measures to ensure that participants are legitimate and transactions are conducted lawfully. Additionally, the blockchain's inherent security features make it resistant to tampering or fraud. This provides a

high level of confidence for users looking to tokenize their assets and engage in lending and borrowing activities within the Centrifuge ecosystem.

These benefits collectively make the Centrifuge Protocol an attractive option for individuals and businesses seeking more accessible, cost-effective, and secure financial solutions. It has the potential to democratize finance by bringing greater transparency and efficiency to the world of asset-backed lending, all while operating on the decentralized and trustless foundation of blockchain technology.

6.3 Challenges

While the Centrifuge Protocol and similar blockchain-based DeFi projects hold immense promise, they are not without their challenges, especially in the early stages of adoption. Blockchain technology and decentralized finance can be complex and require a good understanding of how they work. This can create a barrier to entry for individuals and businesses who are not familiar with these technologies. Overcoming this complexity is essential to broadening adoption.

The regulatory environment for DeFi is still evolving. Different countries have varying approaches to regulating blockchain and cryptocurrency activities. Navigating this regulatory landscape can be challenging for DeFi projects like Centrifuge and its users, as compliance requirements may change over time. DeFi projects like Centrifuge rely heavily on smart contracts, which are not immune to bugs or vulnerabilities. Flaws in smart contracts can lead to security breaches and financial losses. Auditing and securing smart contracts are ongoing challenges for similar projects.

As more users and assets enter the DeFi ecosystem, scalability becomes a concern. The Ethereum network, where many DeFi projects are built, has faced congestion and high gas fees during periods of high demand. Solutions for scaling the network while maintaining security are actively being developed. The cryptocurrency market is known for its price volatility. This can impact the value of assets within the DeFi ecosystem and create uncertainties for users and investors.

Many potential users are not aware of DeFi or do not fully understand its benefits. Educating individuals and businesses about the advantages and risks of DeFi is an ongoing challenge. Despite these challenges, the DeFi space continues to evolve rapidly, with projects like Centrifuge actively addressing these issues and working to make DeFi more accessible and user-friendly. As the technology matures

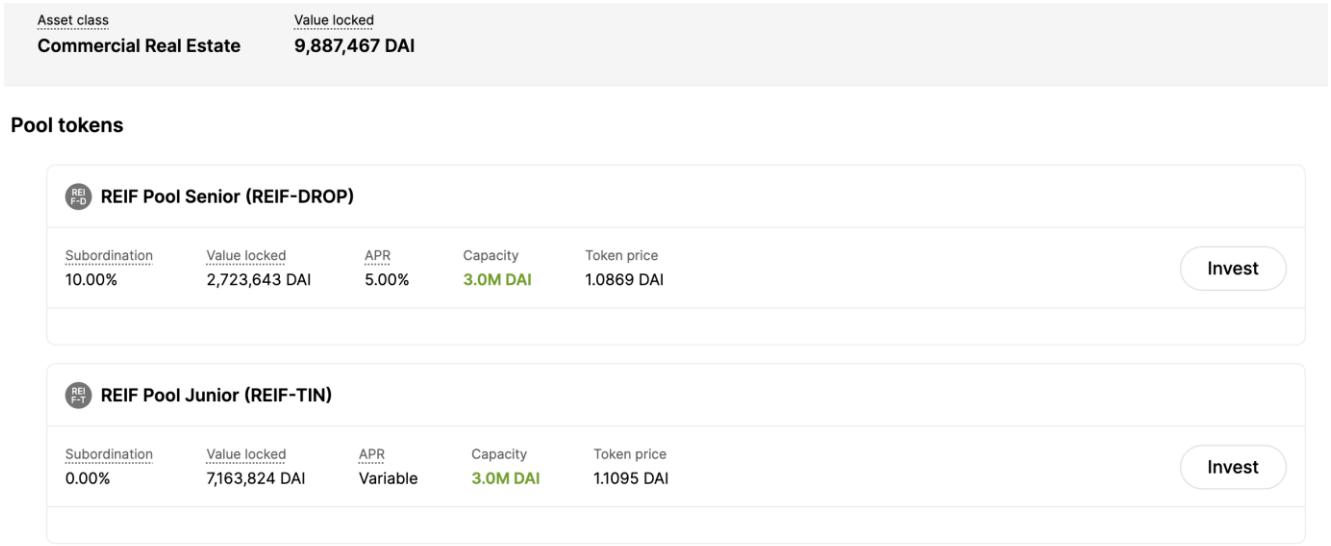
and regulatory clarity improves, the barriers to entry are expected to decrease, and more people and businesses may embrace DeFi solutions.

6.4 Case Study of a Real Company

Centrifuge is managing the companies in several asset classes companies, including Real Estate Loans, Commercial Real Estate, Cargo, Debt Facilities, etc. Details of which can be checked on their public web application, where there are many pools created for several companies. For the sake of the thesis, a company named REIF Pool LLC was considered, which is able to lock 9.8 million dollars of digital assets against its real assets. The value shown is in DAI currency, which is a stable virtual currency pegged against US dollars which means that one DAI is always equal to one dollar.

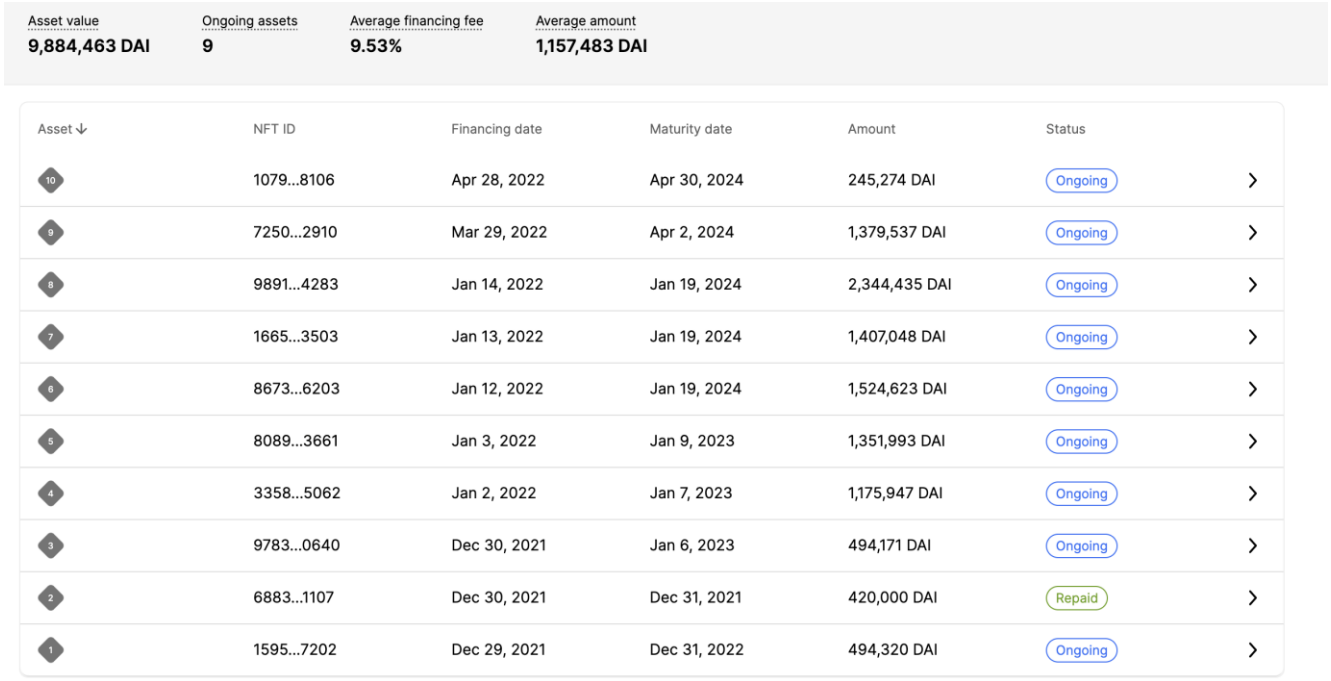
Centrifuge actively collaborates with companies across various asset classes, offering them the opportunity to leverage the benefits of the Centrifuge Protocol for a wide range of assets, including real estate loans, commercial real estate, cargo, and debt facilities. To provide a more concrete example, let's explore a case study involving a company known as the REIF. There are multiple pools created for this company where investors can add their liquidity against their collaterals.

This company is an excellent illustration of how Centrifuge is applied in the real world. It uses the Centrifuge Protocol to tokenize and manage assets worth a substantial $9.8 million in digital assets, all backed by real-world assets. More details can be checked on their website with all the transaction data happening on the blockchain.



PICTURE 7 Centrifuge Pools - REIF Pool (Centrifuge 2023)

In the case of the REIF Pool, Centrifuge facilitates the tokenization of assets, allowing them to be represented as digital tokens on the blockchain. These tokens represent ownership stakes in the underlying real-world assets. In this scenario, the assets can be anything from real estate properties to other valuable assets. Once these assets are tokenized, investors can participate by purchasing these tokens, effectively investing in the underlying assets. This approach significantly broadens the range of potential investors, as individuals and entities can participate without the traditional barriers associated with asset ownership.



PICTURE 8 REIF Investment Pool (Centrifuge 2023)

Centrifuge ensures that the assets remain secure and transparent through its innovative security and privacy features. This is critical for maintaining trust and confidence in the system. Its approach also allows for diversification, spreading the risk across a broader range of assets. This can contribute to stabilizing long-term value and overall protocol health. By enabling companies like the REIF Pool and may others too, to leverage the Centrifuge Protocol, Centrifuge plays a crucial role in making the financial system more inclusive, transparent, and efficient. It empowers businesses to access financing more easily and provides a platform for a diverse range of investors to participate in previously exclusive asset classes.

This real-world case study demonstrates how Centrifuge is actively bringing traditional assets into the DeFi space, making it possible for a broader range of assets to be tokenized, traded, and invested in by a more diverse group of participants. It showcases the practical application of blockchain technology and DeFi principles to revolutionize traditional finance.

7 CONCLUSION

The tokenization of real-world assets on blockchain technology represents a transformative shift in the world of finance and asset management. This thesis has explored the fundamental concepts, challenges, benefits, and real-world applications of this innovative approach, shedding light on the potential and hurdles of this emerging field.

The advent of blockchain technology, coupled with the rise of decentralized finance (DeFi). It has provided the infrastructure to bridge the gap between the traditional financial world and the decentralized digital ecosystem. The blockchain acts as a secure, transparent, and immutable ledger, enabling the conversion of real-world assets, from real estate to fine art, into digital tokens. These tokens can be traded, invested in, and utilized as collateral for loans in a decentralized, peer-to-peer manner.

One of the key challenges addressed in this thesis is the regulatory landscape. Tokenized assets must navigate a complex web of regulations, varying from one jurisdiction to another. Collaboration with legal experts and regulatory authorities is paramount to ensure compliance and to pave the way for wider adoption. Furthermore, technological literacy must be promoted among all stakeholders, from asset owners to investors, to bridge the communication gap and facilitate the implementation of blockchain solutions.

The choice of the right blockchain platform is a critical decision, and careful consideration of factors such as scalability, security, interoperability, and community support is vital. Security and privacy concerns are crucial, as tokenized assets hold significant value. Robust cybersecurity measures, privacy-preserving technologies, and smart contract audits are essential to build trust and protect sensitive information.

Another vital aspect is the cost-effectiveness of implementing blockchain solutions. A comprehensive cost-benefit analysis, along with scalability planning, the use of open-source solutions, and shared infrastructure, can help optimize resources and budget allocation.

This thesis also examined a real-world case study involving Centrifuge, a pioneer in bridging the gap between real-world assets and DeFi. The company's approach showcases how assets, from real estate loans to commercial real estate, can be tokenized and managed securely on the blockchain. This case

study illustrates the tangible benefits of transparency, lower costs, and security that blockchain-based asset tokenization can offer to individuals, businesses, and the broader financial system.

Despite the challenges, including complexity, regulatory uncertainty, user experience, smart contract risks, scalability concerns, market volatility, and the need for education and awareness, the DeFi space continues to evolve rapidly. Companies like Centrifuge actively address these issues, working to make DeFi more accessible and user-friendly. As technology matures and regulatory clarity improves, the barriers to entry are expected to decrease, paving the way for broader adoption.

In conclusion, the tokenization of real-world assets on blockchain technology is a promising solution to revolutionize the financial landscape. It offers transparency, lower costs, and security while creating opportunities for more inclusive, accessible, and efficient financial systems. While challenges remain, the ongoing evolution of blockchain technology and DeFi platforms promises to drive innovation, broaden adoption, and ultimately reshape the way we perceive and manage assets in the real world.

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