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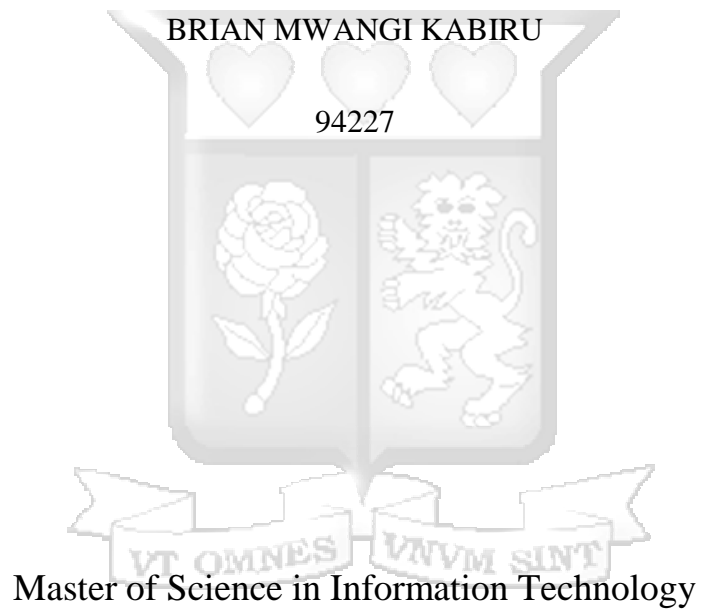
Kabiru, Brian Mwangi  
*School of Computing and Engineering Sciences*  
*Strathmore University*

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# A Prototype for Securing Non-Digital Assets using Non-Fungible Tokens



2022

# **A Prototype for Securing Non-Digital Assets using Non-Fungible Tokens**

By

BRIAN MWANGI KABIRU

94227

Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in  
Information Technology at Strathmore University

School of Computing and Engineering Sciences

Strathmore University

Nairobi, Kenya

October 2022

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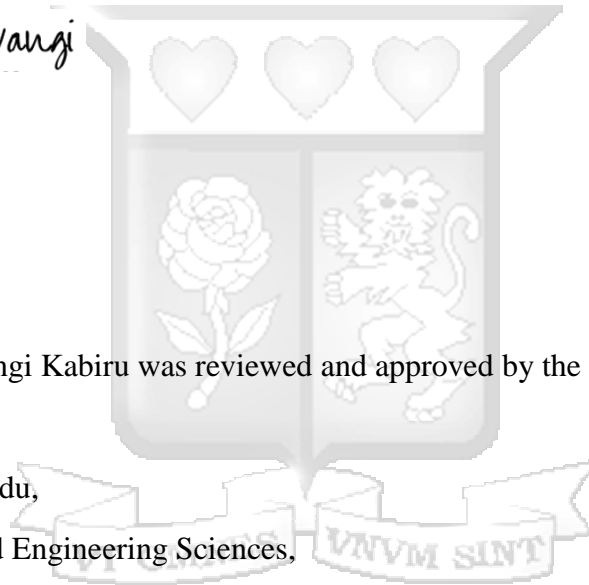
### Approval

The thesis of Brian Mwangi Kabiru was reviewed and approved by the following:

Prof. Ismail Ateya Lukandu,  
School of Computing and Engineering Sciences,  
Strathmore University

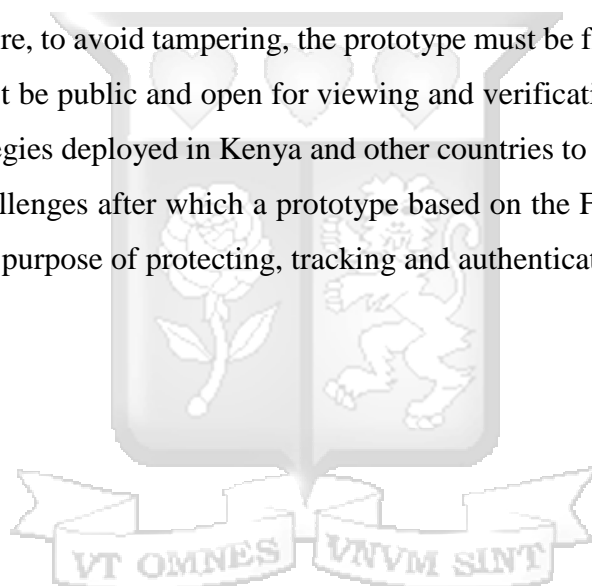
Dr. Julius Butime,  
Dean, School of Computing and Engineering Sciences,  
Strathmore University

Dr. Bernard Shibwabo,  
Director of Graduate Studies,  
Strathmore University



## Abstract

In the capitalistic world, there are many people acquiring and transacting assets. While many of them go about it the legal way, there is also substantial number of those that use any form of trickery to acquire the said assets in the form of forgery. Normal citizens as well as government institutions and financial institutions deal with non-digital asset documents during their day-to-day operations. The analysis of the said documents is not only time consuming but also stressful for the human resources to go through. While there exist many methods to analyse the documents, there is also an affinity to doctor the documents or bypass the process of verification which has many ripple effects. Due to this and other factors, there is need to develop a prototype to protect the integrity of non-digital assets in an automated form that is accessible to both the individual and the institution. Furthermore, to avoid tampering, the prototype must be free from mutable changes and the said changes must be public and open for viewing and verification. This research aims to explore the existing strategies deployed in Kenya and other countries to protect non-digital assets, their merits and their challenges after which a prototype based on the Flow Blockchain Network will be developed for the purpose of protecting, tracking and authenticating non-digital assets.

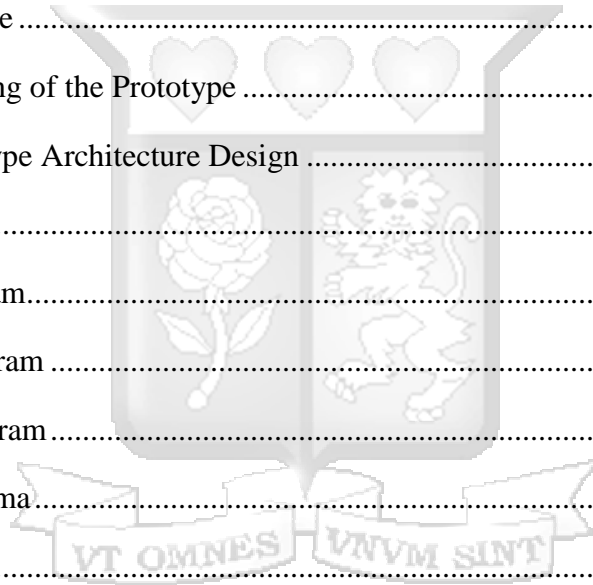


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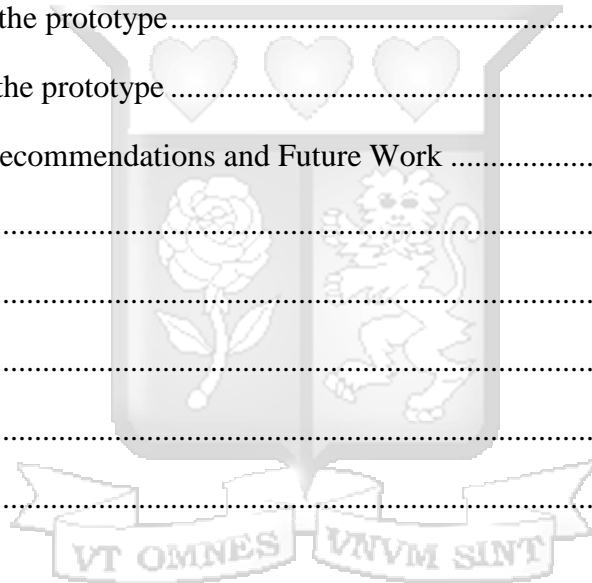
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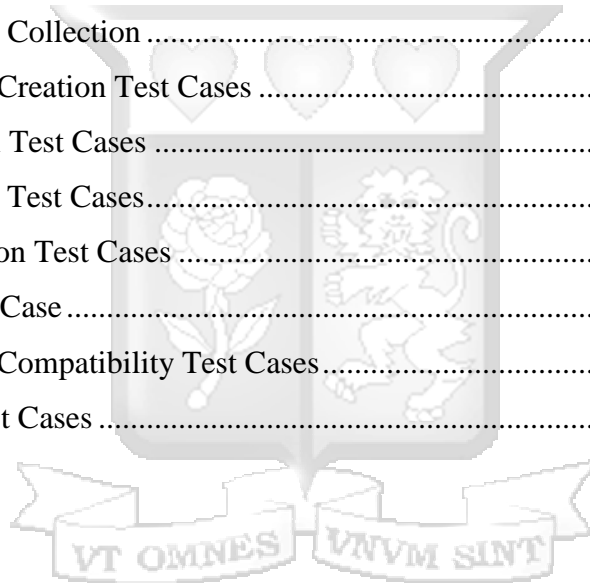
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## Abbreviations and Acronyms

<b>AES</b>	-	Advanced Encryption Standard
<b>DNA</b>	-	Deoxyribonucleic Acid
<b>ECITIZEN</b>	-	Electronic Citizen Portal for Government services
<b>ERC</b>	-	Ethereum Requests for Comments
<b>EVM</b>	-	Ethereum Virtual Machine
<b>ICO</b>	-	Initial Coin Offering
<b>NACOSTI</b>	-	National Council for Science, Technology, and Innovation
<b>PDF</b>	-	Portable Document File
<b>QR</b>	-	Quick Response
<b>RTO</b>	-	Registered Training Organisation
<b>SPSS</b>	-	Statistical Package for Social Science
<b>SURF</b>	-	Speeded Up Robust Features



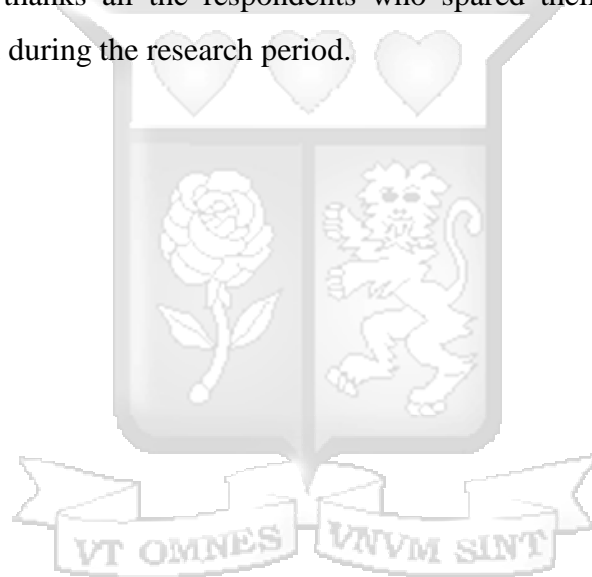
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Lastly, I would like to thank all the respondents who spared their time to respond to my questionnaires conducted during the research period.



## Definition of Terms

### **Ethereum Requests for Comments**

These are technical documents used in the Ethereum community that are used for smart contract development by defining the rules required to implement tokens ("Ethereum ERC Standards You Should Know About", 2021).

### **Initial Coin Offering**

An asset distribution method that involves the sale of digital asset, such as Ether, in exchange for monetary funds with the goal of raising capital for a blockchain project ("Initial Coin Offerings: The Ethereum ICO Boom | Gemini", 2021).

### **Non-Fungible Tokens**

A cryptographic asset on the blockchain with unique identification characteristics and metadata that make it unique. Hence, they cannot be traded at the level of equivalency (Sharma, 2021).

### **Sharding**

A database partitioning technique used by blockchain technologies with the aim to improve scalability by splitting the entire network into smaller partitions (Frankenfield, 2021).

### **Smart Contracts**

A program that is created, deployed and used on the Ethereum blockchain. These programs allow multiple parties to securely perform transactions without having to know or trust each other (Zhang & Lee, 2021).

# Chapter 1: Introduction

## 1.1 Background

### *1.1.1 Assets*

Assets are resources with an attached economic value and whose ownership falls under an individual, company or government (Folger, 2021). The general expectation after the acquisition of an asset is that it will provide benefits such as generated cash flow over a period of time (Barone, 2021). The ownership of an asset via means of a right or access is legally enforceable which means that the owner can use it as they please.

While there are various categories of assets, the focus will be on non-digital and digital assets. Digital assets refer to files that are generated electronically on various devices such as a computer or mobile phone. Examples of digital assets include images, video and documents. Further than that, digital assets include more than just files and can be generated data or tokens (Graham, 2021). While it is easy to create a file and term it as a digital asset, its monetary value is highly based around the context it is used. Hence, if a PDF, short of portable document file, of a book is sold at select platforms generating income in a free market, then the PDF can be said to have monetary value ("The Value of Digital Assets in Your Estate Plan - Stephen Scriber", 2021).

Non-digital assets are well known as tangible assets. These assets exist in physical form and have monetary value and one gains ownership over them with the prospect of financial gain over a period of time. Tangible assets are split into two: fixed assets and current assets. Fixed assets are assets that are held on for a long period of time and include land, real estate, equipment and vehicles and are less liquid because they take time to be transacted. On the other hand, current assets are more liquid and can easily be exchanged and examples include cash and securities (Kenton, 2021). Since assets need ownership, there are legal documents that record the ownership of various assets and are held by the individual or company and these document act as evidence ("Asset Ownership or Interest - Asset Management Software | Ansarada", 2021).

### *1.1.2 Blockchain protocol*

The blockchain protocol is a distributed database that is shared among the nodes within a computer network. Though it was first proposed in 1991, the concept became famous after the conception of the cryptocurrency system Bitcoin whereby it is used to maintain a secure and decentralized, public and immutable record of transactions (Hayes, Brown & Kvilhaug, 2022).

The major difference between the blockchain protocol and a normal database is in the structures of the data stored. The blockchain protocol hold information together in blocks which have certain storage parameters that when met, hashes the block then closes the block after which it is linked to the previous block making the data in it immutable. These blocks are built using transaction information which goes through the following process to be validated:

- i. A new transaction is initiated.
- ii. The transaction is then transmitted to a network of peer-to-peer computers called nodes.
- iii. The network of computers then solves a mathematical equation to confirm the validity of the transaction.
- iv. Once confirmed to be a legitimate transaction, the transaction is clustered in the current highest block in the chain.
- v. These blocks are then chained together thus creating a history of all transactions that are permanent.
- vi. The transaction is marked complete.

(Hayes, Brown & Kvilhaug, 2022)

The blockchain protocol includes three major concepts that are all essential in its running and ensuring the transactions are stored as needed:

#### *1.1.2.1 Blocks*

A blockchain block is a data structure where the transaction data in the network are permanently recorded. Each block on the blockchain has three basic elements which are the data in the block, a 32-bit whole number called nonce which is a random number generated at the blocks creation and a hash which is a 256-bit number that is wedded into the nonce (Frankenfield, 2022).

#### *1.1.2.2 Nodes*

A blockchain node is any electronic device connected to the network that maintains copies of the blockchain and ensures the network is functioning. All nodes keep a local copy of the

current state of the blockchain and for any update to be done, the network must algorithmically approve a new mined block after which the nodes update their local copy (Bertagnoli, 2022).

#### *1.1.2.1 Miners*

A blockchain miners create new blocks on the network through a process called mining. To achieve this, miners have to solve incredibly complex math problem of finding a nonce that generates an accepted hash which will be attached to the new block. The massive computation power needed to find the nonce is because in an instance, there exists more than four billion possible nonce-hash combinations that must be computed before the right one is found. Whichever node finds the right nonce, it is rewarded by the network and the new block is created and added to the chain (Bertagnoli, 2022).

#### *1.1.3 Ethereum*

Ethereum is the most popular blockchain protocol that supports a virtual machine on which Turing-Complete scripting languages can be executed (Buterin, 2013). Due to the fact that Ethereum is a public and permissionless blockchain protocol, it allows for any individual to create, deploy and use programs on its infrastructure. These programs, also called smart-contracts, allow multiple parties to securely perform transactions without having to know or trust each other (Zhang & Lee, 2021).

The Ethereum protocol is similar in infrastructure with the blockchain protocol with the only addition being that can be programmable using smart contracts. Also, from 2013, Ethereum also uses proof of work as it's consensus protocol but as of 2020, Ethereum is moving to a different consensus protocol called proof of stake (Reiff & Anderson, 2022).

#### *1.1.3.1 Fungible tokens*

Due to Ethereum's popularity, there exists a community of developers that update its core structure, develop code around it and build various use cases. Hence, for structure and interoperability, the community agreed on various application-level standards called Ethereum Requests for Comments ("Ethereum ERC Standards You Should Know About", 2021). The most popular standard is called the ERC-20. The ERC-20 is a standard for fungible tokens and an interface that allows for tokens on the Ethereum blockchain to be used by different applications from wallets, decentralized exchanges and even decentralized applications. The ERC-20 standard has grown popular due to the Initial Coin Offerings boom of 2017 and 2018 where \$6.3 billion was raised in the first three months of 2018 alone ("Initial Coin Offerings: The Ethereum ICO Boom | Gemini", 2021). An Initial Coin Offering is an asset distribution

method that involves the sale of digital asset, such as Ether, in exchange for monetary funds with the goal of raising capital for a blockchain project.

### *1.1.3.2 Non-Fungible tokens*

While the ERC-20 standard was popular with fungible tokens, a token standard for non-fungible tokens was lacking. To understand a non-fungible token, one must first grasp what the term fungible means. The Merriam Webster dictionary defines fungible as “*being something (such as money or a commodity) of such a nature that one part or quantity may be replaced by another equal part or quantity in paying a debt or settling an account*” (“Definition of Fungible”, 2021). The Kenyan fifty-shilling note, for example, is fungible. Hence, if you give a cashier such a note, they can swap it for another fifty-shilling note and give it back to you. The notes in the example have the same value and thus exchangeable. Ether, the cryptocurrency of the Ethereum network, is also a fungible token. 1 ether in my wallet is equal to 1 ether in another individual’s wallet and both can be exchanged with minimum effort.

Non-fungible tokens, on the other hand, represent a unique, authentic and distinct object of value. Due to their nature, non-fungible tokens have the following characteristics: they cannot be replicated, they cannot be counterfeited, they cannot be created on demand and possess ownership rights (Sharma, 2021). The characteristics of a non-fungible token makes it the ideal standard to digitally represent physical assets like collectibles, artwork and real estate. With this need, the ERC-721 standard was introduced in the Ethereum network in 2017 specifying a standardized interface for non-fungible tokens and whose purpose was to represent ownership (Ethereum Proposals, 2021).

The most widely known use case for non-fungible tokens is the virtual online game called CryptoKitties. The game allowed for players to collect, breed and sell their virtual cats for real money. The selling point was that all the virtual cats were created by a ‘genetic algorithm’ which ensured that all cats were different. Because of their uniqueness, the virtual cats were based on the ERC-721 standard which made them non-fungible tokens (Ivan, 2021). CryptoKitties was so popular that at one point, the game took more than half of the Ethereum transaction capacity in late 2017 (Hertig, 2021).

Non-fungible tokens can help facilitate the tokenization of assets, both digital and non-digital, such as artwork, software licenses, intellectual property, educational certificates and even legal documents. Many experiments are now taking centre stage with websites such as NBA Top Shot tokenizing NBA moments, the CEO of Twitter Jack Dorsey selling a tokenized version

of his first tweet for \$2.9 million and an artist by the name Beeple selling his non-fungible token painting for \$69 million (Sharma, 2021).

#### ***1.1.4 Tokenization***

Asset tokenization is the process through which a blockchain token is issued to digitally represent any real tradable asset. This digital representation can either be a complete or shared ownership for the entity that has specific value (Geroni, 2022). Under the hood, a digital representation, or data structure, is created holding all the characteristics pertaining the physical asset and then submitted on the blockchain for permanence.

Tokenization is also different from securitization whereby low-liquidity assets are converted into higher-liquidity security instruments that can be traded in financial markets. It also differs from fractional ownership which provides an opportunity for unrelated parties to join forces and enjoy the benefits of trading digitally ("The Ultimate Guide for Asset Tokenization on Blockchain", 2022).

Some of the advantages of tokenization include:

- i. Great liquidity – Tokens representing physical and private assets can easily be created and pushed on platforms where interested parties can easily find them when before the visibility took more time. The owners can also exit the platform at their own will.
- ii. Higher accessibility – Tokenized assets can easily be fragmented to the minimum possible denomination when represented digitally and can encourage investment.
- iii. Transparency – Tokenized assets are also embedded with information on the owners and the assets history. They can also contain instructions that allow the original owners to benefit from every consecutive sale.

("The Ultimate Guide for Asset Tokenization on Blockchain", 2022).

#### **1.2 Problem Statement**

Keeping track of one's assets requires a lot of time and effort. This is also coupled with having to authenticate one's ownership or authority over the asset. While various documents accompany the asset to certify the ownership of the assets such as land and vehicles, there is the burden of physically securing the documents, keeping track of them and avoiding forgery. Recently, the government unleashed a new online portal for the land registry called ArdhiSasa. However, according to their FAQ, the platform "is a one-stop shop for all land transactions, currently only covering Nairobi area" (Is Ardhisasa the official site for the Ministry of Lands

and Physical Planning? - Ministry of Lands and Physical Planning, 2021). As noted, just covering the Nairobi area is a limiting factor when other services like E-citizen are available countrywide and even for the illiterate, they easily receive help from places such as cyber cafes. While the government promised Kenyans that the website will help curb fraud by putting an end to manual transactions, it is still not clear how the system aims to do so in the background to ensure the transactions are genuine (Muriithi, 2021).

## 1.3 Objectives

### 1.3.1 General Objectives

The aim of this study was to develop a prototype for tokenizing non-digital assets in order to prove their ownership, authenticity and uniqueness. The history of the asset from creation would be tracked with new developments being appended to the token.

### 1.3.2 Specific Objectives

- i. To investigate the challenges faced in securing non-digital assets
- ii. To analyse the different techniques and models used for detecting fraud in documenting non-digital assets
- iii. To review existing frameworks used for the development of the blockchain applications
- iv. To design a blockchain prototype to tokenize non-digital assets in Kenya.
- v. To test the developed prototype.

## 1.4 Research Questions

- vi. Which challenges are faced in securing non-digital assets?
- vii. Which techniques and models are used for detecting fraud in documenting non-digital assets?
- viii. Which existing frameworks are currently used for the development of the blockchain applications?
- ix. How can a blockchain prototype to tokenize non-digital assets in Kenya be designed?
- x. How can a blockchain prototype be tested?

## **1.5 Justification**

The government of Kenya and private practitioners have come up with ways to streamline the registration and verification of documents representing non-digital assets such as land and vehicles. The methods used are both manual and automatic. However, there is still a need of having a centralised and reliable system that individuals can use to secure their non-digital assets. Blockchain technology and the ERC-721 token standard can come in handy to tokenize non-digital assets as they offer transparency, easy tracking of ownership and enhanced security.

A further review of literature revealed that research on the use of non-fungible tokens for purposes of tokenizing non-digital assets, their benefits and their challenges has been minimal in Kenya and the world (Muthupalaniappan, 2021). This additionally justifies the need for conducting this research.

## **1.6 Scope and Limitation**

The scope of the prototype built for the tokenization of non-digital assets in Kenya will involve the primary functionalities of the minimal viable product which are to allow user authentication, allow users to view their tokenized assets, allow users to tokenize new assets and allow users to transfer assets they own to other users in the system. Authentication is key as it allows the prototype to query the logged in user and hence allow them to transfer assets that they own. Other than that, authentication allows for the user to be assigned a Flow blockchain address where all their non-fungible tokens will be stored. During tokenization of a new asset, a non-fungible token will be made on behalf of the user and stored on the Flow blockchain and the transaction ID will be saved for later validation. The transfer of assets will also be done on behalf of the user by changing the ownership of the non-fungible token from their own Flow blockchain address to the recipient's Flow blockchain address.

On the other hand, the limitation of the prototype is pegged on the Flow blockchain. Since it is a new blockchain that is actively being developed, it still does not have the capability to store files. In terms of the prototype, this would be essential when a user wants to upload scanned copies of the non-digital asset's documentation as more proof of ownership. Once this feature is implemented on the Flow blockchain, the prototype can then be updated to make use of it.

## Chapter 2: Literature Review

### 2.1 Introduction

According to Maslow's hierarchy of needs, there are five different tiers to human needs. Beginning from the bottom of the pyramid going up, with the bottom tier having the most crucial needs, the levels include: physiological needs, safety needs, belonging needs, esteem and self-actualization (McLeod, 2021). After the bottom needs are satisfied, humans aim for safety needs which include different types of security such as financial security. Financial security by means of employment, the acquisition of assets and even social welfare also elevate the living conditions of the individual. Many people tend to go about the acquiring of assets through the legal and proper channels but others do not. While dealing with documents proving ownership of assets, the act of document falsification and forgery is on the rise especially in the digital age and many cases still go undetected (Ana, 2017). This research shows several measures in place to detect non-digital asset document falsification and forgery and the challenges faced. The research will go through both traditional and automated systems used to counter this type of fraud and finally the design, development and testing of a non-fungible token prototype for securing non-digital assets in Kenya.

### 2.2 Empirical and Theoretical Literature

#### *2.2.1 History of Forgery and Types of Document Fraud*

The crime of forgery has existed since writing existed and documents were used to trace transactions between peers. Laws against this crime can also be traced back to the 1500 where in England it was officially prohibited to forge publicly recorded and sealed documents. In the West, falsely making and alteration of any kind for the purpose of getting financial gain was introduced in the year 1823 ("History of Forgery", 2007).

In Kenya, there have been numerous documented cases of document such as title deeds and log books been forged or falsified and being used in various transaction (Openda, 2021) as well as ambiguous title deeds leaving Kenyans in Eldoret unsettled (Badoux, 2018). The Ndungu Report on land and graft in Kenya also indicates that land issues in Kenya are mainly caused by social problems and lack of the proper tools and technology to manage the issuance of legal title deeds (Southall, 2017).

The seven types of documents and identify fraud according to Onfido ("How to Detect the 7 Types of Document and Identity Fraud", 2018) are split into three categories and include:

- i. Modified documents which are original documents with alterations include:
  - a. Forged Documents – These are documents where the information presented is altered through either changing certain variables, inserting foreign pages or removing some pages.
  - b. Black Stolen Documents – These are documents which get leaked with blanks from their origin and false information is inserted.
- ii. Illegitimate documents which are entirely new but false creations include:
  - a. Counterfeit Documents – These are documents which try to mimic the original document. They are created after one gets a hold of the original template used.
  - b. Compromised Documents – These are documents which are government-issued made available to the public.
  - c. Camouflage Documents – These are documents created by authorities that do not exist or those that are not allowed to generate documents.
- iii. Falsely Represented documents which might be legitimate or not but which do not belong to the individual presenting them include:
  - a. Fraudulently Obtained Documents – These are documents obtained in ways that compromise their validity such as using different user details but not your own.
  - b. Imposter Documents – These are documents that are legitimate but they get presented by another person claiming they belong to them.

### **2.2.2 History of Blockchain technology**

The Blockchain technology is often synonymous with Bitcoin which was created by an anonymous person or group of people using the pseudo name 'Satoshi Nakamoto'. However, this blockchain concept borrows from proposals done years earlier. The first known public proposed blockchain-like protocol was done by cryptographer David Chaum in 1982 under his dissertation called "Computer Systems Established, Maintained, and Trusted by Mutually Suspicious Groups" (Sherman, Javani, Zhang & Golaszewski, 2019). Further work by Dave Bayer in 1992 added Merkle trees to the design which allowed multiple documents to be collected into a single block whose timestamp was immutable (Narayanan, Bonneau, Felten, Miller & Goldfeder, 2016). Building upon this, Satoshi Nakamoto implemented a proof-of-work system to timestamp blocks without a trusted signing party which then became the core

concept of the Bitcoin cryptocurrency. By using this timestamped block system, the blockchain then transformed into a public ledger holding all transactions made in the history of its existence (Conway, 2021).

## **2.3 Methods and Frameworks**

### ***2.3.1 Traditional Methods of Document Verification***

The traditional methods of document verification mainly involve manually going through the document itself. Since this method is mainly reliant on human resources, there are several challenges that arise from the manual process. Some of problems arising from manual document verification include the betrayal of individuals who are meant to do the verification taking advantage of their position, bigger expenses since more human resources are needed to do the verification, slow and time-consuming processing and also human errors ("Manual vs. Automated Identity Check: What's Better and Why? | Biometric Update", 2021).

Looking at the history of Kenya, important documents such as title deeds begun with simple registration under the Registration of Documents Act by the colonial administration even though land was still communally owned. This process showed a record of transaction but the state could still not vouch for the validity. After, came the Government Land Act which gave the president the ultimate power to sign documents granting title. Now we have the Land Act which states various methods involving acquisition, administration and management of land – public or private (Guandaru, 2021).

While all these acts came in place to help validate land ownership including the digitization of the land registry, service delivery still experiences bottlenecks. An individual has to visit the Ministry of Lands or the Land Offices in their Sub County in person or through the E-Citizen website which could take up to two weeks to receive feedback.

### ***2.3.2 Automated Methods of Document Verification***

There have been various methods proposed for automatic methods of document verification. One such proposed method proposed by Sumeena and Muhammed (2020) is the use of unique Quick Response (QR) codes for vehicle verification. Their implementation would take all the documents related to the vehicle, digitize them by scanning then uploading them to a central database where an RTO admin will be in charge. The system would use AES algorithm to provide security and ensure the documents are not easily tampered with. Once the documents

are uploaded, a QR code is generated which when scanned using a mobile device, fetched the documents pertaining the vehicle.

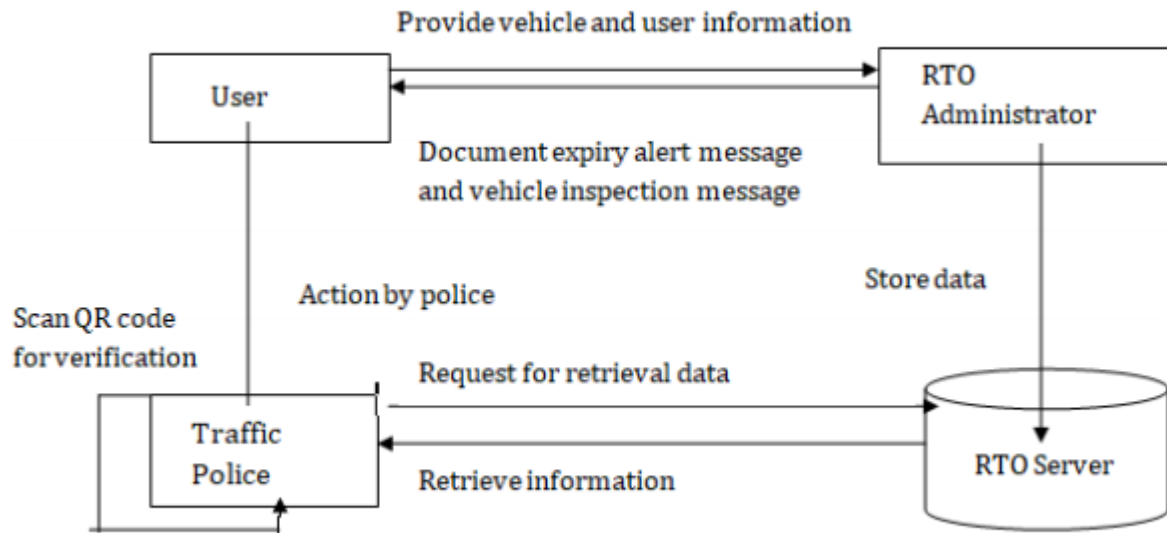


Figure 2.1: Unique QR Code for Vehicle Verification Proposed System (Sumeena, S., Muhammed Hassan, A., & Vasav, V, 2020)

The weakness of using unique QR codes for vehicle verification is that the data is stored in a centralized server. While it can be backed up regularly, downtime or connection issues to the server can have impact on the service delivery of the QR codes. Other than that, the data stored can also be manipulated by the RTO administrators without the knowledge of the vehicle owners.

Another method for document verification is the use of deep learning for offline signature recognition and forgery detection proposed by Poddar et. al (2020). Especially in banking systems, offline signatures are the most widely adopted biometric authentication technique. The proposal introduces a novel method for signature recognition and forgery detection using a convolution neural network, Crest-Trough method, SURF algorithm & Harris corner detection algorithm.

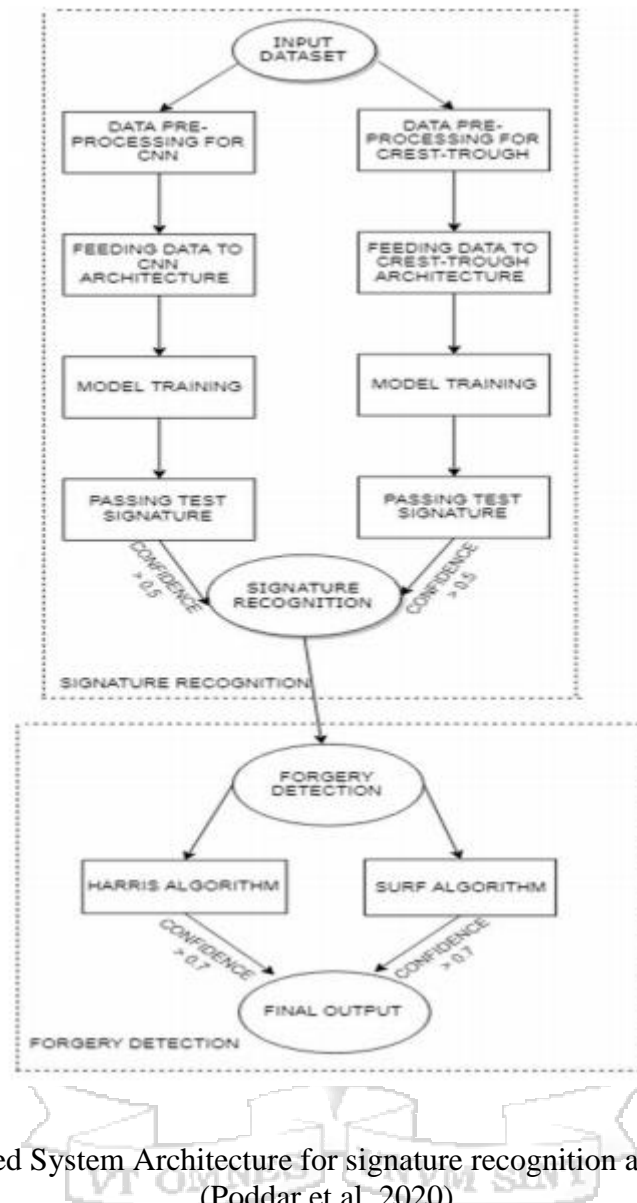


Figure 2.2: Proposed System Architecture for signature recognition and forgery detection (Poddar et.al, 2020)

Once the signature is detected, two algorithms are enforced to detect any forgery. The Harris algorithm checks for corner points detected from the training set and the SURF algorithm checks for index points detected from training set. Based on this model, the associate accuracy ranges between 85-89% (Poddar et. al, 2020). The weakness from this study is the scope of the proposed system in relation to this study. The study focused on just signatures when the documentation of non-digital assets involves much more details beyond the owner’s signature. Hence, the other contents of the document could be forged but the signature could be the owners and it would still recognise the signature as true and not consider the validity of the information provided.

While using the deep learning models to detect the forgery of signature is crucial in ensuring the validity of signed documents, there is also the automatic detection of real estate documents done by the company Axis AI (Axis Technical Group, 2021). They go beyond detecting signatures by extracting data from documents, document classification from grant deeds to release form which make the whole process smoother.

Another automated method for document verification aimed at proving land ownership proposed by Mukiibi and Wangari (2017) is that of using blockchain technology. The proposal aimed to provide a solution to end users with a mobile based application that can be used to check validity of land ownership. For this to work, it was assumed that there already exists an integrated system which houses all the title deeds together with the transactions involving them. In implementing their blockchain solution, they took two approaches: account-based and transaction-based. The account-based approach would allow keeping track of the land owners. On the other hand, the transaction-based approach would allow keeping track of all the transactions happening to a piece of land from change of ownership, to leasing and the period of lease.

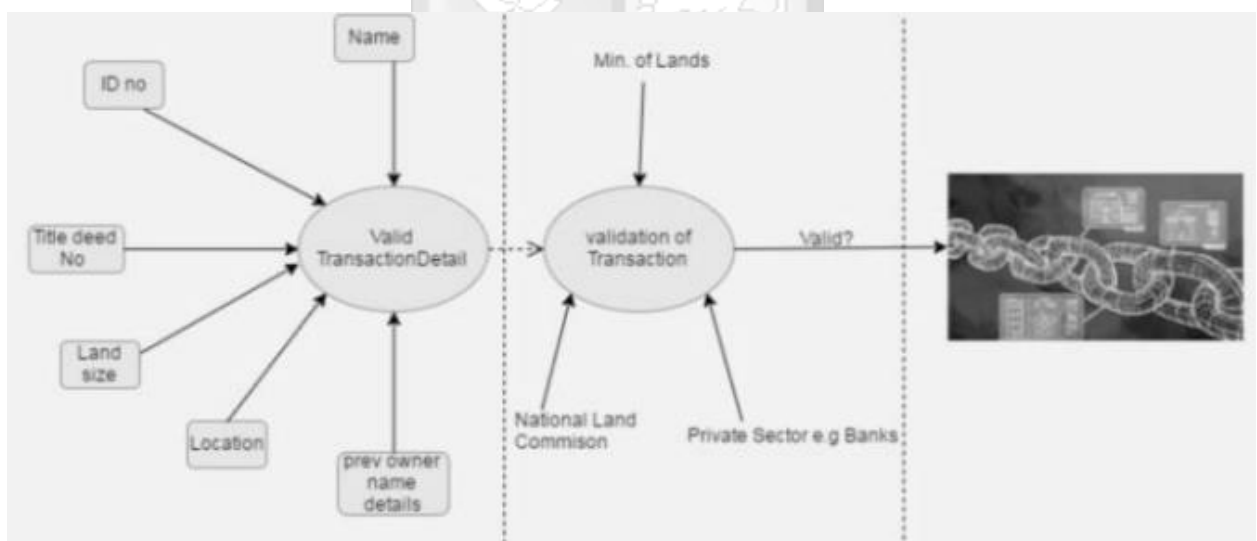


Figure 2.3: System overview of blockchain based system (Mukiibi, H., & Wangari, R., 2017)

The system would have a first phase of determining what information about the land title should be stored on the blockchain. The second phase would include involving key players such as the Ministry of Land under which lies the National Land Commission who verify the data keyed in after which they sign off for the transaction to be put on the blockchain.

The main weakness from the proposed system by Mukiibi and Wangari for proving land ownership is the use of the Bitcoin network. While the network is the pioneer blockchain network, it was built mainly for payment solution. Hence, value transactions such as payment would not be easy to differentiate from transactions of data. Other than that, Bitcoin network's consensus model, proof of work, requires a lot of computational power which also translates to lots of time and fees being used for single transactions. Where proving land ownership is crucial, these slow transaction speeds and high transaction fees are not ideal.

The last automated method for verification aimed at tracking products in supply chain logistics proposed by Kiano (2018) is that of also using blockchain technology. The proposal aimed to provide an effective, efficient and secure way to track and verify products in a supply chain using a mobile application. For the proposal to work, it needed for the manufacturers to have a uniform way of appending QR codes to all their products such that they can be scanned at each individual point and the transaction submitted to the blockchain. With these transactions, the journey of the product can be followed from source to destination (Kiano, 2018). This proposal uses the Tendermint blockchain consensus which uses proof-of-stake and one weakness of this consensus method is that the validator nodes with large holdings can end up having excessive influence on the network and it might require nodes to lock up their coins for some amount of time (Daly, 2022).

## **2.4 Architectures and Designs**

### ***2.4.1 Ethereum Blockchain Network***

Ethereum is an open-source, blockchain-based, decentralized software platform first proposed by its founder Vitalik Buterin in 2013 with the first beta version going live in 2015 (Buterin, 2013). It was developed to primarily improve on Bitcoin by expanding its features. While Bitcoin is mainly a store of value, with Ethereum, it is also programmable. These programs are called smart contracts and are pieces of code that self-execute and are embedded on the blockchain itself (Hayes, 2020). Ether, the cryptocurrency on the Ethereum network, is used both as a digital currency but also to run and execute smart contracts on the network.

#### ***2.4.1.1 How Ethereum Works***

At its highest level, Ethereum is made up of many parts that work together to ensure it is a completely decentralized system with no control from any one entity. The key pieces include:

- i. Ethereum blockchain – This is just a ledger with the entire history of the Ethereum network including all transactions from the genesis block.
- ii. Ethereum Virtual Machine – This is the part of Ethereum that executes the rules on the network and make sure any transaction follows the rules or it will fail to execute. Another highlight of the EVM is that it is Turing complete meaning that it can calculate everything dependant on if there is enough memory.
- iii. Smart contracts – These are programs that run themselves on the Ethereum blockchain. They contain code to be executed and the data that holds it state. The smart contracts reside on specific addresses and for them to be executed, one has to call the address.
- iv. Ether – This is Ethereum’s main token which is required to run transactions smart contracts.
- v. Proof-of-Work – This algorithm secures Ethereum since there is no central entity to keep track of how much Ether each address has and also avoids the “double-spending problem”. The algorithm works by confirming transactions and produce new blocks after miners compete against each other to solve a mathematical puzzle. Once a miner solves the puzzle, they receive a reward in form of new Ether being mined.

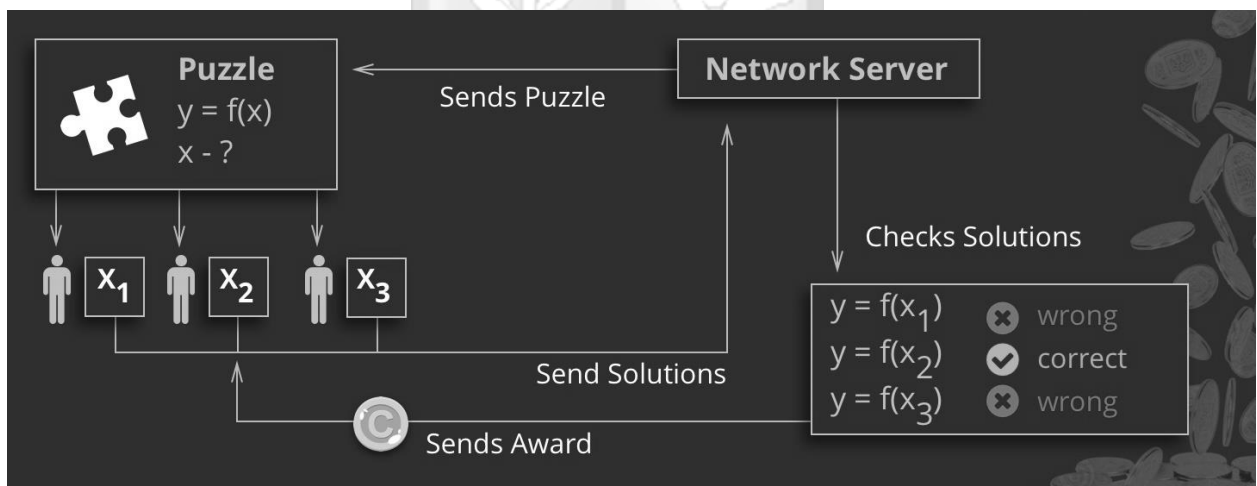


Figure 2.4: Diagrammatic representation of Proof-of-Work algorithm ("Ethereum 101 - CoinDesk", 2021).

Due to Ethereum’s nature of being decentralized, it allows for decentralized applications to be made. While decentralized applications are just like normal applications in terms of the solution provided to the user, under the hood, they use blockchain technology to eliminate the need for

a central entity being in command. Hence, the applications built on top of the network tend to also be decentralized, open-source and use smart contracts to execute commands triggered by the user. Most of the decentralized applications on the Ethereum network are financial applications which have inspired new markets such as Decentralized Finance where peer-to-peer transactions are the order of the day. Other than financial applications, there are also Decentralized Autonomous Organizations which are leaderless companies that are governed by peers under a set structure of rules. Such companies can be used as investors and the members can vote on which projects to fund and how much money to be released ("Ethereum 101 - CoinDesk", 2021).

While Ethereum positions itself as a better version of Bitcoin, it has its advantages and disadvantages. Some advantages of Ethereum include:

- i. Decentralized – Ethereum has no central entity with complete authority over what happens hence consensus is needed for any changes to be made to the core code.
- ii. A robust developer community – Ethereum has a large developer community that work together to maintain and improve the code. They also decide on different Ethereum milestones such as the release of Ethereum 2.0
- iii. Interoperability – Ethereum allows for applications built on top of it to interact with different protocols that already exist hence the applications do not exist in a bubble.

Some disadvantages of Ethereum include:

- i. Slow speeds – Ethereum, as a decentralized protocol that required consensus in the network, experience slow speeds when confirming transactions. On average, Ethereum has a speed of 15 transactions per second which is insignificant compared to Visa which does around 1,700 transactions per second.
- ii. High gas fees – Due to the slow speeds of confirming transactions, the fee needed to run a transaction, called gas, can shoot high due to the demand in the system and end up being unreasonable.
- iii. Programming – Ethereum requires developers to use the Solidity language, which is similar to JavaScript, to create smart contracts. Because of this unfamiliarity, it creates a steep learning curve that can discourage new players or developers into the ecosystem.

#### *2.4.1.2 Non-Fungible Tokens*

Non-Fungible Tokens evolved from an Ethereum standard called ERC721. The premise for these non-fungible tokens is that each token is unique, scarce and thus cannot be easily exchanged for another token. This characteristic of non-fungible tokens makes them an ideal interface to use when representing physical assets like artwork, real estate, land or equipment (Ivan, 2021). For the moment, non-fungible tokens mostly represent collectibles such as artwork or tokenized NBA moments in the case of NBA Top Shot.

The game that brought worldwide attention to non-fungible tokens is called CryptoKitties. It is a simple game that allows users to breed and exchange digital cats. By basing the digital cats on the ERC721 tokens, this means that every digital cat is unique and only that instance of it exists across the whole Ethereum network. It works similar to human DNA which allows for each individual to be unique even though they borrow from their parents' DNA. At one point, the CryptoKitties game was so popular that it caused a slow up of Ethereum transactions (Hertig, 2021).

At the moment, non-fungible tokens are opening up new opportunities which will allow the digital representation of physical assets. The idea that physical objects being represented in digital format is not new but when combined with the power of the blockchain where the ledger is immutable, more opportunities open up to represent more assets. Other than that, by tokenizing non-digital assets and representing them using non-fungible tokens, it immediately cuts off the intermediaries and allows the producer to communicate directly, peer-to-peer, with the consumer.

Non-fungible tokens present many use cases where digital representation can ease processes such as identity management, real estate and even in the art field. In identity management for example, one does not have to carry around their national identification card which is prone to getting stolen or getting lost. Instead, with a tokenized version of the national identification, they can present it anywhere and it can be verified on the blockchain network (Sharma, 2021).

#### **2.4.2 Flow Blockchain Network**

While the Ethereum network and the ERC721 standard is a powerful interface for non-fungible tokens, the constraints of slow speeds and high gas fees are discouraging for some players. Instead of waiting for the Ethereum 2.0, the people at Dapper Labs created a new kind of

blockchain whose sole purpose was to support non-fungible tokens and large-scale cryptocurrency games (Hayward, 2021).

Flow sells itself as the “blockchain for open worlds”. It is a decentralized and developer-friendly blockchain designed as the base for new digital assets. Flow is based on a multi-role architecture which allows it to scale up without sharding – which is one of the ways that different blockchain protocols try to improve their performance by making each node hold bits and pieces of the entire blockchain but not the whole of it.

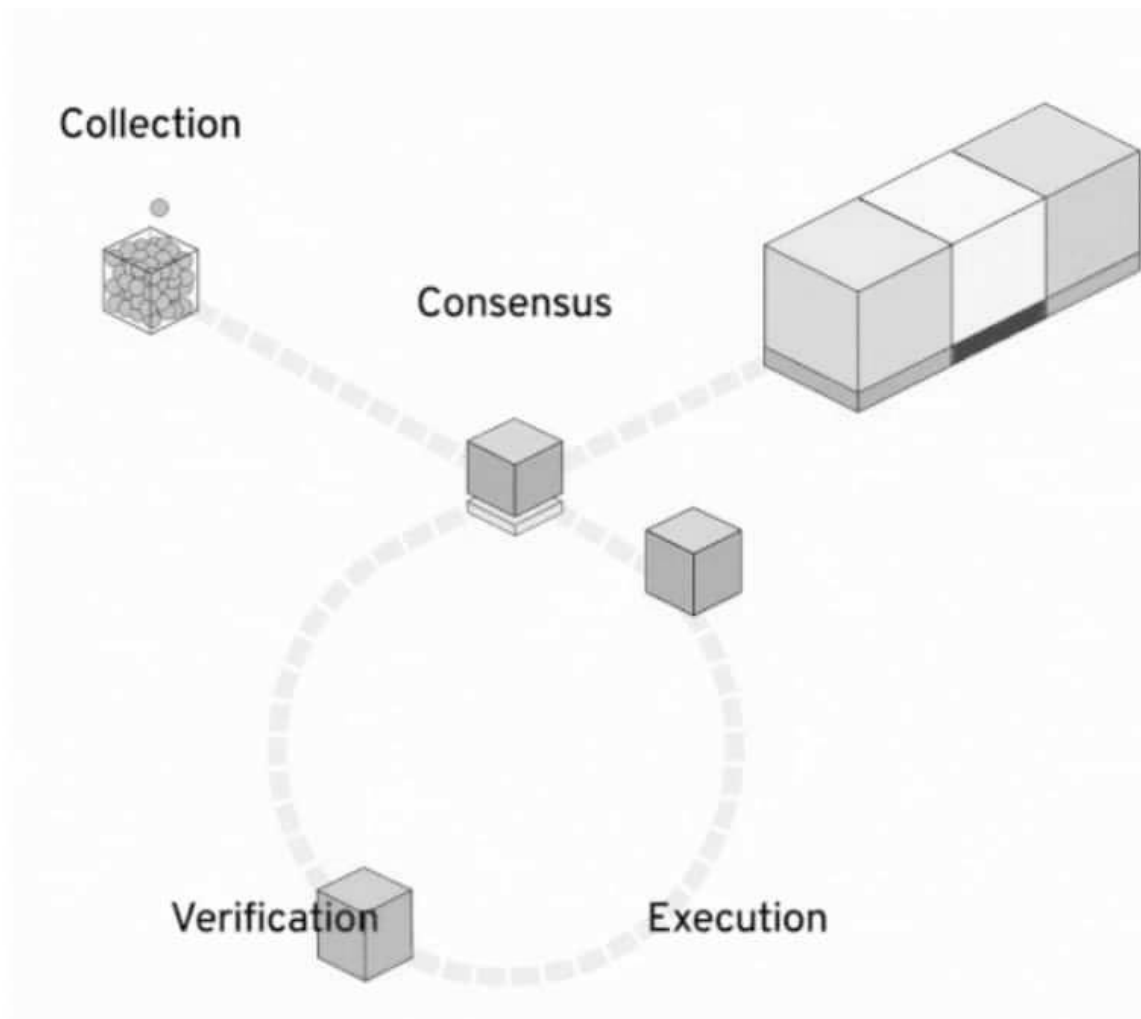


Figure 2.5: Flow Blockchain Architecture from Flow Blockchain ("Flow Primer: the blockchain for open worlds", 2021)

The Flow Blockchain network is set apart from other networks such as Ethereum due to some of its characteristics as stated in its primer ("Flow Primer: the blockchain for open worlds", 2021) including:

- i. Multi-role architecture – Flow separates the jobs of a validator node into four parts namely: Collection, Consensus, Execution and Verification. By splitting the role of the node, it means that each node focusses on one part of the transaction and thus increasing efficiency.
- ii. Resource-oriented programming – Flow uses the programming language called Cadence to write its smart contracts. While also new and requiring some learning on the developer’s side, the language is easier and safer for the development of digital assets.
- iii. Developer ergonomics – Flow allows for smart contracts to be updated after being uploaded to the network. This is unlike Ethereum whereby when a smart contract is deployed, it cannot be changed. This brings about a security issue where if a vulnerability is found, it can be exploited and a new smart contract would have to be deployed to replace the old one. On the Flow network, it is as easy as pushing an update.
- iv. Consumer onboarding – Flow Blockchain network puts the consumer first by allowing fast transactions, zero clogging of the network and low friction when moving from fiat currency to the cryptocurrency world.

While relatively new, Flow Blockchain network has come up with several platforms for collectibles such as NBA Top Shot where people can purchase tokenized NBA Moments. It is also noteworthy that Dapper Labs, the creator of the Flow Network, is also the creator of CryptoKitties. While the game run on the Ethereum network since it began, they recently moved the smart contracts to the Flow network due to the high fees and congestion of the Ethereum network which were also discouraging gameplay (Cardona, 2021).

Due to the advantages provided by the Flow Blockchain Network, this project will use the protocol to create a prototype that secure digital assets in the form of non-fungible tokens.

## **2.5 Research Gaps**

While many non-fungible tokens have been deployed and used as experimental use cases such as the case of CryptoKitties, a deeper understating of non-fungible tokens would be beneficial especially from an Information Systems view. As highlighted by Regner, Urbach and Schweizer (2019), this deeper understanding of non-fungible tokens will fill the existing gap in three ways: understanding the benefits and opportunities presented, the proper processes of designing and evaluating applications based on non-fungible tokens and an increased awareness of the remaining practical challenges that can be solved using them.

Locally in Kenya, blockchain technology has been adopted especially in the form of payments and as a store of value via coins such as Bitcoin. According to reports from LocalBitcoins, Kenya is the one of the three largest Bitcoin markets in Africa just next to Nigeria and South Africa (The Countries Driving Bitcoin Adoption in Africa - Kenyan Wallstreet, 2021). Recently, a major driving factor in the adoption of cryptocurrency in Kenya was the recent COVID19 lockdown that drove people to unemployment and looking into cryptocurrency for day trading in order to make some money. Hence, in February 2021, LocalBitcoins reported that transactions reached Ksh.100 million on a weekly basis (The Countries Driving Bitcoin Adoption in Africa - Kenyan Wallstreet, 2021). While this remains a very good indicator of the adoption of cryptocurrencies in Kenya, there lies more to it that just payment. Many different blockchain technologies are coming up to solve different problems in society including Hyperledger for private and permissioned blockchains to be used in financial institutions for example (Introduction — Hyperledger Fabric, 2021) to TradeLens which is powered by IBM to create a global supply chain of all shipping containers and port documents (TradeLens Platform | TradeLens, 2021).

While most of the players in the blockchain eco-system focus heavily on using it as a store of value, blockchain technology can also be used as a store of data. The immutable aspect of blockchain technology make it the perfect solution to use when storing sensitive data that one wishes not to change. However, since this data cannot be deleted, it will eventually pile up and cause the network to be slow. This leads to the data being stored being split into two: on-chain and off-chain. On-chain data is mainly the logging of the event happening on the blockchain while off-chain data is that data that pertains the event which can be stored elsewhere (Wodehouse, 2022). The main problem with storing the off-chain data elsewhere is that it is often in a centralized server which then negates the advantages of decentralization offered by blockchain technology. To solve the issue of data piling up on all nodes, the Flow blockchain network and its multi-role architecture guarantees that specific nodes will hold the data while other nodes perform the transactions and validate the transactions.

Hence, there exists a gap in asset management such as in land and other forms of non-digital assets which can leverage using blockchain technology as a store of data. The Kenyan Ministry of Information, Communication and Technology under the Distributed Ledgers Technology and Artificial Intelligence Taskforce came up with a report detailing how the two emerging technologies can be used to improve service provision and address various challenges. In total, 12 recommendations on how Blockchain and AI can be utilised to fight corruption, counterfeit

and cybercrime were highlighted (Distributed Ledgers Technology and Artificial Intelligence (AI) Taskforce Report, 2019). However, a major hindrance in adopting the solutions outlined have been lack of awareness among citizens and the linear outlook of blockchain which is that only Bitcoin exists which is currently slow and has high transaction fees. However, with the coming up of newer, faster and less expensive networks such as Flow Blockchain, it is easier to build a prototype for securing non-digital assets.

## **2.6 Conceptual Model**

This research study's conceptual framework is a web application prototype based on the Flow Blockchain. The model will allow for non-digital assets to be tokenized and stored in an immutable ledger that is public and verifiable. The prototype will have a front-end interface that will allow the users to interact with the system. In the back-end, the interface will connect to the Flow Blockchain by use of smart contracts while also maintain a user management database under tight security safeguards to protect the data.

During the acquisition or transfer of an asset, the user will enter the details on the user interface. Under the hood, the entry will be checked against all existing items in order to avoid a double entry. If the asset is found, the transaction is added to its history. If, however, the asset does not exist, then a resource type will be created matching its characteristics thus tokenizing it and adding it to the Flow Blockchain. Once the transaction is done, the asset can be found together with its history and ownership by using the unique ID generated. Due to the nature of the blockchain, all the transactions will be available publicly for verification. Also, unlike other blockchain solutions, the smart contracts on the Flow Blockchain can be updated in order to patch up a security issue or a bug or even add a feature. As illustrated in the diagram below, here are all the components and how they will work:

- i User Interface – this is the front-end part of the prototype. It will be an easy-to-use interface that will guide the user during their asset registry, update or simple search journey. The user interface can stand alone but also be plugged in as a module in the existing E-citizen service for ease of access and use. The user interface back-end, reserved for the administrators, will also have auto generated reports that will show the usage, the transactions made and from which locations. This will help guide and steer and future updates.

- ii Asset Registry – this is the immediate back-end of the prototype. This is where communication between the services will be linked. The asset registry will receive, translate and work on the commands streaming in from the user interface. If the action to perform includes the registry of an asset or an update, it will then call the underlying smart contract to perform the action and register it on the blockchain. If the command is the creation of an administrator, it will pass the command to the user management module to handle the such request. Also, the registry will be connected to an SQL Data warehouse which will house different data including the administrators, the requests being made and also the logs generated by the system for easy error handling. The data stored in the database is what will be passed to the report generation tool called PowerBI to generate reports displayed on the front-end.
- iii Smart Contracts – the smart contracts will be the link between the prototype and the Flow Blockchain. Simply, the smart contract allows for pieces of code to be executed on the blockchain thus creating an immutable record that can easily be verifiable. Case in point, if a resource representing a piece of land is created, the smart contract will run the create function creating a unique representation of the asset including reference data. The representation created will be that of a non-fungible token which is unique, scarce and which cannot be directly exchanged for another token. Another example is when updating the asset resource created. Since it exists already on the blockchain, the transaction will be appended to the result to form a sort of history on whatever takes place such as leasing of the land. Hence, when the asset is looked up on the prototype, the history including the dates of transaction will be detailed on the page.
- iv Flow Blockchain – this will be the underlying blockchain network that will be used for the prototype. Unlike other networks such as Bitcoin or Ethereum which have some limiting factors such as transaction fees and transactions speeds, the Flow Blockchain is designed with non-fungible tokens at its core. Hence, the creation of unique asset representation is fast and easy using their Candace programming language. Another advantage to the Flow Blockchain is that it allows smart contracts to be updated on the fly in case a new feature or variable is to be added or when a security vulnerability is being fixed.
- v User Management Module – the user management module will manage the users using the prototype. Users will have different access levels depending on their rights and

privileges. They will be categories for the rights and privileges including super administrators, administrators and simple users. This data will not be stored on the blockchain but on the SQL Data warehouse to avoid having user data permanently stored on the blockchain. Also, having an automatic backup of the data will ensure uptime is maintained and at any point of failure, it will be easy to spin up the data again and have the prototype running as intended.

- vi SQL Data Warehouse – the SQL Data Warehouse will primarily hold data that supports the optimum operation of the prototype. This includes the users of the prototype including their access levels to maintain security. The storage will also hold logs generated by the system in case of any downtime or errors which will help in troubleshooting the problem. Furthermore, the user journey will be stored as events which will then be used to generate administration reports to be displayed on the front-end. Only data that is needed will be stored and all security measures will be put in place to ensure that confidentiality, availability and integrity is maintained at all times.
- vii Power BI – Power BI is a powerful reporting tool that can be used to create visualizations from data for the purposes of reporting. It is easy to drag and drop, drill into data for a clearer view and even export the reports for presentation online or in protected web portals. Hence, the tool will come in handy when tracking the activities of the users on the prototype in order to tell things such as the ease of use, the time spend on each module, the time of day that most people spend on the application, the successful and unsuccessful transactions and more. These reports will not be public but will be viewable by the administrators to help in decision making on future updates.

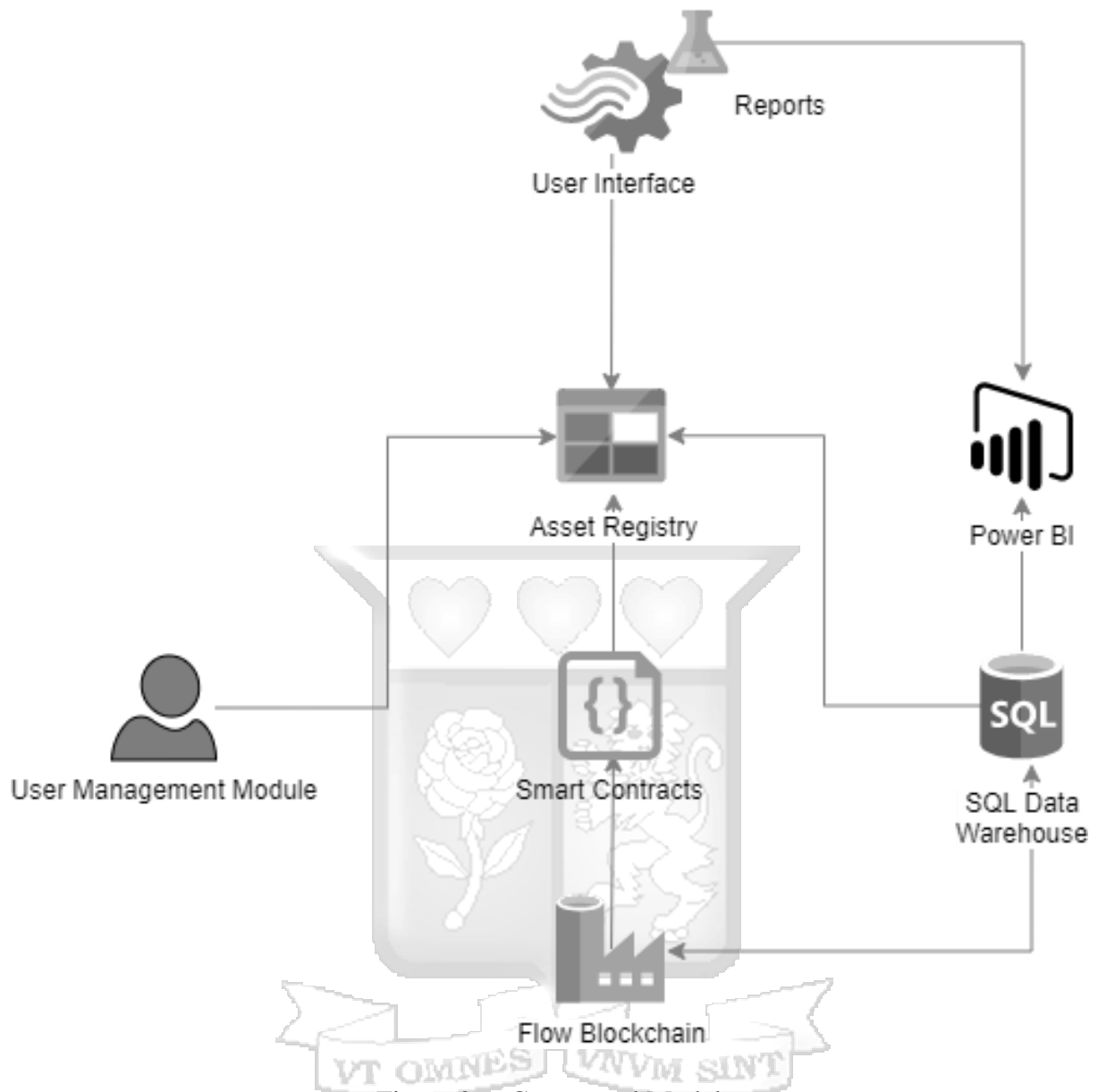
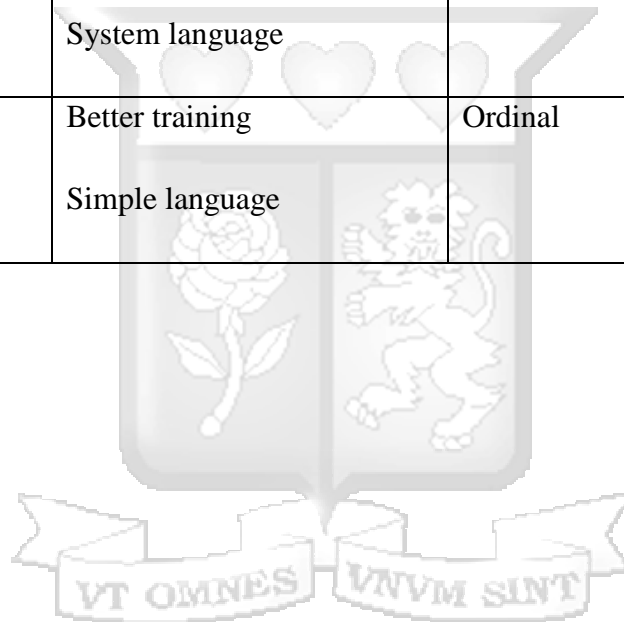


Figure 2.6: Conceptual Model

## 2.7 Operationalization of Variables

Table 2.1: Operationalization of Study Variables

Type	Specific Measurements	Category of Data	Measure
<b>Dependent Variables</b>	User understanding	Ordinal	Likert Scale
Asset Security	User knowledge		
Block Chain Security	System language		
<b>Independent Variables</b>	User interface	Ordinal	Likert Scale
	System logic		
Challenges faced	System language		
Way forward	Better training	Ordinal	Likert Scale
	Simple language		



## Chapter 3: Research Methodology

### 3.1 Introduction

Research methodology is presented in this chapter. Specifically, the chapter provides in detail the research design that was used for the study. The research design chosen enables the objectives and purpose of this study to be achieved. The chapter provides a broad outline of the overall approach to be used in this study together with the method and sources of data collection.

### 3.2 Research Design

The research design that is selected needs to incorporate the multiple components of the study in a logical manner. It needs to ensure the problem statement is addressed effectively and achieved through identification, collection and analyzation of the data sample (Roller & Lavrakas, 2015). While there exist many research designs, the subsequent section will be restricted to the design used for the design, development and testing of a prototype used to secure non-digital assets.

#### *3.2.1 Mixed Research Design*

During the overall lifespan of an asset from creation, to purchase to securing it, there are three main actors involved. The actors include the asset being exchanged, the buyer interested in purchasing the asset and the seller interested in selling the asset. For assets such as land, however, the government often comes in as an intermediary because it holds the central database of the land under its territory. Descriptive research will aid in this study by providing the answers to who, what, where, when and how questions linked to the asset acquisition, transaction and security (Jagtap & Jagtap, 2015). The reason this process is crucial is it will enable the researcher to observe and understand at a deeper level the process of acquiring, transacting and securing assets, identify the vulnerabilities in the securing the said assets and hence design a prototype as a justified solution. Furthermore, applied research comes in and provides a scientific approach whose aim is to provide a feasible solution to an identified practical problem. Based on current innovative technology, applied research will aid in mapping problems to innovative solutions (Schabenberger & Gotway, 2017).

The applied research design will include predefined steps followed from the initial observation of a problem to the time an appropriate solution is identified and applied as follows:

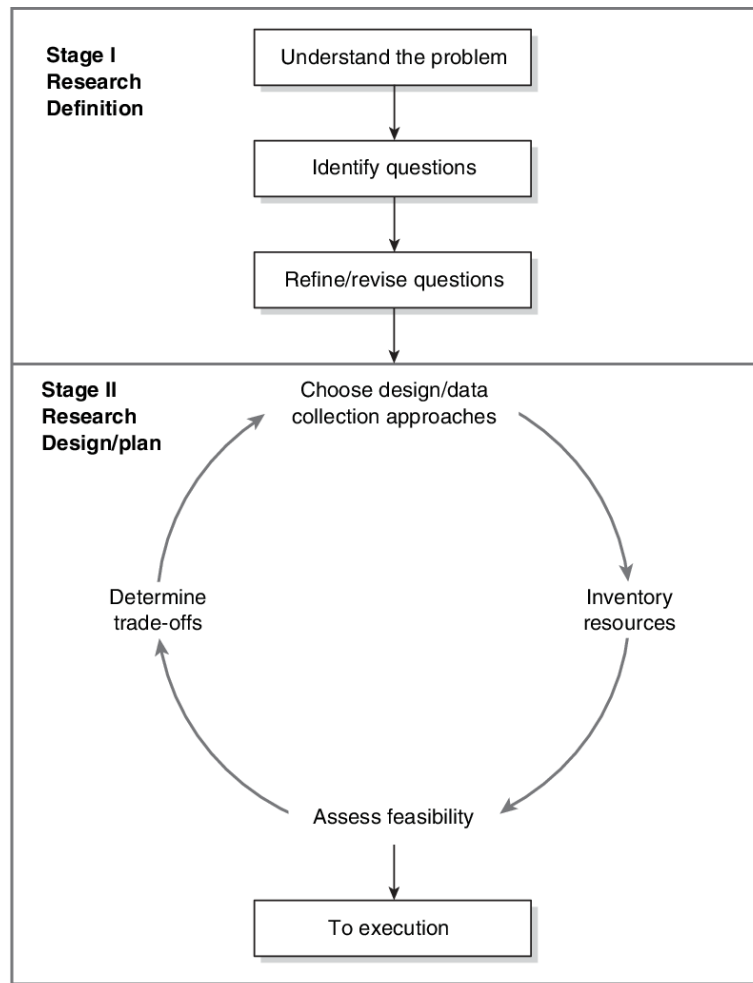


Figure 3.1: Applied Research Design ("Applied Research Design: A Practical Approach", 2019)

### 3.3 Data Collection Methods

Data collection methods are a set of tools and methods that the researcher uses in order to gather primary data for a research study (Sajjad Kabir, 2016). The drafting of recommendations and the drawing of conclusions will then be based on the data collected using the following methods:

#### 3.3.1 Questionnaires

A questionnaire is a predefined list of questions that is distributed with the intention being to gather information on a specific area of study (Sajjad Kabir, 2016). With the intention being easy access and anonymity of both the respondents and the responses, the questionnaire as shown in Appendix A will be administered through an online platform such as Google Forms. By using an online platform, it will allow the respondents to tackle the questions at their own time and convenience without any external pressure. By design, the online questionnaire will have both open-ended and closed questions for qualitative and quantitative respectively.

### 3.4 Data Analysis

Data analysis after data collection involves a myriad of activities including but not limited to the tabulation and categorizing of the collected data during the research study (Chambers, 2017). The responses resulting from the online questionnaire will be analyzed using the open coding approach which includes conceptualizing, segmenting data into meaningful expressions and categorizing data into a presentable form. The open coding approach will be adapted to provide the researcher with recurring patterns in data through classification and categorizing in order to discover and draw conclusions. The open coding technique will be used to analyze qualitative data and as part of the many qualitative data analysis methodologies like Grounded Theory.

#### 3.4.1 Open Coding Technique

The first step when using the open coding approach is for the researcher to go through the data collected and break it down into easily understandable pieces while finding similarities or dissimilarities. This goes hand in hand with qualitative data analysis which is a non-linear process that is repeated that involves observation, data collection and analysis as shown in the diagram below.

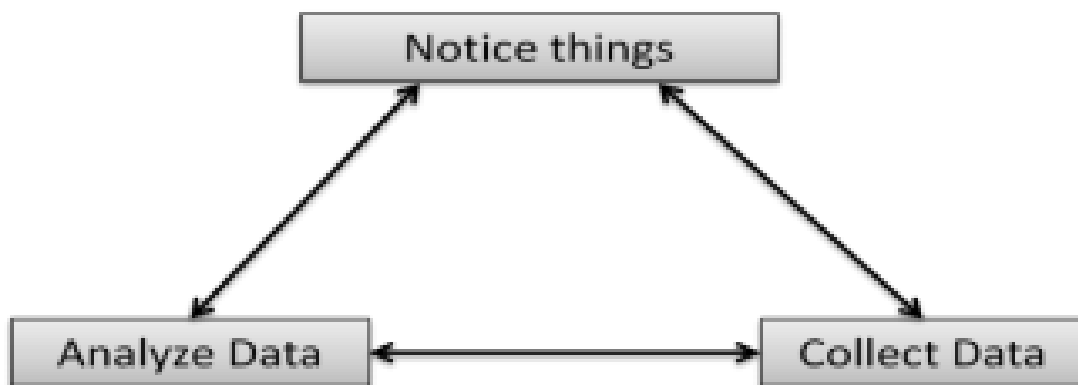


Figure 3.2: Workflow of Qualitative Data Analysis (Khandkar, 2021)

With the data collected, different parts will be marked with the appropriate label or code that act as identifiers for further analysis. Building on top of the codes, the researcher identifies concepts which are significant to facts represented by the data collected. In this case, concepts are abstract representations that can be used to group similar information to better understand

it. In the example of the data collected, concepts such as security of an asset and the authority over an asset can be drawn (Khandkar, 2021).

The process continues where the researcher has a list of codes from the data collected and analyzed and it is at this point the codes are analyzed in order to group similar ones into categories based on their common nature. The name given to the category may or may not differ from the codes but should be one that expresses its scope. The categories extracted from the data can then give the researcher patterns to work with, look into, analyze further or even pivot into a different area (Khandkar, 2021).

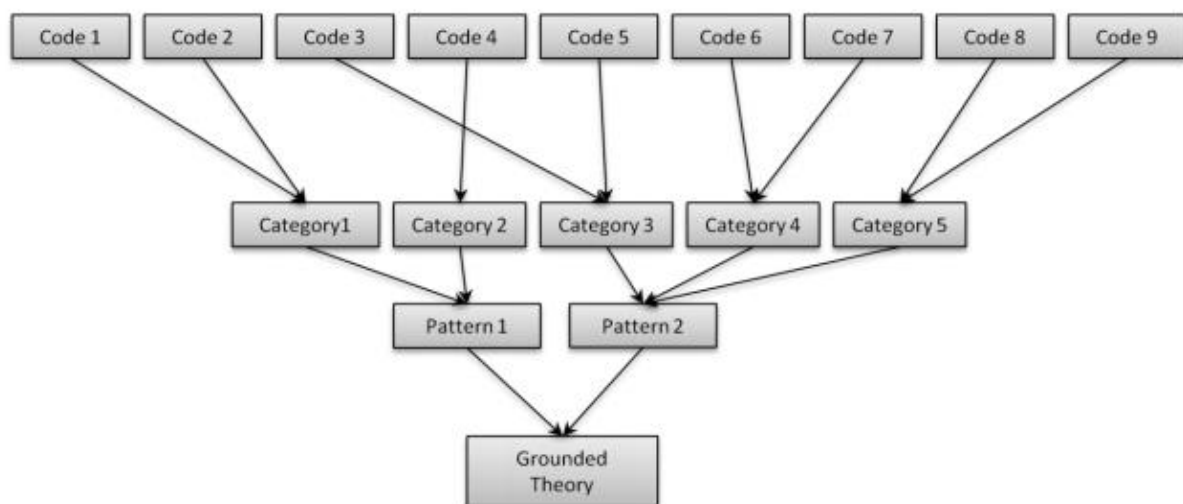


Figure 3.3: Workflow of Grounded Theory Methodology (Khandkar, 2021)

The goal of open coding technique is to build a framework which is descriptive of the data collected for analysis and the process ensures its own validity as it is built directly from the raw data. In summary, using this technique with the data collected, the process will involve:

- i Turning the data into small components of data
- ii Create codes for the small data components with a descriptive label
- iii Find connections between the identified codes
- iv Aggregate and condense the codes into broader categories
- v Find an overarching pattern or category to bring all the data together

("How To Do Open, Axial, & Selective Coding in Grounded Theory — Delve", 2021)

The codified data is then analyzed using descriptive statistics using programming languages such as R and Python ("R vs. Python for Data Science", 2021). Finally, the results of the analysis are represented in human friendly formats such as charts, tables and graphs.

### **3.5 Research Quality**

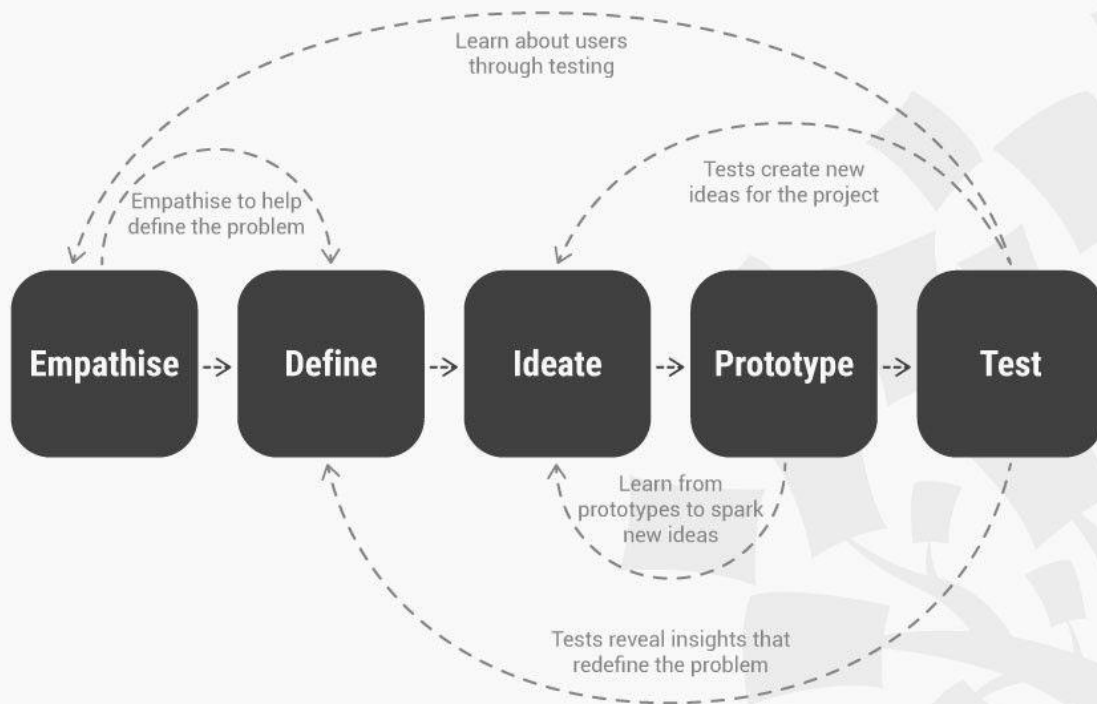
Validity, in this context of a research study, refers to the range of amount within which the results received from the examination of the data are the actual representation of the variables of the study (Creswell & Creswell, 2017). This research study aims to validate its instruments through content validity. Based on the content relatedness technique, a measure of degree will certify that the questions asked in the online questionnaire relate to the study directly.

The Cronbach's coefficient of reliability will also have to be satisfied by the research instruments used in this study (Bonett & Wright, 2015). In essence, a coefficient correlation of five and above will be an accepted response. Furthermore, the research methodology will be limited to questions that are not only relevant but that provide answers and solutions to the study's problem statement and therefore ensuring the research objective is attained. It is also good to note that information provided to the researcher during the study period from the respondents and other people will be confidential and the proper safeguards and channels will be implemented.

### **3.6 System Development Methodology**

The system development methodology that will be used for this study is called Design Thinking. This methodology provides a solution-based approach to solving problems. The process goes through various cycles which include understanding the human elements involved, brainstorming several ideas and going hands on in both prototyping and testing.

# DESIGN THINKING: A NON-LINEAR PROCESS



INTERACTION DESIGN  
FOUNDATION

INTERACTION-DESIGN.ORG

Figure 3.4: Design Thinking Process from Interaction Design Foundation (2019).

## 3.6.1 Empathise

This is the first step in Design Thinking and whose major aim is to understand the human aspect of the problem at hand. This process might involve consulting the experts in the field through interviews or just through normal observation. By doing so, and going to a human level, one is able to understand the struggles, experiences and also their aspirations. The information gathered at this stage is then used to inform the next stage so it is paramount to really understand the people and their needs.

## 3.6.2 Define the Problem

This is the second step in Design Thinking and whose major aim is to put together the information gathered in the empathise stage and from there draw the major problems. The problem statement derived from this process should also try to be human-centred as an

amplification of the first step. Other than that, once the problem is defined definitely, it is easy to then gather ideas, establish features and even possible outcomes.

### ***3.6.3 Ideate***

This is the third step in Design Thinking and the major aim is to generate possible ideas that can be used to fix the users' needs as derived from step one and two. With that structured background of information and a definite problem, possible solutions can be generated, deconstructed for feasibility purposes and thrown out if they do not make sense. This process can be made easier using different Ideation techniques such as brainstorm and "worst possible idea" which allow for free thinking.

### ***3.6.4 Prototype***

This is the fourth step in Design Thinking and the aim is to produce both cheap and scaled down versions of the solution arrived at from step three. For the prototype, it can be tested internally or by a group of people in order to gather feedback that can help in the next iteration. By the end of this step, it becomes clear the type of constraints the solution faces as well as how the users interact with the solutions.

### ***3.6.5 Test***

This is the fifth step in Design Thinking and the aim is for the solution proposed to be rigorously tested. However, it is good to note that this step is iterative since the results of this step help define the problem better and thus lead to more ideas and solutions coming up. It also allows for a deeper understanding of the users and their experience with the solution.

## **3.7 Ethical Issues**

After the study questionnaire is developed, the researcher will conduct a pilot test of the questionnaires with 10 respondents to assess its reliability. According to Leon, Davis, and Kraemer (2011), the purpose of pilot research is to establish the suitability of an approach intended for use in a wider study. These 10 respondents will be selected from the study population but will not be included in the final sample size. After the response had been received, the data will be coded onto the Statistical Package for Social Science (SPSS) tool, where the Cronbach Alpha test will be conducted to measure the reliability of the instrument. Kothari and Garg (2016) note that, for an instrument to be declared reliable, it requires to attain a threshold of  $\geq 0.7$ , and therefore, the study questionnaire variables will be tested using the same threshold, and the results determine whether reliable or not.

According to Allen (2017) the process of research requires the collaborative efforts of various people to ensure that high ethical standards are observed during the process. To ensure that the researcher keeps to the ethical requirements of conducting the research, the researcher will obtain approval from the university and also get a research permit from the National Council for Science, Technology, and Innovation (NACOSTI). Once these documents are obtained, the researcher will present these permits to ministries and national bodies of interest, together with the respondents' consent and debriefing forms that will be sent to the respondents for data collection. Allen (2017) highlights those issues of confidentiality, accountability, trust, fairness, and mutual respect are paramount during research. For this study, the researcher will ensure that the collected data will be treated with utmost confidentiality, and anonymity was observed by ensuring that none of the participants provided their personal details. The data collected will also be used for the purposes of this research alone and not any other purpose.

According to Dadhe (2016), surveys are a significant option to contemplate when dealing with a highly dispersed population, since the method is generally cost effective compared to other alternatives. Also, the use of this method helps conduct the research during the current COVID-19 pandemic where personal interactions are limited. The research questionnaire will be created in the Google Forms platform, and the link will be sent to the target population. The online method of data collection will be used to facilitate the researcher's ability to access the entire target population. Follow-up using phone calls and short messages to encourage the respondents to willingly participate in the study will also be done.

Pertaining the prototype for tokenizing non-fungible tokens, there exists the ethical concern of accountability and anonymity. While it is true that all the transactions on the Flow Blockchain are public, there is the risk of something going wrong and finding whoever that would be deemed responsible. This is because all transactions are initiated by addresses which are a string of letters and numbers that cannot clearly identify the person which is how blockchain technology allows for anonymity. Hence, anyone with malicious intent can do harmful transactions and it would be hard to track them. In the case of the prototype, a user account is tied to a Flow blockchain address which means that if any action is taken and deemed wrong, the user can be identified by matching the accounts.

## Chapter 4: System Analysis, Design and Architecture

### 4.1 Introduction

This chapter discusses the system design and the architecture of prototype. The requirements that were also gathered as described in Chapter Three section 3.4.1 and using the questionnaire as shown in Appendix A captured the asset information needed as well as some of the problems experienced. Further, this chapter outlines the functional and non-functional requirements of the prototype. The various high level system architecture and designs are also presented using use case, sequence and context diagrams.

### 4.2 Requirement Analysis

This section discussed the different function and non-functional requirements of the prototype that will be developed.

#### 4.2.1 Functional Requirements

Functional requirements refer to the critical functions performed by the prototype which enables the researcher to meet the research objective. The functions performed by each participant were as follows:

#### **Administrator:**

- i) Asset registration: The prototype should allow the admin to create and register an asset on behalf of the asset owner.
- ii) Asset history query: The prototype should allow the admin to query and keep track of an asset history including purchase, transfer, leasing and sale. Relevant information should be appended with each action as well as a timestamp accompanying the action.
- iii) Report generation: The prototype should allow the admin to generate reports based on the activities taking place on the portal. The reports can then be used for business decision making.

#### **Asset Owner:**

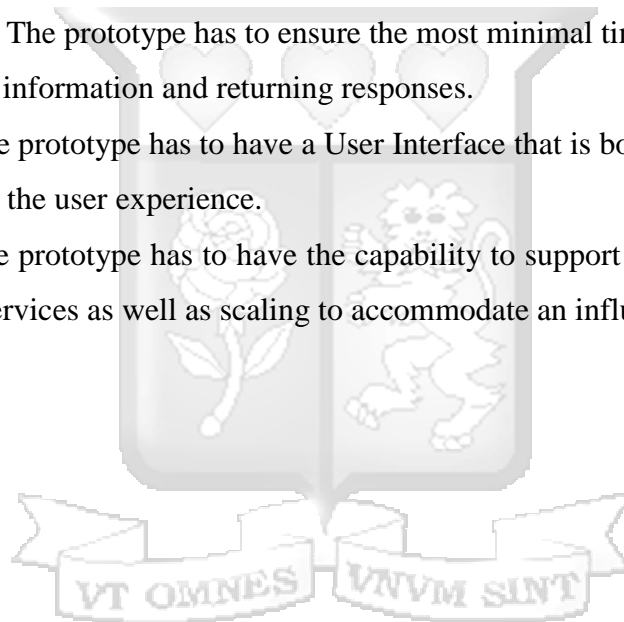
- i) Asset registration: The prototype should allow the asset owner to create and register a new asset either on creation or as a new purchase.
- ii) Asset transfer: The prototype should allow the asset owner to transfer the assets under their ownership to other entities such as people or organisations. Coupled with the asset transfer is the ability to confirm the transaction as well as cancelling it.

- iii) Asset history query: The prototype should allow the asset owner to query and keep track of assets under their ownership and view their history including purchase, transfer, leasing and sale. Relevant information should be appended with each action as well as a timestamp accompanying the action.

#### ***4.2.2 Non-Functional Requirements***

Non-functional requirements refer to the criteria used to measure and critic the operation of the developed prototype beyond the core operations that it performs. The non-functional requirements include:

- i) Connectivity – The prototype has to have a stable Internet connection to allow effective communication between the different components within it.
- ii) Performance – The prototype has to ensure the most minimal time in sending requests, processing the information and returning responses.
- iii) Usability – The prototype has to have a User Interface that is both friendly and easy to use to enhance the user experience.
- iv) Capacity – The prototype has to have the capability to support the traffic to and from the different services as well as scaling to accommodate an influx of users.



## 4.3 System Architecture

### 4.3.1 Overall Working of the Prototype

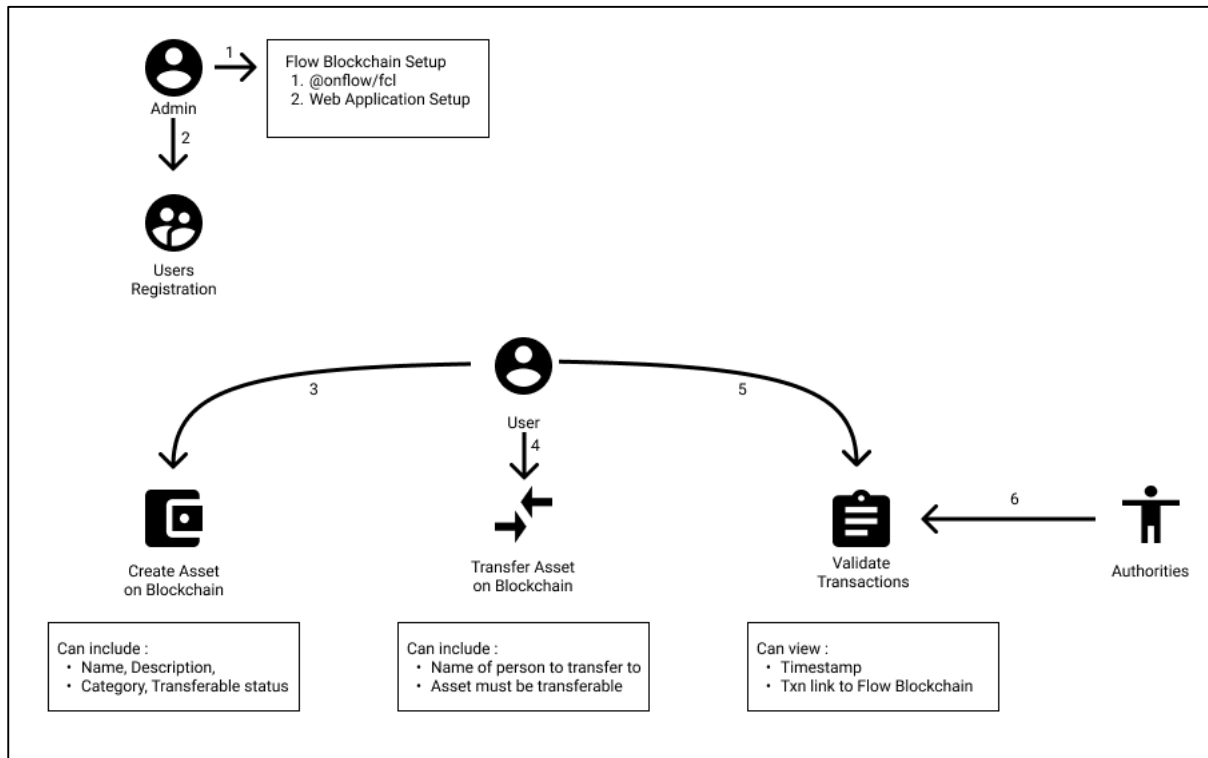


Figure 4.1: Overall Working of the Prototype

As shown in Figure 4.1, the Administrator is the most superior user in the prototype and is the one that sets up the web application and connects it to the Flow Blockchain. By virtue of doing this, they can then be able to view the transaction logs from the blockchain while fixing any issues or making any updates. Other than that, their roles and privileges allow them to administer the registered users. These duties include registering them, viewing their activity logs and even removing them if a cause arises.

The other category of user in the prototype is the general user. This user can create an asset by outlining the details required including name, description, category and the transfer status. The ownership of the asset is assigned to them on creation. This user can also transfer the asset under their ownership to another user and once successful, the user initiating the transfer can no longer perform actions on the asset. Finally, the user can view the transaction and validate the asset using the transaction identification numbers on the Flow Blockchain.

The other category of user in the prototype is the authority user such as the National Transport and Safety Authority Act or the Ministry of Lands and Physical Planning. For this user, their primary role is to validate the digital assets through the web application portal.

#### 4.3.2 Overall Prototype Architecture Design

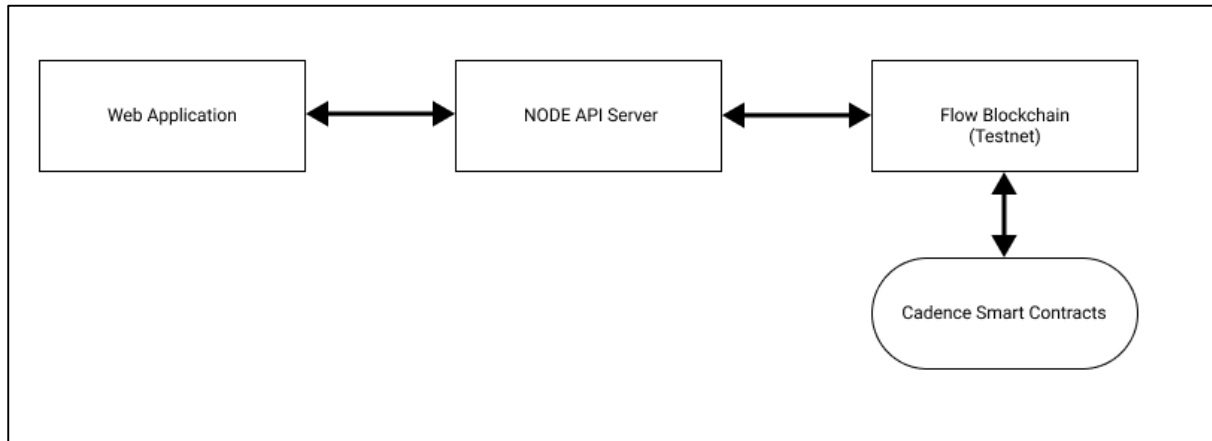


Figure 4.2: Overall Prototype Architecture Design

As shown in Figure 4.2, the overall prototype architecture design includes:

- i) **Web Application** – The Frontend Web Application will be the portal through which the administrator and the users can interact with the prototype.
- ii) **Node API Server** - The RESTful Application Program Interface server acting as the backend for the prototype will be receiving HTTP requests from the Web Application and implementing them before sending back a response.
- iii) **Flow Blockchain** – This is the Blockchain platform that will be used for this prototype. The test network will be used for now to allow for experimentation while not accumulation real transaction fees.
- iv) **Cadence Smart Contracts** – The smart contracts, written in a language called Cadence will allow us to make transactions on the Flow Blockchain.

##### 4.3.2.1 Development Environment Tools

- i) **NPM (version 8.1.1)** – This is the package manager for the Node JavaScript platform. This helps in putting the needed packages for both the web application and the node server together, updating them and resolving any dependency issues (NPM, 2020)
- ii) **Node (version 16.13.0)** – This node version manager allows one to switch between the multiple available versions of both Node JS and NPM on the system in order to test the web application and node server. However, it is always recommended to use the latest version to avoid the resulting dependency issues.
- v) **Libraries and Frameworks** – The library to be used to create the web application is React JS which is a free and open-source JavaScript library for creating interactive websites and user interfaces (React, 2021). On the other hand, the framework that will be used to create the node server is Express JS which is a web framework for Node that will allow us to handle different requests such as GET, POST, PUT, PATCH and DELETE (Expressjs, 2021).
- iii) **Programming Languages** – The JavaScript programming language will be used for both the web application and the node server. For the Flow Blockchain smart contracts, the Cadence programming language will be used.
- iv) **Flow Client Library** – The Flow Client Library is a library that will allow the web application and the node server to trigger the Cadence smart contracts and thus allow the sending and signing of transactions as well as querying the Flow Blockchain (Flow Docs, 2021).
- v) **Neovim** – This is a hyperextensible Vim-based text editor (Neovim, 2021) that will be used to write the code for developing the prototype.
- vi) **Browser** – Brave Browser will be used to view the prototype as well as perform the needed tests.

#### *4.3.2.2 Flow Blockchain Multi-Role Architecture*

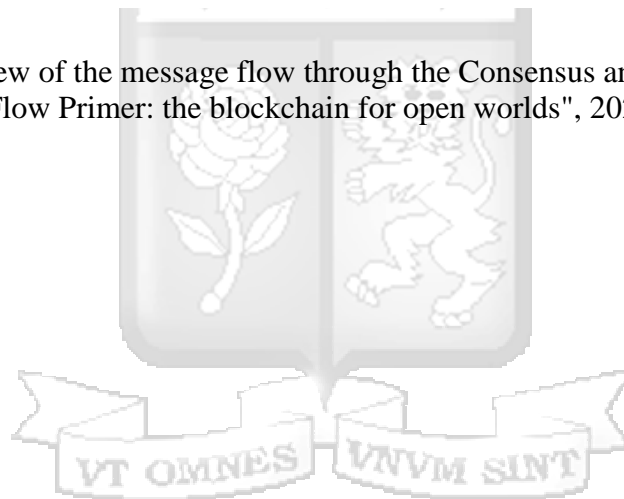
The Flow Blockchain is founded on the principle of “separation of concerns”. By separating non-deterministic processes from deterministic processes, it allows the processes to be assigned to the nodes that have the capacity to perform the action. By definition, non-deterministic tasks such as determining the order of transactions on the Blockchain require a consensus process such as Proof of Work. On the other hand, deterministic tasks such as determining the results of the ordered transactions always have a “single, objectively-correct outcome” (“Flow Primer: the blockchain for open worlds”, 2021).

Hence, the Flow Blockchain splits the validator across the following roles:

- i) **Consensus Nodes** – These nodes decide the presence and order of transactions on the blockchain.
- ii) **Verification Nodes** – These nodes are responsible for keeping the Execution Nodes in check.
- iii) **Execution Nodes** – These nodes perform the computation associated with each transaction.
- iv) **Collection Nodes** – These nodes enhance the network connectivity and the data availability for decentralized applications.



Figure 4.3: Overview of the message flow through the Consensus and Execution Nodes ("Flow Primer: the blockchain for open worlds", 2021).



## 4.4 System Design

The tools to design the prototype including context diagram, use case diagrams, sequence diagrams, database schema and wireframes are shown in the section that follows.

### 4.4.1 Context Diagram

This is the highest-level of the prototype. The Figure 4.4 shows the actors (Administrator, Asset Owner and Third Party) that interact with the Flow Blockchain. The Administrator can create an account and create an asset on behalf of a user. The Asset Owner can also create an account, an asset as well as querying its history and performing validations. Similarly, an Authority user can also validate assets.

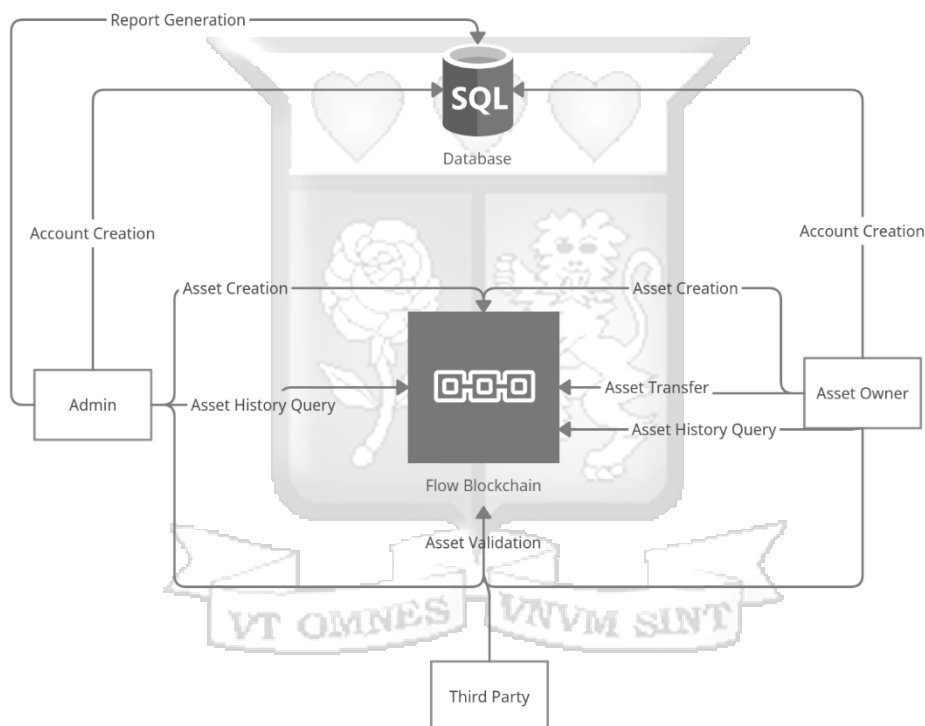


Figure 4.4: Context Diagram

### 4.4.2 Use Case Diagram

Use case diagrams showcase the behavioural aspect of a system by highlighting the different actions that it can perform after being triggered by external actors. The Figure 4.5 shows the interaction between the actors and the system processes:

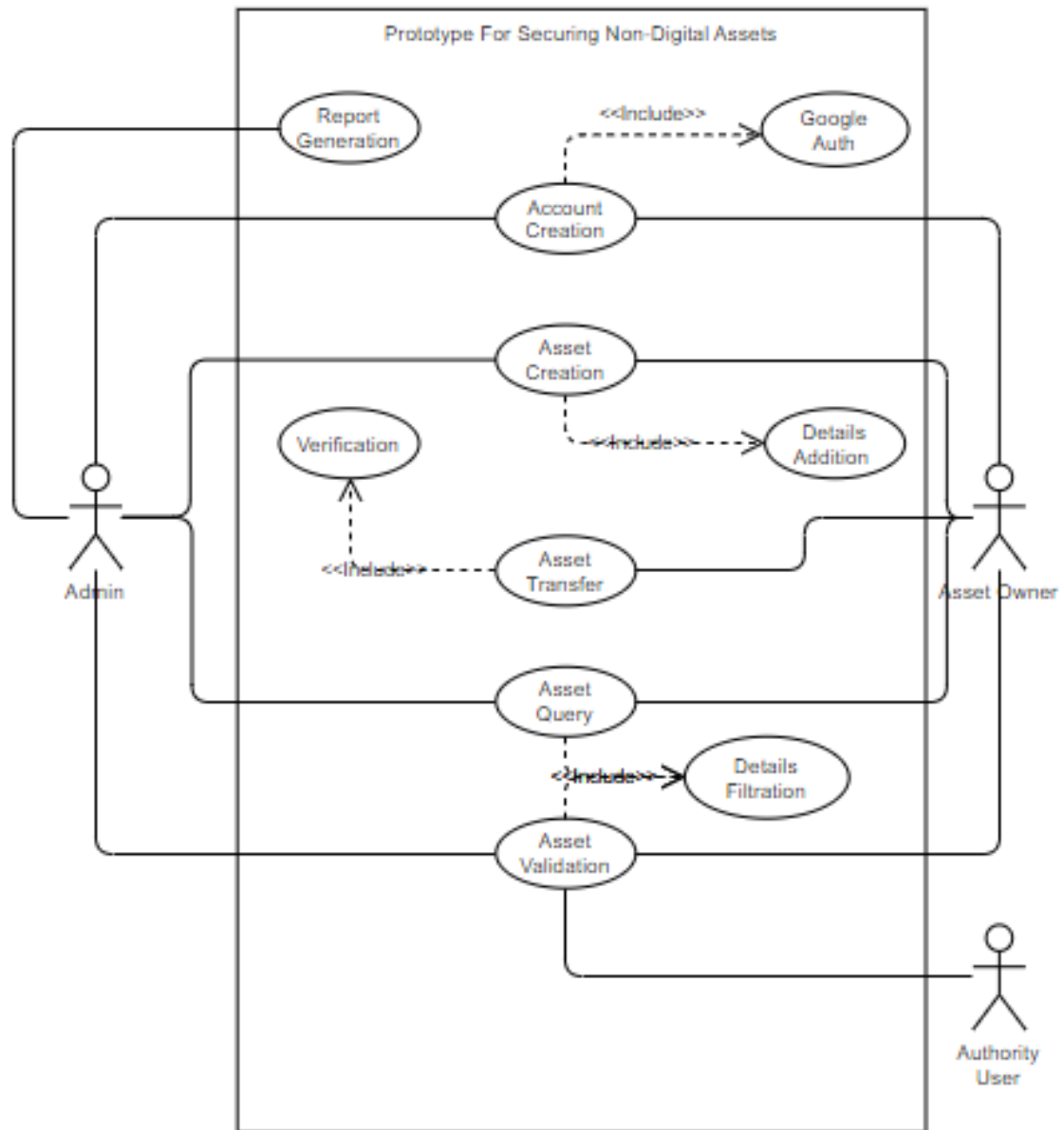


Figure 4.5: Use Case Diagram

4.4.2.1 Use Case Diagram Descriptions

**Account Creation**

Table 4.1: Use Case Description for Account Creation

<b>USE CASE ID</b>	UC_1
<b>Title</b>	Account Creation

<b>Description</b>	User accesses the account creation component on the User Interface
<b>Actors</b>	Admin, Asset Owner
<b>Pre-conditions</b>	User must have accessed the prototype webapp using the appropriate URL and the page has finished loading
<b>Success Scenario</b>	<ol style="list-style-type: none"> <li>1. User selects “Create New Account” button</li> <li>2. User enters all the required details for creation of a user account</li> <li>3. User clicks on the “Create” button</li> <li>4. The form details are validated and the details are sent to the database for storage</li> </ol>
<b>Alternative Scenario</b>	System declines the values entered after validation and displays an error message to the user

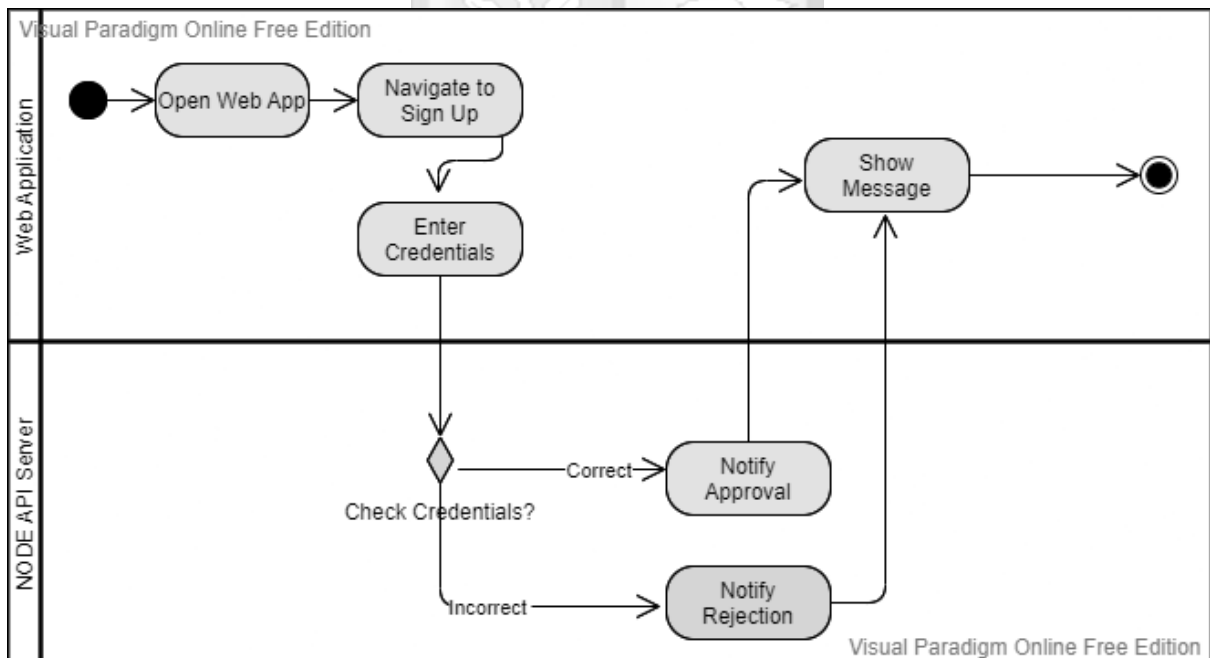


Figure 4.6: Activity Diagram for Account Creation

## Asset Creation

Table 4.2: Use Case Description for Asset Creation

<b>USE CASE ID</b>	UC_2
<b>Title</b>	Asset Creation
<b>Description</b>	User accesses the asset creation component on the User Interface
<b>Actors</b>	Admin, Asset Owner
<b>Pre-conditions</b>	User must have a user account in the system and must have successfully logged in
<b>Success Scenario</b>	<ol style="list-style-type: none"><li>1. User selects “Create New Asset” button</li><li>2. User enters all the required details associated with the specific asset. Details might vary depending on the asset type.</li><li>3. User clicks on the “Create Asset” button</li><li>4. The form details are validated and the tokenized asset in the form of a non-fungible token is added to the Flow Blockchain</li></ol>
<b>Alternative Scenario</b>	System declines the values entered after validation and displays an error message to the user

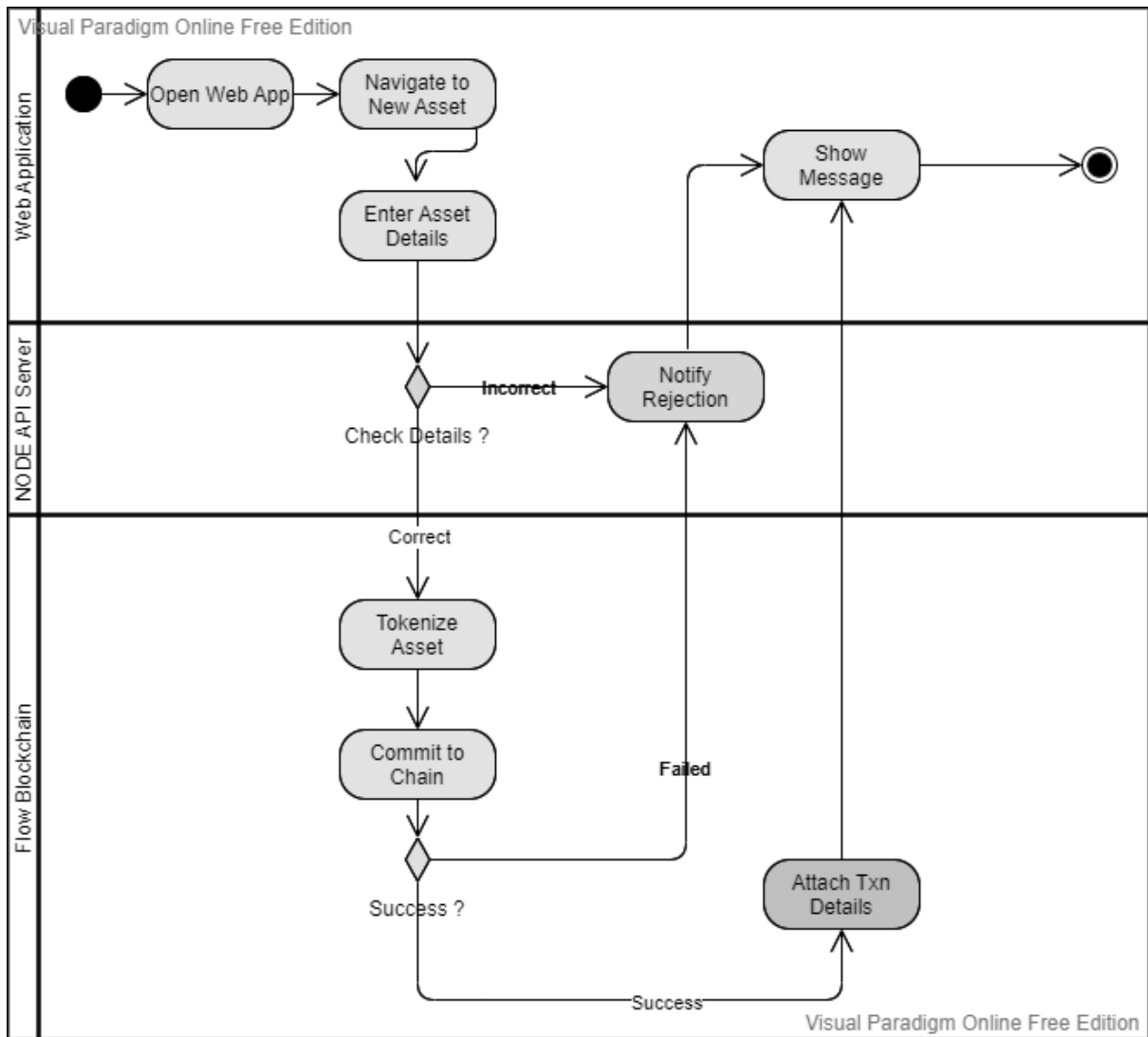


Figure 4.7: Activity Diagram for Asset Creation

## Asset Transfer

Table 4.3: Use Case Description for Asset Transfer

<b>USE CASE ID</b>	UC_3
<b>Title</b>	Asset Transfer
<b>Description</b>	User accesses the asset list component on the User Interface
<b>Actors</b>	Asset Owner
<b>Pre-conditions</b>	User must have a user account in the system and must have successfully logged in
<b>Success Scenario</b>	<ol style="list-style-type: none"><li>1. User selects “Transfer Asset” button next to their listed asset</li><li>2. User enters all the required details associated with the recipient account. Details might vary depending on the asset type.</li><li>3. User clicks on the “Transfer Asset” button</li><li>4. The form details are validated and the asset is transferred to the recipient account. The transaction is appended to the asset’s history and added to the Flow Blockchain</li></ol>
<b>Alternative Scenario</b>	System declines the values entered after validation and displays an error message to the user

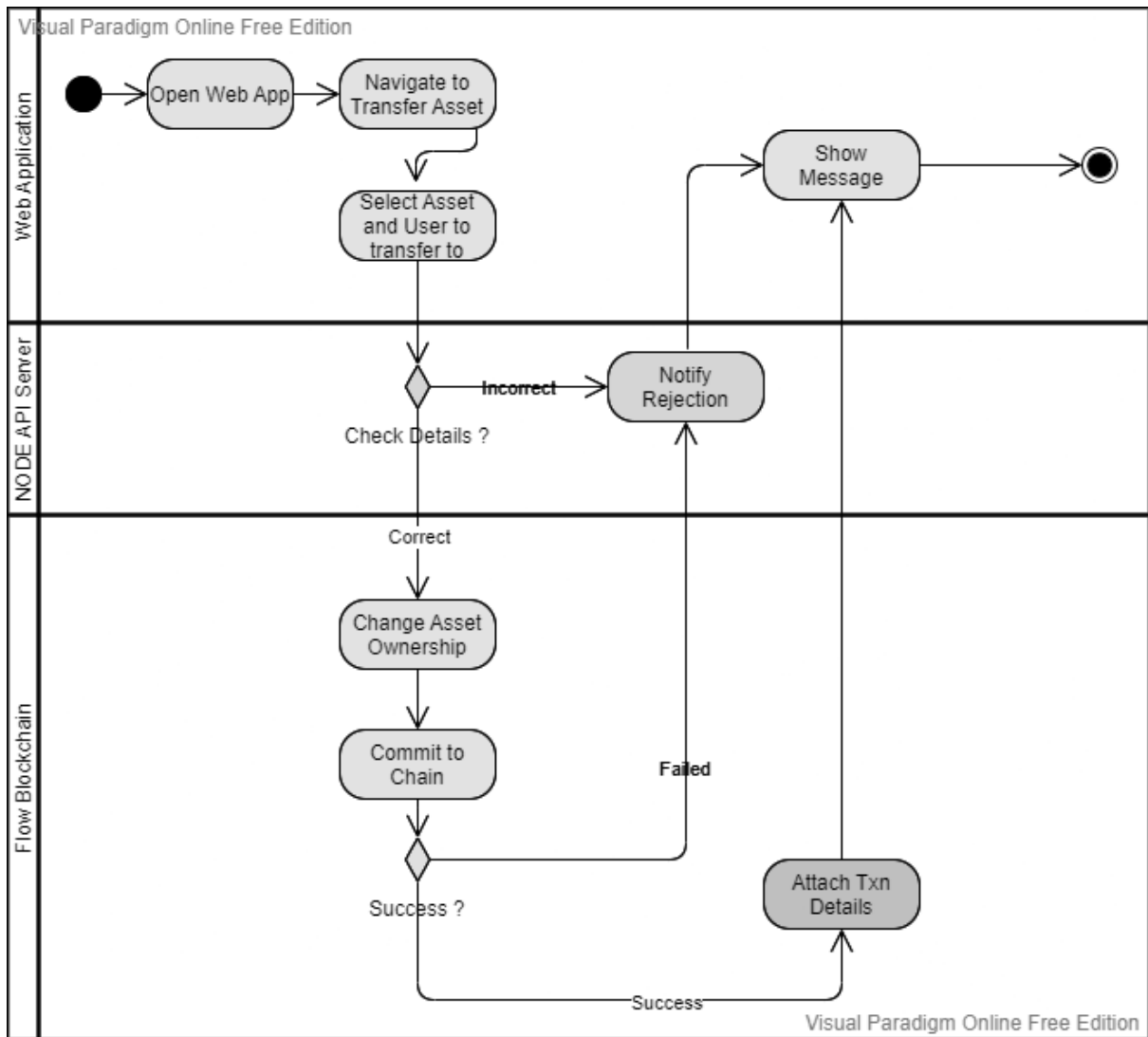
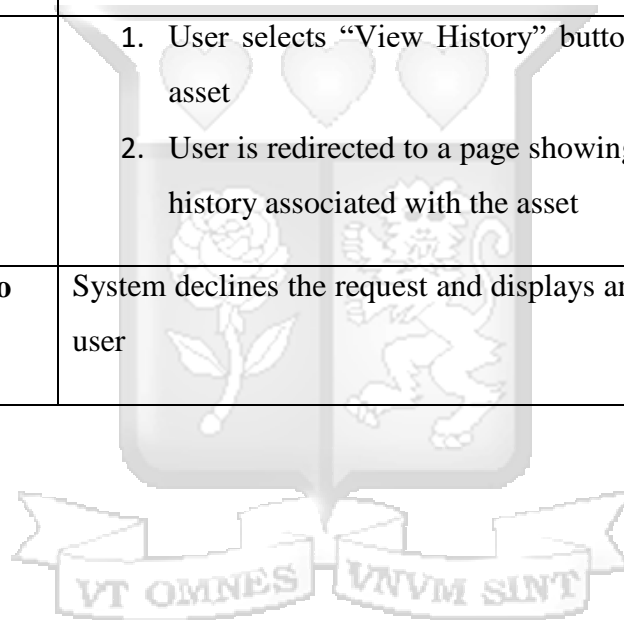


Figure 4.8: Activity Diagram for Asset Transfer

## Asset History Query

Table 4.4: Use Case Description for Asset History Query

<b>USE CASE ID</b>	UC_4
<b>Title</b>	Asset History Query
<b>Description</b>	User accesses the asset list component on the User Interface
<b>Actors</b>	Admin, Asset Owner
<b>Pre-conditions</b>	User must have a user account in the system and must have successfully logged in
<b>Success Scenario</b>	<ol style="list-style-type: none"><li>1. User selects “View History” button next to their listed asset</li><li>2. User is redirected to a page showing the transactions and history associated with the asset</li></ol>
<b>Alternative Scenario</b>	System declines the request and displays an error message to the user



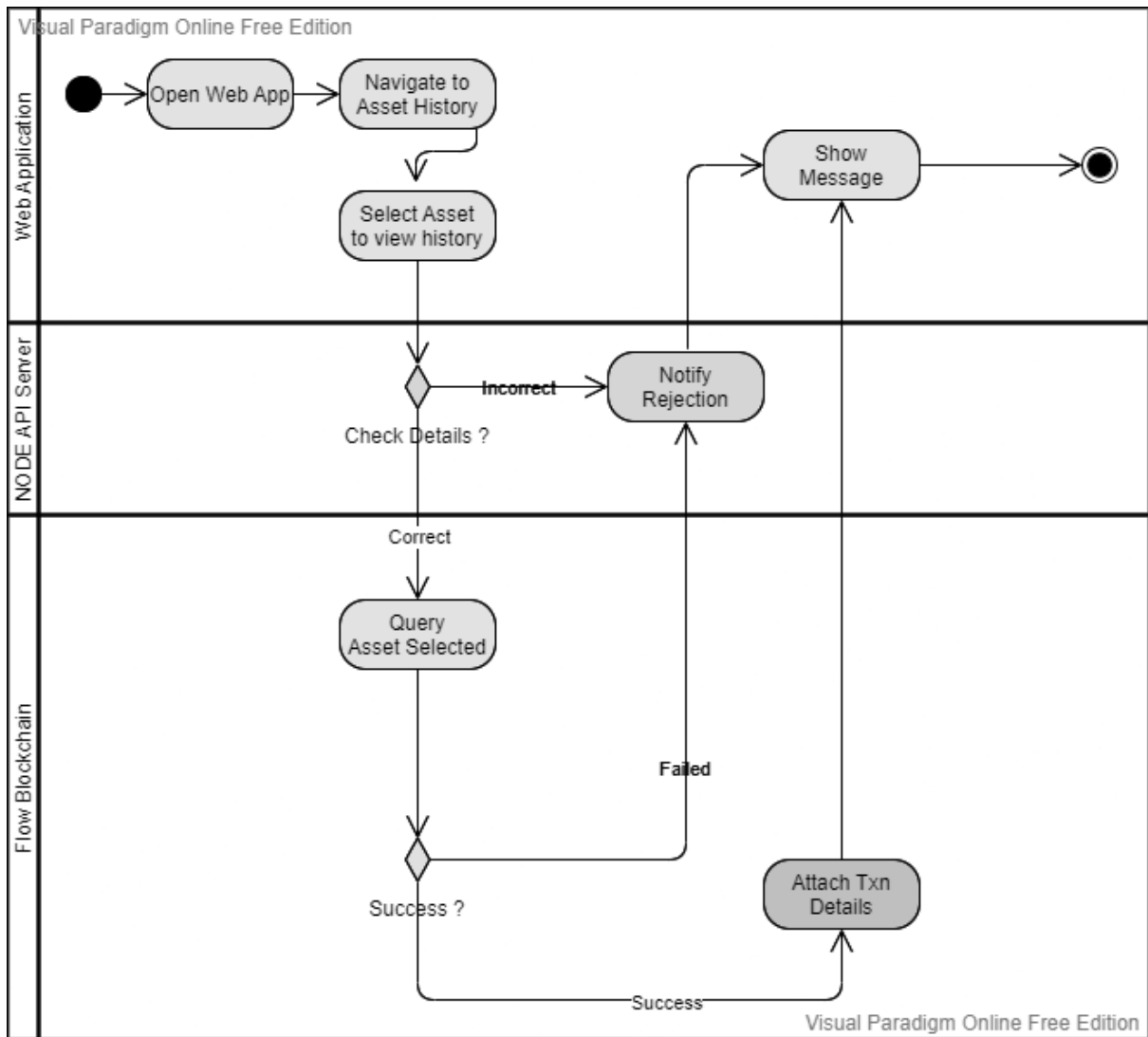


Figure 4.9: Activity Diagram for Asset Query History

## Asset Validation

Table 4.5: Use Case Description for Asset Validation

<b>USE CASE ID</b>	UC_5
<b>Title</b>	Asset Validation
<b>Description</b>	User accesses the asset validation component on the User Interface
<b>Actors</b>	Admin, Asset Owner
<b>Pre-conditions</b>	User must have a user account in the system and must have successfully logged in
<b>Success Scenario</b>	<ol style="list-style-type: none"><li>1. User enters the ID of the specific asset or filters by specific details</li><li>2. User is redirected to a page showing the transactions and history associated with the asset</li></ol>
<b>Alternative Scenario</b>	System declines the request and displays an error message to the user



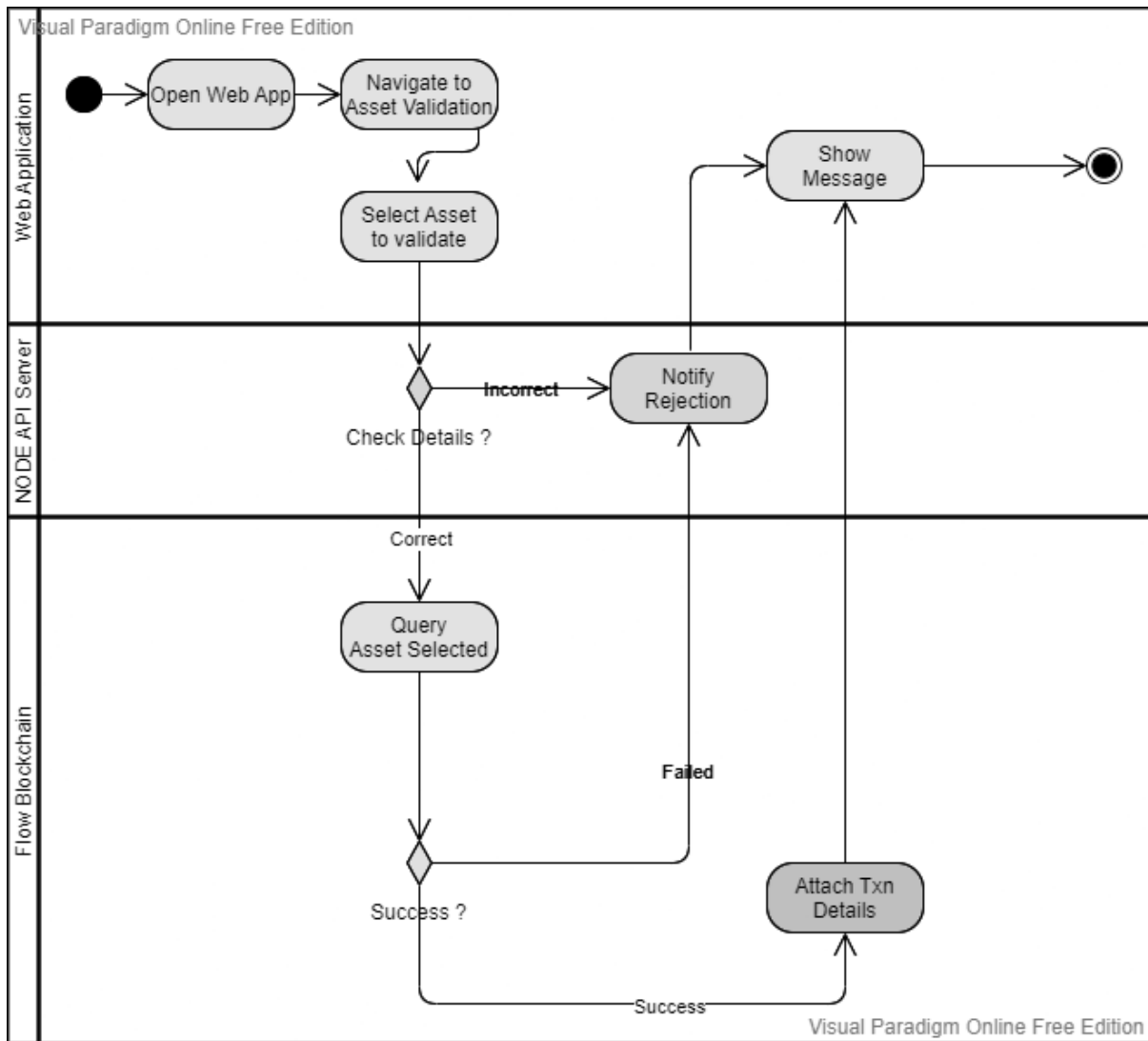


Figure 4.10: Activity Diagram for Asset Validation

## Report Generation

Table 4.6: Use Case Description for Report Generation

<b>USE CASE ID</b>	UC_6
<b>Title</b>	Report Generation
<b>Description</b>	User accesses the reports component on the User Interface
<b>Actors</b>	Admin
<b>Pre-conditions</b>	User must have a user account in the system and must have successfully logged in
<b>Success Scenario</b>	<ol style="list-style-type: none"><li>1. User enters the ID of the specific asset or filters by specific details such as date range or asset type</li><li>2. User clicks “Generate Report” and is redirected to a different page to view the report</li></ol>
<b>Alternative Scenario</b>	System declines the request and displays an error message to the user



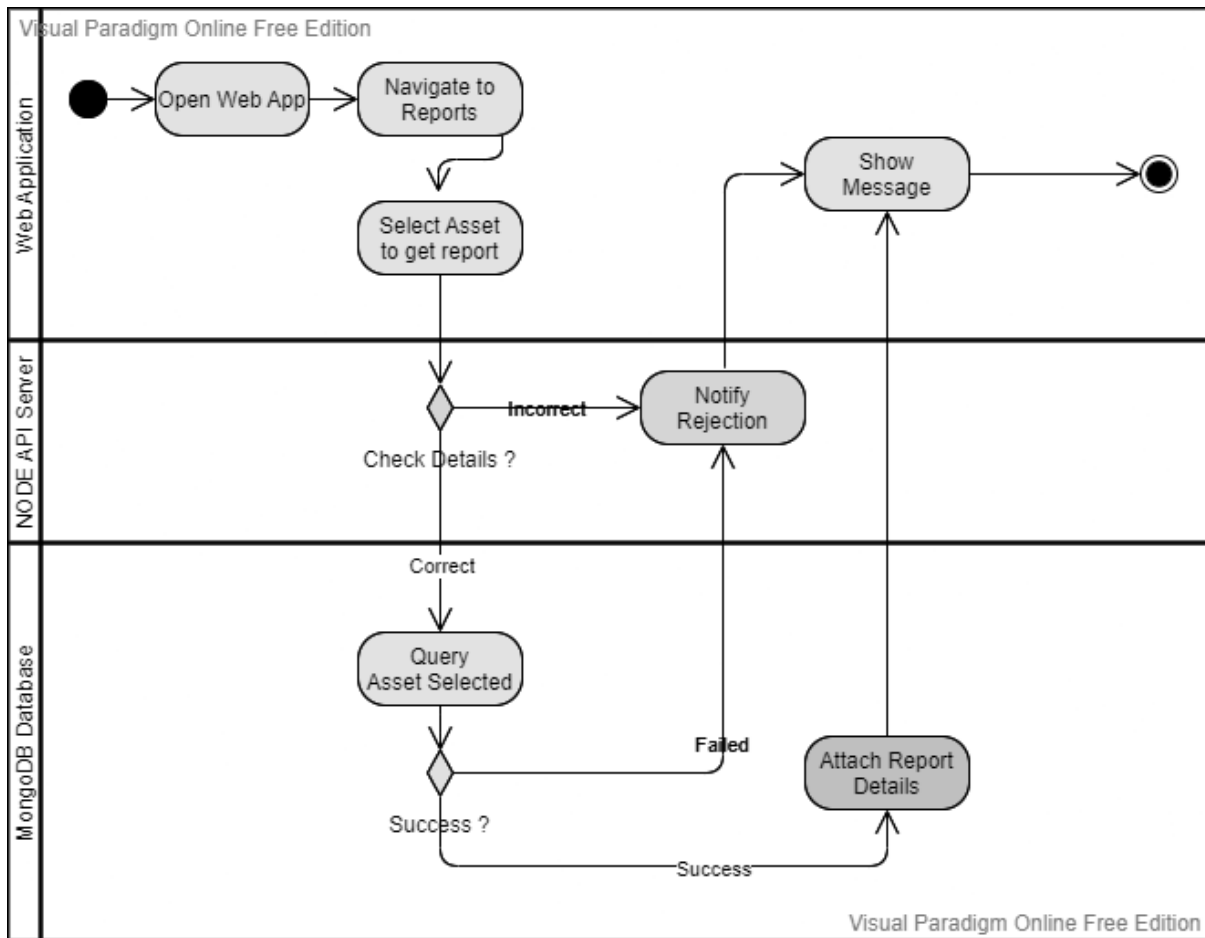


Figure 4.11: Activity Diagram for Report Generation

#### 4.4.3 Sequence Diagram

Sequence diagrams help in knowing how the system will behave and to discover potential responsibilities of a class in the process of system modelling (Kenpro, 2012). The figure below demonstrates the prototype's sequence diagram:

Sequence Diagram for Prototype

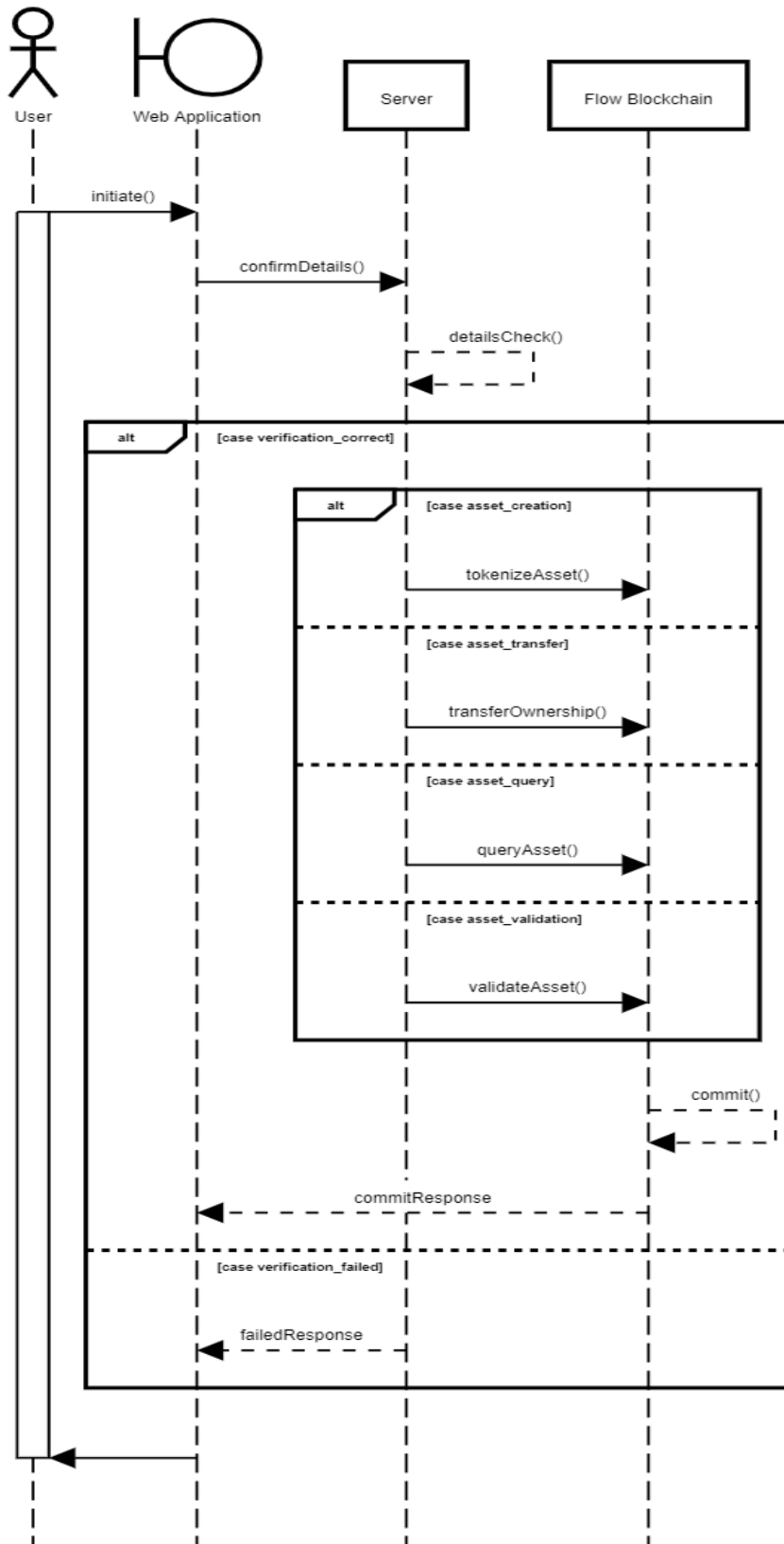


Figure 4.12: Sequence Diagram

#### 4.4.4 Database Schema

A non-relational MongoDB database will be used to help with storing the user details after authentication when interacting with the prototype. The authentication process will be facilitated using Firebase by Google hence the fields in the User model. It will contain users' information, users' roles and types. Also, in acting as a backup, it will hold some asset information which can be help in logging as similar actions are committed on the Flow Blockchain such as asset creation, transfer and querying.

The non-relational database will have the following collections:

i) **Users** - This collection will be generated from the User model containing the following details:

- user\_id – This is the unique identifier for the user
- email – This is the email address of the user
- photoURL – This is the link to the profile picture of the user
- displayName – This is the username of the user
- role – This designates the roles and permissions of the user
- phoneNumber – This is the phone number of the user
- country – This is the country of the user
- address -This is the address of the user
- state – This is the state of the user
- city – This is the city of the user
- zipCode – This is the zip code of the user
- about – This is the additional information about the user
- isPublic – This is the state of the user account

ii) **Assets Collection** - This collection will be generated from the Asset model containing the following details:

- title – This is the title of the asset
- description – This is the description of the asset
- category – This is the category of the asset
- owner\_id – This is the ID of the user who owns the asset
- can\_transfer – This is a boolean value that indicates whether an asset can be transferred or not

- is\_deleted – This is a boolean value that indicates whether an asset is soft deleted or not
- iii) **Asset History Collection** - This collection will be generated from the Asset History model containing the following details:
- asset\_id – This is the ID of the asset on which an action has been performed
  - action\_type – This is the type of action that has been performed
  - action\_initiator\_id – This is the ID of the user that has initiated the action
  - action\_reason – This is the description of the action type and why it has been performed

#### 4.4.4.1 Logical Schema

The figure below shows an entity relationship diagram that illustrates the database design of the prototype:

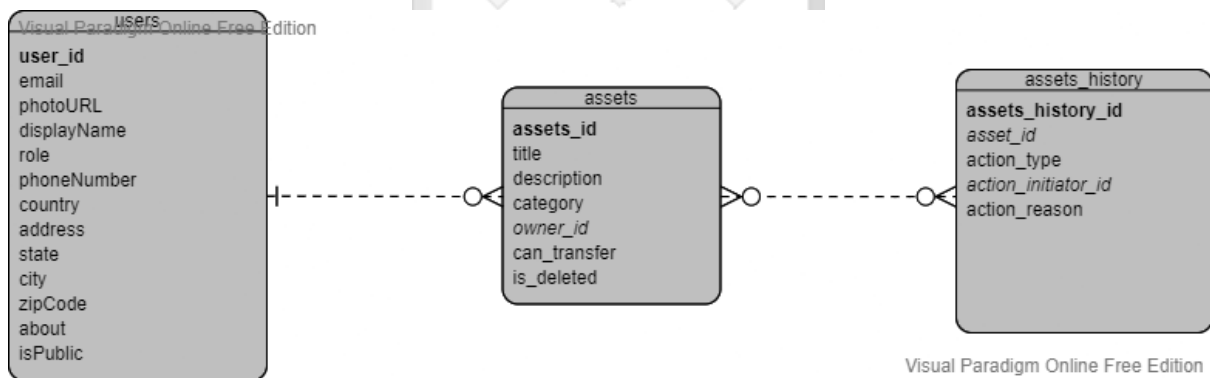


Figure 4.13: Entity Relationship Diagram

#### 4.4.4.2 Physical Schema

The sections below outline the physical schema of the collections to be used by the prototype:

##### Users Collection

Table 4.7 contains the users that are used to keep track of the users interacting with the prototype. This also helps in keeping track of the user roles and also map them to actions done to assets.

Table 4.7: Users Collection

Column Name	Data Type	Index
user_id	Object ID	Primary Key

email	String	
photoURL	String	
displayName	String	
role	String	
phoneNumber	String	
country	String	
address	String	
state	String	
city	String	
zipCode	String	
about	String	
isPublic	Boolean	

### Assets Collection

Table 4.8 contains the assets created while interacting with the prototype:

Table 4.8: Assets Collection

Column Name	Data Type	Index
asset_id	Object ID	Primary Key
title	String	
description	String	
category	String	
owner_id	String	Foreign Key

can_transfer	Boolean	
is_deleted	Boolean	

### Assets History Collection

Table 4.9 contains the history of actions performed on the assets created while interacting with the prototype. This collection will act as a backup and for log purposes after transactions take place on the Flow Blockchain.

Table 4.9: Assets History Collection

Column Name	Data Type	Index
asset_history_id	Object ID	Primary Key
asset_id	String	Foreign Key
action_type	String	
action_initiator_id	String	Foreign Key
action_reason	String	

### 4.4.5 Wireframes

The following section deals with the flow of the prototype screens as accessed through a web application.

#### 4.4.5.1 Login and Register

Users of the prototype will sign up or log in to the system as shown in the Figure 4.14 or using Google Firebase Authentication:

The wireframe shows a web browser window titled "Assets KE". On the left side, under the heading "Sign Up", there are five text input fields stacked vertically: "Full Names", "National ID", "Email Address", "Password", and "Confirm Password". Below these fields is a "Sign Up" button. On the right side, under the heading "Or Log In", there are two text input fields stacked vertically: "Email Address" and "Password". Below these fields is a "Log In" button.

Figure 4.14: User Authentication

#### 4.4.5.2 Assets List

Users of the prototype will be able to see their assets listed once they successfully log in as shown in Figure 4.15:

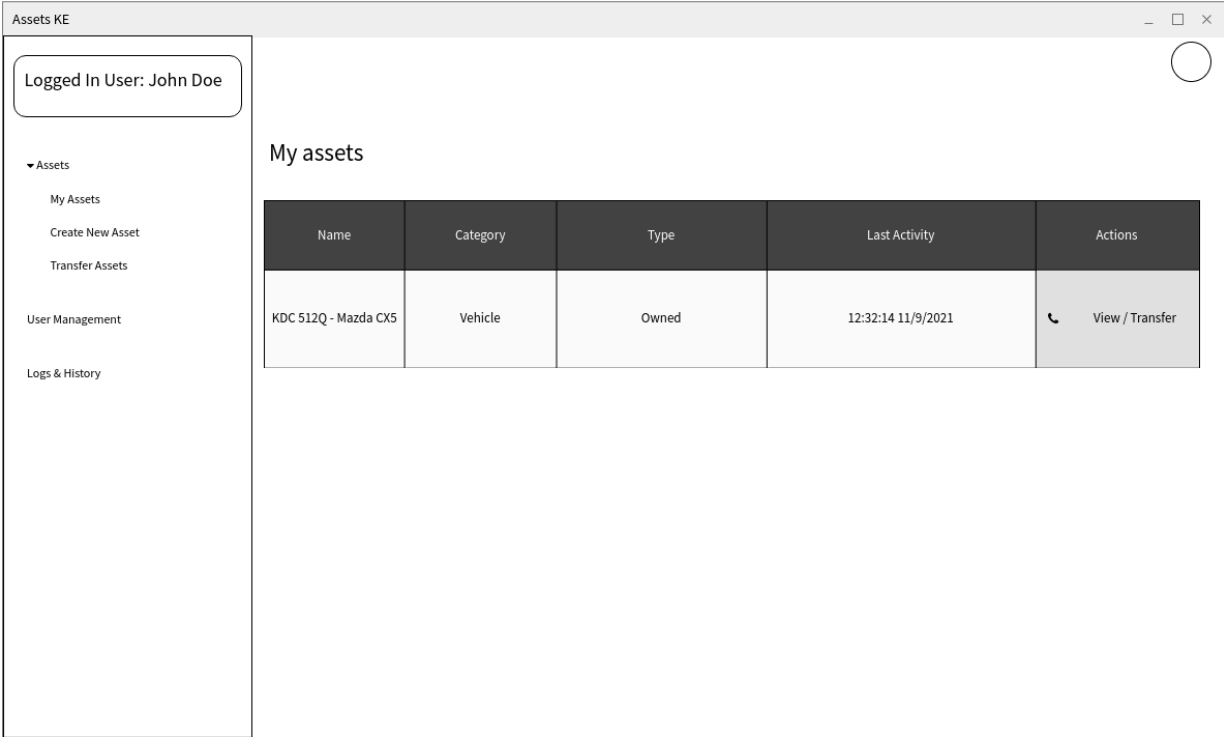


Figure 4.15: Assets List

4.4.5.3 Asset Creation

Users of the prototype will be able to create new assets using the form shown in the Figure 4.16:

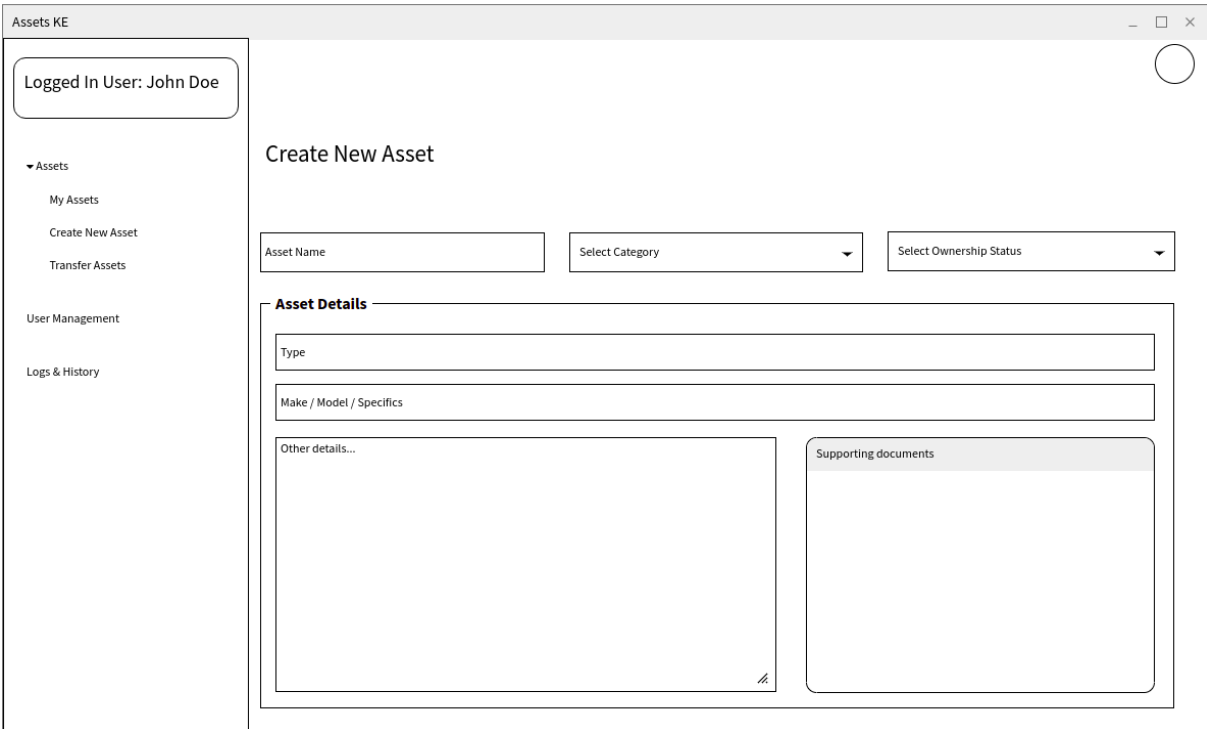


Figure 4.16: Asset Creation

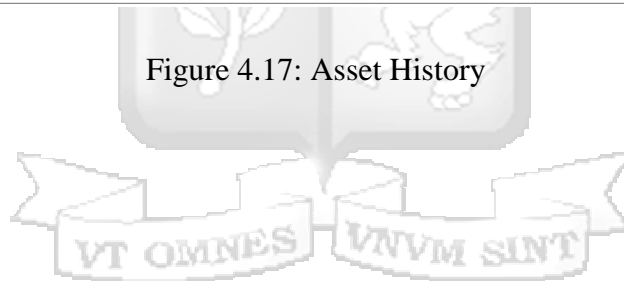
#### 4.4.5.4 Asset Transfer

Users of the prototype will be able to create transfer assets using the form shown in the Figure 4.17:

The screenshot shows a web application window titled "Assets KE". On the left is a sidebar with a user profile "Logged In User: John Doe" and a menu with options: "Assets" (expanded), "My Assets", "Create New Asset", "Transfer Assets", "User Management", and "Logs & History". The main content area is titled "Transfer Asset" and contains the following form elements:

- An input field for "Asset Name".
- A dropdown menu for "Select Type of Transfer".
- A section titled "New Owner Details" containing:
  - An input field for "Full Names".
  - An input field for "National ID".
  - An input field for "Length of transfer".
  - A large text area for "Reason for transfer".

Figure 4.17: Asset History



## Chapter 5: System Implementation and Testing

### 5.1 Introduction

This chapter focuses on the development of the prototype for securing non-digital assets using non-fungible tokens. It also explains the implementation of the system functionality and the requirements needed for the application to function. Screenshots are provided to show the different system modules and how the user interacts with the application.

### 5.2 Implementation Environment

The prototype was built and tested on a computer with 8 Gigabytes RAM, Intel Core i5 11<sup>th</sup> Generation processor of speed 2.4 Gigahertz and 256 Gigabytes Solid State Drive capacity. The operating system on the computer was Ubuntu Linux 20.04 LTS.

### 5.3 System Implementation

The prototype implemented is a web application integrated with the Flow Blockchain known as *Assets-KE*.

#### 5.3.1 Web Application Overview

The web application for the prototype allows users to create their accounts, create and tokenize assets, transfer them and validate them. It communicates with the Flow Blockchain and the MongoDB database through REST APIs exposed by the NODE server.

#### 5.3.2 Web Application Modules

##### 5.3.2.1 User Authentication Module

Users authenticate themselves before using the system using their Google credentials. This implementation is provided by the Google Firebase API. The authentication module is shown in Figure 5.1.

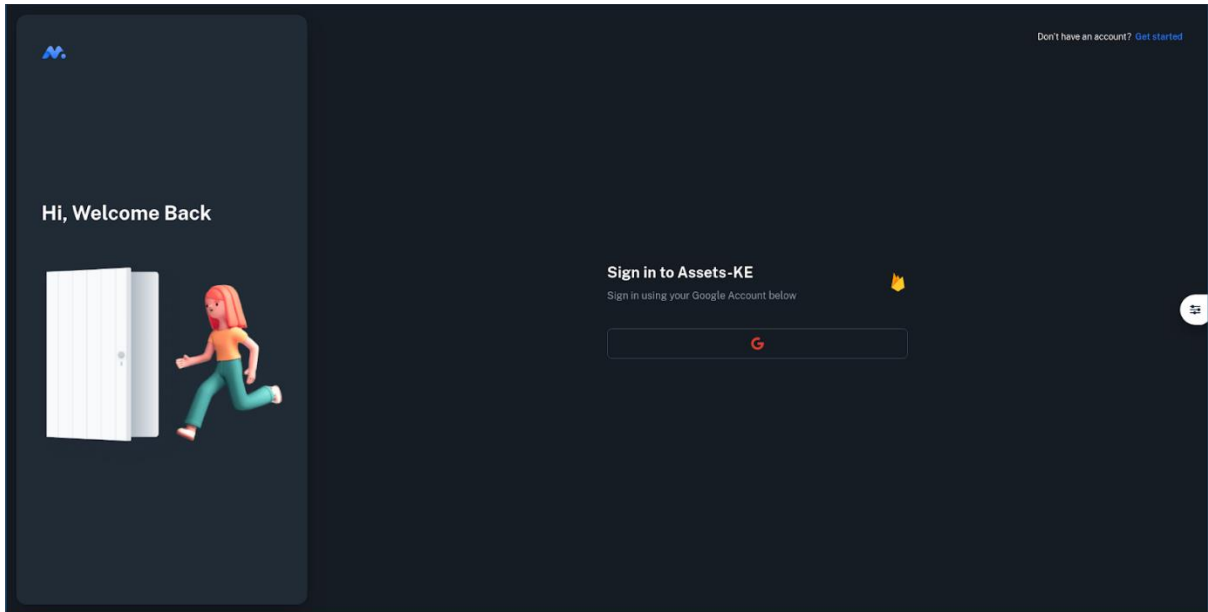


Figure 5.1: User Authentication

### 5.3.2.2 Assets List Module

On successful authentication, the user is presented with a table listing their existing assets. The hamburger menu next to the asset provides the option to either validate the asset on the Flow Blockchain or delete it. This is shown in Figure 5.2.

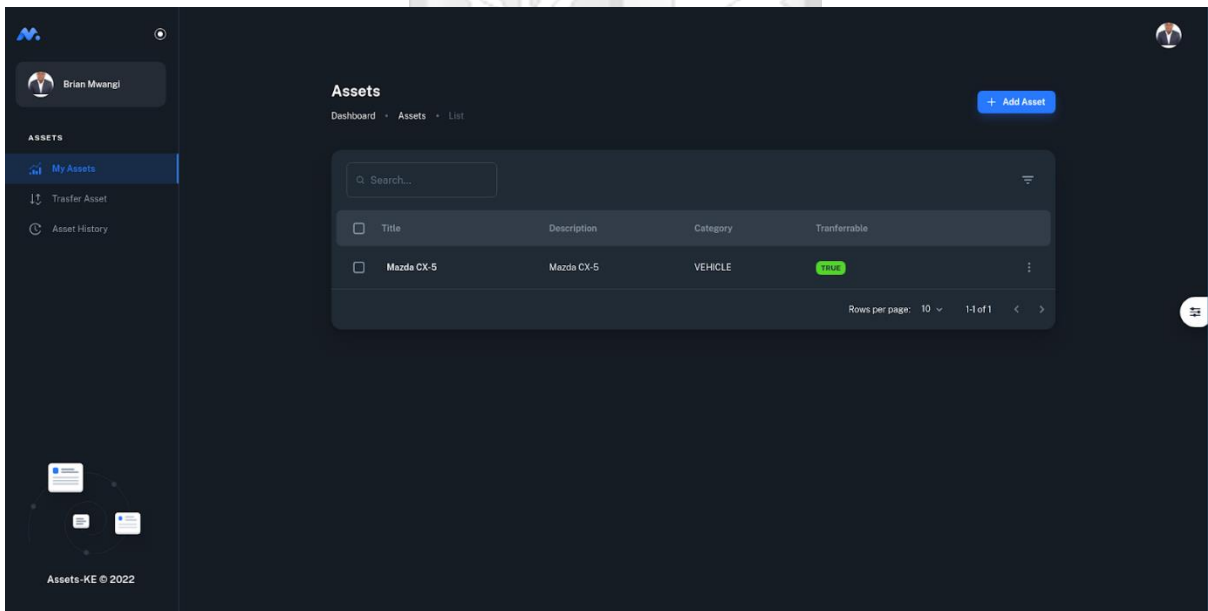


Figure 5.2: Assets List

### 5.3.2.3 Assets Creation Module

The asset creation module allows for users to add new assets by filling out the form as shown in Figure 5.3.

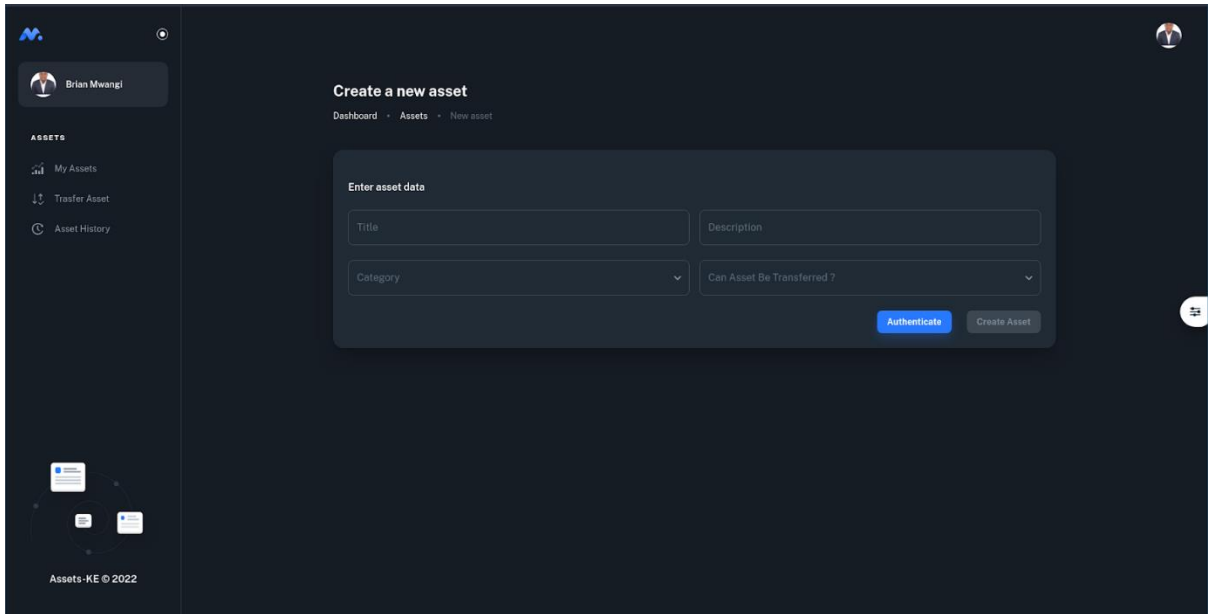


Figure 5.3: Asset Creation Form

To complete the asset creation and tokenization of the asset, the user is requested to authenticate themselves again and attach their account to the subsequent Flow Blockchain transaction. This is done through the pop-up shown in Figure 5.4

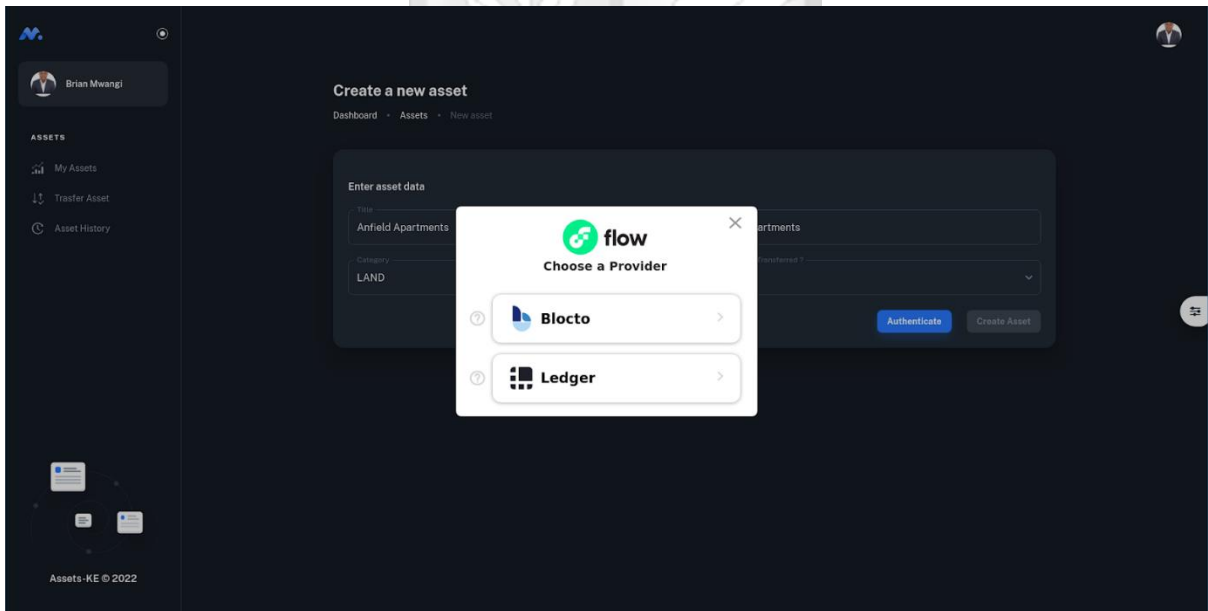


Figure 5.4: Flow Blockchain Authentication

Once the user authenticates themselves, they can then proceed to complete the transaction to tokenize the asset as shown in Figure 5.5.

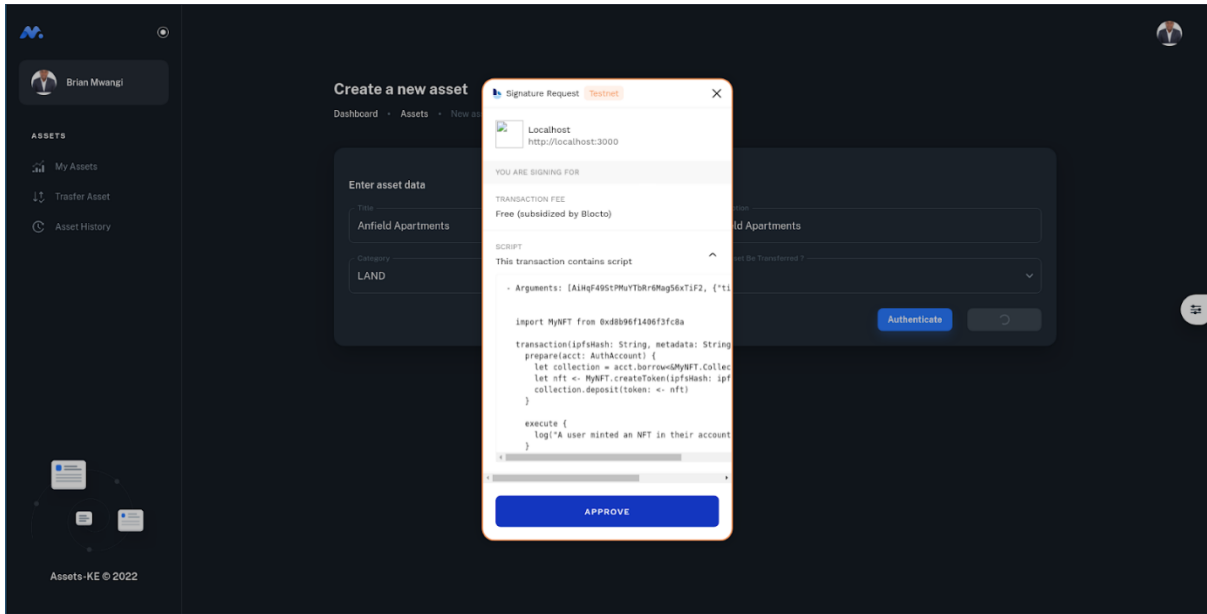


Figure 5.5: Approve Flow Blockchain Transaction

#### 5.3.2.4 Asset Transfer Module

This module allows the authenticated user to transfer the asset to another user in the system as show in Figure 5.6. They select the user to transfer to as well as the asset to transfer.

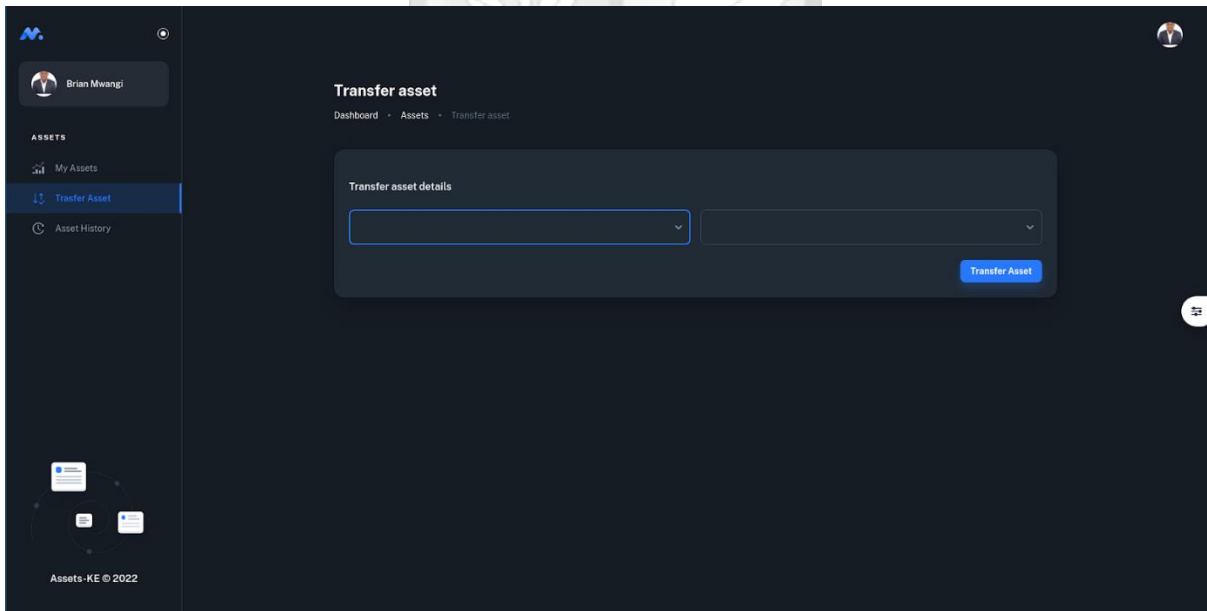


Figure 5.6: Assets Transfer Module

#### 5.3.2.5 Assets History Module

This module allows the authenticated user to view the history pertaining their assets from creation, transfer and even deletion as shown in Figure 5.7.

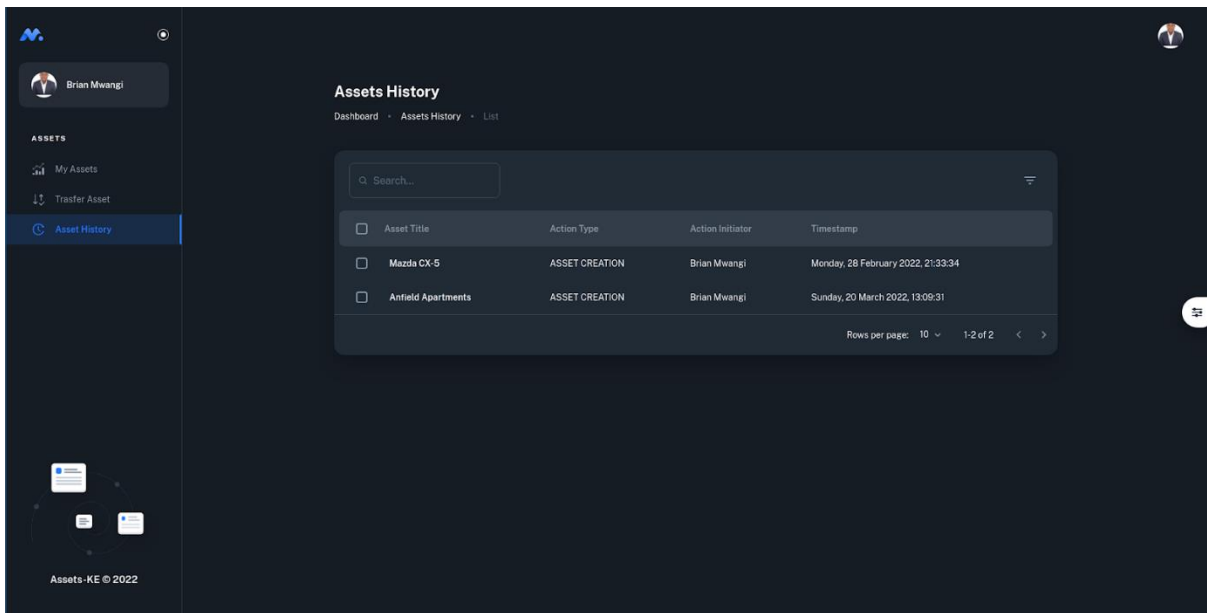


Figure 5.7: Assets History Module

### 5.3.2.5 Assets Validation Module

This module allows users to validate their assets using the Flow Blockchain transaction scanner as shown in Figure 5.8.

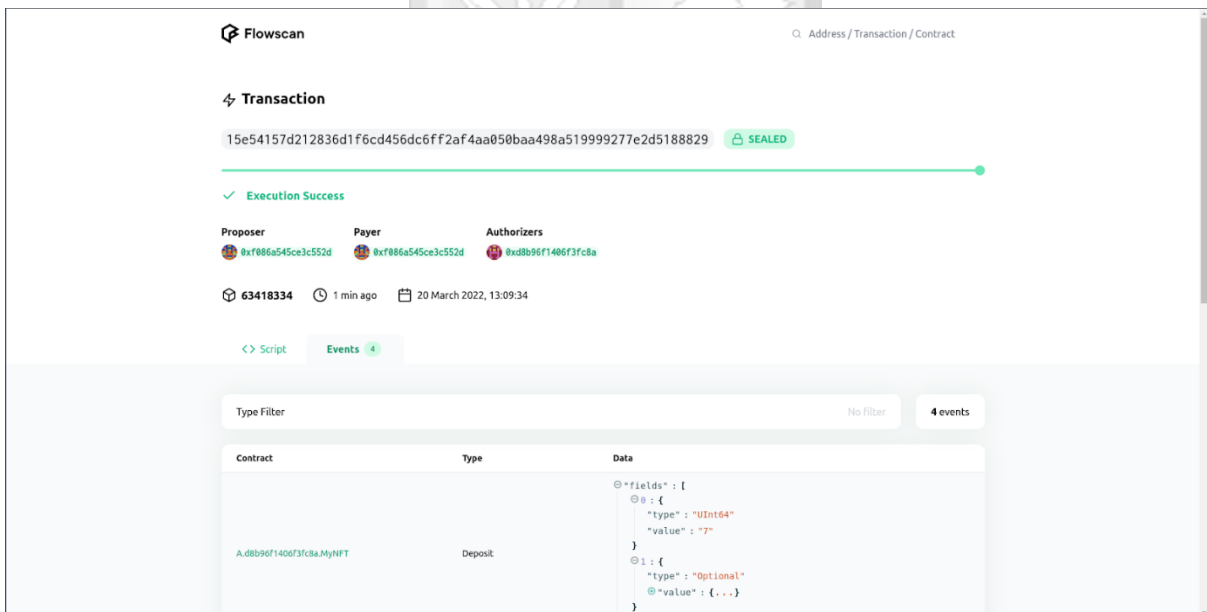


Figure 5.8: Flow Blockchain Transaction Scanner

Figure 5.9 shows an example of the transaction script executed on the Flow Blockchain to tokenize the asset.

```

Cadence

ARGUMENTS
  arguments: [
    0: {
      type: "String"
      value: "AiHqF49StPMuYtBrR6Mag56xTiF2"
    }
    1: {
      type: "String"
      value: "{\"title\":\"Anfield Apartments\",\"description\":\"Anfield Apartments\",\"category\":\"LAND\",\"can_transfer\":\"true\"}"
    }
  ]
}

import MyNFT from 0xd8b96f1406f3fc8a

transaction(ipfsHash: String, metadata: String) {
  prepare(acct: AuthAccount) {
    let collection = acct.borrow<MyNFT.Collection>(from: /storage/MyNFTCollection) ?? panic("This collection does not exist")
    let nft <- MyNFT.createToken(ipfsHash: ipfsHash, metadata: metadata)
    collection.deposit(token: <- nft)
  }

  execute {
    log("A user minted an NFT in their account")
  }
}

```

Figure 5.9: Transaction Script on Flow Blockchain

## 5.4 System Testing

This section describes tests that were performed on the web application prototype. The main areas the testing focussed on were: functionality tests, usability tests, compatibility tests and validation tests.

### 5.4.1 Functional Testing

Functional tests were carried out to determine if the prototype's design and implementation was a success or a failure. This testing was manually done and included the main use cases for the prototype including: user creation, asset creation, asset transfer and validation.

Below are the test cases and their results.

#### *User Account Creation*

Table 5.1: User Account Creation Test Cases

<b>Test Case Name: User Account Creation</b>	<b>Test Case: 1</b>
--	---------------------

Description: User create their accounts by using the Google Firebase API. This allows them to select their accounts of choice			
Pre-Condition: The user should have visited the web application.			
Step	Action	Expected Results	Pass/Fail
1.	User opens the web application	The application loads the login page	Pass
2.	User clicks the Sign in with Google button	The Google Firebase API loads the module to select user account	Pass
3.	User selects the account to sign in with	The application returns a success message and redirects the user to the portal	Pass
Post condition: User gets access to the system			

*Asset Creation*

Table 5.2: Asset Creation Test Cases

<b>Test Case Name: Asset Creation Test Case</b>		<b>Test Case: 2</b>	
Description: User adds the asset details for the new asset then submits it to the Flow Blockchain			
Pre-Condition: The user should have successfully logged in.			
Step	Action	Expected Results	Pass/Fail
1.	User logs into the application	The application loads portal	Pass

2.	User clicks the “Add Asset” button	The application loads asset creation form	Pass
3.	User fills the asset’s particulars and commits the asset	The application sends a request to the Flow Blockchain and commits the tokenized asset	Pass
Post condition: User can save the asset and view them in their list			

*Asset Transfer*

Table 5.3: Asset Transfer Test Cases

<b>Test Case Name: Asset Transfer Test Case</b>		<b>Test Case: 3</b>	
Description: User can transfer an asset they own to another user on the system			
Pre-Condition: The user should have successfully logged in and have an asset they own			
Step	Action	Expected Results	Pass/Fail
1.	User logs into the application	The application loads portal	Pass
2.	User clicks the “Transfer Asset” button	The application loads asset transfer form	Pass
3.	User selects the asset to transfer and the user to transfer to	The application sends a request to the Flow Blockchain and changes ownership of the tokenized asset	Pass
Post condition: User can no longer view the asset they have transferred			

### Asset Validation

Table 5.4: Asset Validation Test Cases

<b>Test Case Name: Asset Validation</b>		<b>Test Case: 4</b>	
<b>Test Case</b>			
Description: User can validate the asset created or transferred to them on the Flow Blockchain			
Pre-Condition: The user should have successfully logged in.			
Step	Action	Expected Results	Pass/Fail
1.	User logs into the application	The application loads portal	Pass
2.	User clicks the “Validate” button next to their assets	The application loads Flow Blockchain Transaction scanner where they can view the asset particulars	Pass
Post condition: User can validate the asset			

#### 5.4.2 Usability Testing

Usability tests were carried out to confirm the user friendliness of the web application and whether a new user interacting with the system finds it easy or not. The input from the users that tested the system was collected through the questionnaire shown in Appendix B.

The pie chart showing the results is shown in figure 5.10 below.

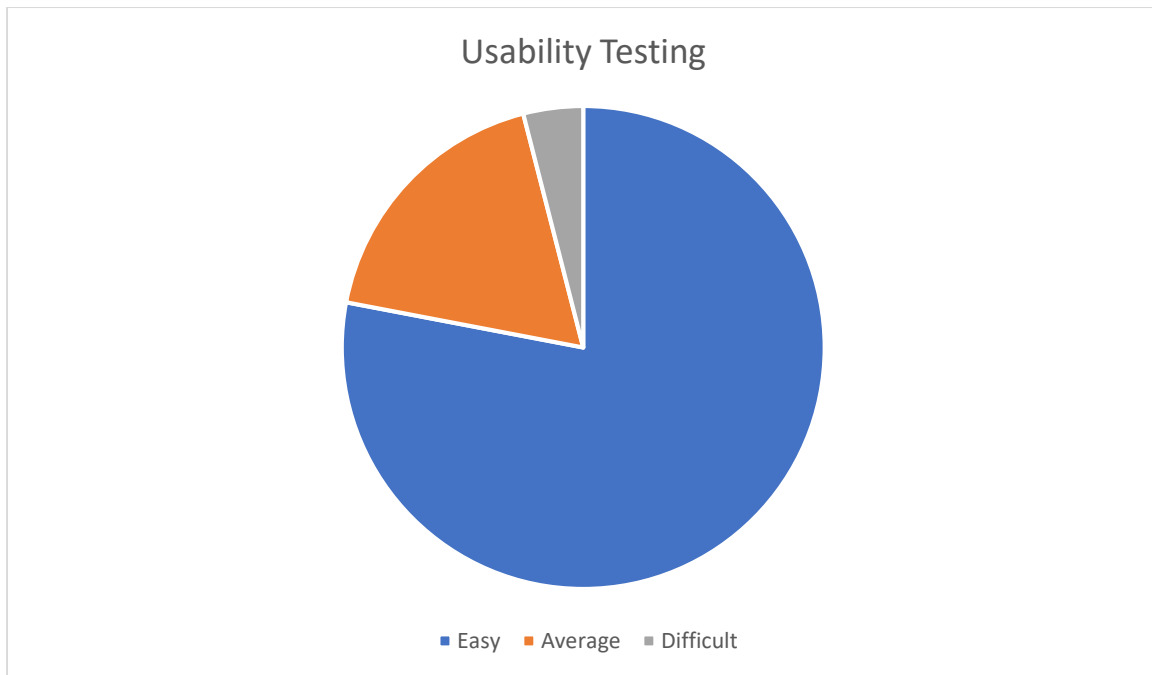


Figure 5.10: Usability Testing

Table 5.5 outlines the usability tests performed.

Table 5.5: Usability Test Case

<b>Test Case Name:</b> Usability of the Application			
<b>Description:</b> Test to gauge the overall usability of the application			
<b>Pre-Condition:</b> Web application must have been launched successfully.			
<b>Post Condition:</b> Ease of use of the application by the system			
Step	Action	Expected Results	Pass/Fail
1.	User can access the portal, menu items and interact with them easily	Menu items should be visible, clickable and descriptive	Pass
2.	User can navigate the application with ease	Web application interface should be clear and concise	Pass

### 5.4.3 Compatibility Testing

Compatibility tests were done to ensure that the web application was compatible with the current existing platforms. Since it is a web application, the most commonly used web browsers were used to test.

Table 5.6: Web Browser Compatibility Test Cases

Web Browser	Compatibility
Safari	Yes
Mozilla Firefox – Version 4 and above	Yes
Chrome – Version 4 and above	Yes
Microsoft Edge	Yes

### 5.4.4 Validation Testing

The prototype was validated through the use of the test cases in Table 5.7 together with the questionnaire given to the users as shown in Appendix B.

The pie chart showing the results is shown in figure 5.11 below.

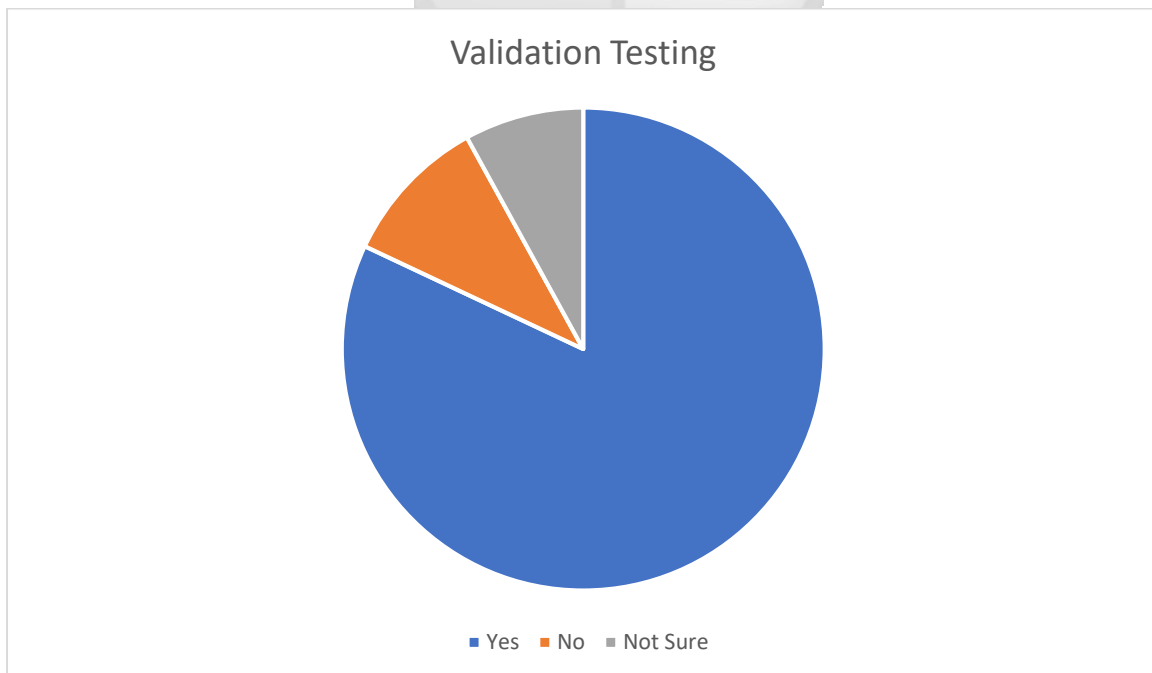


Figure 5.11: Validation Testing Response

Table 5.7: Validation Test Cases

<b>Test Case Name:</b> Validation of the Application			
<b>Description:</b> Test to gauge the overall validation of the application			
Step	Action	Expected Results	Pass/Fail
1.	System accuracy and speed	User input is validated to ensure only correct input and the actions take less than 20 seconds to complete	Pass



## **Chapter 6: Discussions of Key Findings**

### **6.1 Introduction**

The motivation of this thesis was to review how assets are protected in Kenya and understand the issue of fraud involving the forgery of the documents used to represent non-digital assets. Thereafter, there was the need to discover whether a blockchain backed technology can address the gap which led to the designing, testing and implementing a prototype to secure non-digital assets using non-fungible tokens. This chapter will describe the findings and achievements, ways the objectives were attained, the advantages of the implementation as well as its limitations.

### **6.2 Key Findings and Achievements**

The literature reviewed during the carrying out of this thesis shows that there are indeed several ways of dealing with the forgery problem that affects documents used to represent non-digital assets. The different ways of dealing with this are both manual and also automated. The manual way of detecting forgery is heavily prone to human error and has proven to be taxing in terms of time and money. Also, the very important pieces of documents are prone to other forces of nature that can lead to their destruction or loss such as fires and theft. When it comes to the automatic ways of document verification, they are still in the initial phase and are a mix of trial and error using QR codes and signature detectors to using Artificial Intelligence which is more experimental than practical. These ideas also exist in isolation and are yet to be connected to the concerned government bodies and third parties. Hence, there is no decentralized platform that can help keep track and also update all parties as needed. Without this common platform, the issue of accountability arises as the common citizen has no robust, easy and efficient way to validate both their assets and those belonging to other people.

Another key finding of this thesis is that there already exists some blockchain applications that have tried to solve the problem at hand. However, the applications have yet to be tried and tested as most of them have focused on the payment aspect of the blockchain technology. Also, the blockchain applications have been build either on top of the Bitcoin or Ethereum network which experience extremely high gas fees and slow transaction times even for simple transactions. In line with blockchain applications, the use of permissioned blockchains such as Hyperledger Fabric have come into play but for one to join such a network they need permission to join which ends up feeling like more of a centralized platform with gatekeepers rather than an open immutable platform.

### 6.3 Discussion of the Research Objectives

The following section will highlight how the objectives were achieved in order to eventually design, implement and test a prototype for securing non-digital assets using non-fungible tokens. The knowledge herein was acquired from research done on online websites, books and electronic-books, journals and user feedback.

The first objective outlined in section 1.3.2 was to investigate the challenges faced in securing non-digital assets. After the study, it was identified that one of the main challenges faced in securing non-digital assets using their documentation was documentation fraud. While forgery is the main type of documentation fraud, it also includes counterfeit documents and even imposter documents. This is also a problem facing our country Kenya where cases of title deed theft are rampant.

The second objective outlined in section 1.3.2 was to analyse the different techniques and models used for detecting fraud in documenting non-digital assets. The main take home as highlighted in section 2.3.1 was that the current systems were prone to human error and manipulation and in terms of detecting fraud was the heavy reliance on manual methods which ended up on being expensive in monetary terms and in time too. The literature as outlined in section 2.3.2 also showed that there was also the use of QR codes and the use of deep learning for document verification. While these processes were helpful, they consumed a lot of time and lacked the assurance of the immutability of the documents been verified. Hence, the use of the blockchain was seen as a more appropriate method as it offers strong degrees of ownership and immutability.

The third objective outlined in section 1.3.2 on reviewing existing frameworks used to develop blockchain applications allowed the researcher to understand the pros and cons of the available frameworks and settle on the one that offered the most utility. After the review of the Ethereum blockchain in section 2.4.1, the Flow Blockchain was selected to power the prototype. The architecture of the Flow Blockchain, the building blocks and the processes were also discussed thus giving the researcher a better understanding as shown in section 2.4.2. During this process, various ways in which blockchain technology can be used were also identified.

The fourth objective was to design a blockchain prototype to tokenize non-digital assets in Kenya. For this objective, the System Design and Architecture as well as the wireframes were covered in Chapter 4. Both the functional and non-functional requirements were outlined and

with the help of diagrams such as use case, sequence and context diagrams the end-to-end flow of the prototype was idealized.

The fifth objective was to test the developed prototype. After the implementation using mainly JavaScript for both the Frontend and Backend and the Flow Blockchain for the on-chain functionalities, the prototype was tested to gauge its functionality and responsiveness as outlined in section 5.4. Due to the fact that the prototype was initially web based, it was tested with different browsers and by different users who filled out the questionnaire shown in Appendix C. The prototype met all the requirements and passed the usability tests.

### **6.3 Prototype Assessment**

The prototype has a number of advantages compared to existing systems – both manual and automatic. The first and major advantage is since the underlying blockchain technology used is open to everyone, all transactions happening are permanent and immutable. This means, everyone can easily keep track of what is happening and be sure that no one else has the ability to change the existing data. Second, by using the Flow Blockchain specifically which is built with non-fungible tokens in mind from the ground up, the prototype leverages this ability to easily keep track of which user owns which asset as an asset can only exist with one user at a time in their storage. Another benefit of using the Flow Blockchain is that the transactions are quick and the gas fees are low compared to other blockchain networks. This hugely cuts from cost and the barrier of entry is greatly reduced meaning more useful applications can also spring from this.

The breakdown of the advantages and limitations of the prototype after assessment are outlined below:

#### ***6.3.1 Advantages of the prototype***

- i. Immutability and ownership benefits are realised due to the underlying Flow blockchain technology.
- ii. The Flow Blockchain is built with non-fungible tokens as an integral part which makes packaging of assets easy in terms of creation and transfer.
- iii. By virtue of using the Flow Blockchain, transactions on the assets happen quickly and the gas fees are low and manageable.

- iv. Since the prototype is a web application, the prototype can be used across all platforms independent of the operating system and browser. The responsiveness also allows for the web application to be used on a mobile phone.
- v. The prototype eliminates the hinderances brought about by manual verification processes such as time wastage and human errors.
- vi. Security of the assets is enhanced as the underlying blockchain technology has strong cryptographic mechanisms in place.

### ***6.3.2 Limitations of the prototype***

- i. The prototype requires the user to have an internet connection to be able to use it.
- ii. The prototype does not address issues that may arise from user impersonation.
- iii. The prototype is limited to the verification of few asset categories.



## Chapter 7: Conclusion, Recommendations and Future Work

### 7.1 Conclusion

This study was aimed at developing a prototype for securing non-digital assets using non-fungible tokens with the help of blockchain technology. The aim for this project came from the need to have a new way of securing assets for the ordinary person in a way that was open, decentralized and easy to verify. From this aim, a few ideas were floated but in the end, blockchain technology was the most viable option for this study. Hence, the goal was to see if the new non-fungible token data structures could be used to secure assets instead of the ordinary data structures.

Before the study could take place, there was the need to set objectives that would guide the thesis. Since the original idea was the security of non-digital assets, there was the need to dive through previous research on the same issue. Hence, the objectives that were set revolved around finding the problems that circled around the security of non-digital assets and how that had been dealt with previously. This was really important because it allowed the study to be justified in that there was actually a problem to be solved. Once this objective was achieved, then it would allow for the implementation of the prototype to follow.

The first objective involved investigating the challenges faced in securing non-digital assets. This was a key objective since it would drive the gap that needed to be filled by the proposed prototype. By pursuing this objective, the findings indicated that indeed there were many challenges that faced the securing of assets in our country Kenya. With this information, the next obvious question was on the different techniques that were already in place to solve the issues that had been identified. This study found out that apart from the manual process that were commonly used for verification, there existed other ideas that people had brought forth to solve this issue which also tied in with the second objective of the study. These ideas included using technology such as QR codes and Artificial Intelligence to distinguish true documents from false documents. Locally in Kenya, the manual process had been integrated with platforms such as ArdhiSasa and eCitizen. Even though this documents aided in some aspects, they were prone to a lot of downtime and regional constraints.

The third objective highlighted by this study provided the researcher with the opportunity to review different frameworks within the blockchain eco-system that could be used to fill the gap of securing non-digital assets using non-fungible tokens. This research found out that the

blockchain eco-system had come a long way since the invention of the Bitcoin network in the year 2008 - at the height of the stock market and housing market crash. Primarily, the blockchain network concept allowed for a universal ledger to be used to track monetary transactions for all the players in the network. Using complex cryptography techniques, the transactions would be appended onto the blockchain and they would be immutable and verifiable by anyone. Following closely from the Bitcoin network invention, other blockchain networks started springing up offering different incentives. In 2013, Vitalik Buterin conceived the Ethereum blockchain. While it offered the same concept as the Bitcoin blockchain network, it had additional benefits. These included the use of smart contracts that could be triggered by other addresses in the network and could in turn trigger different actions. The idea of smart contracts took the blockchain world by storm as they allowed for actions to take place when certain parameters were met and these actions would then be imprinted onto the network which was immutable. Apart from having smart contracts, Ethereum allowed for different data structures to exist and this brought about the ERC-721 standard which allowed for assets such as art to be tokenized and stored on the blockchain. While this was a good use case for the network, the downside of was the long transaction times and the high gas fees on the network. Due to this shortfall, other blockchain networks such as Stellar and Flow came into play solving the issue. The research found that the other blockchain options had optimized their flows by either performing actions off-chain or by splitting the node actions. Through this research also, Flow Blockchain came in as a very prominent contender since the blockchain was built with non-fungible tokens in its core. The Flow Blockchain had been previously used to create the addictive game called CryptoKitties that at some point slowed down the whole Ethereum network and the team behind it decided to create their own network which now powered this prototype.

Building on the results from the first three objectives, the study allowed the researcher to go ahead with the building of the prototype. This included getting familiar with different technologies that would allow for the prototype to be functional. From understanding JavaScript as well as the Node environment, the decision was made to use the language to power both the frontend and backend of the prototype. The customer facing user interface would be built using ReactJS which is a popular framework for websites. The backend would also use JavaScript but through the widely accepted Expressjs framework. Using JavaScript also made it easy to integrate the Flow Blockchain library which also used JavaScript. Hence, the end-to-end journey would allow the user to interact with the frontend which would then

send request to the backend and in turn send the request to tokenize the asset on the Flow Blockchain. The transaction hash would then be saved to allow for future verification. It was also paramount to test the developed prototype by allowing different users to interact with the system. The feedback was crucial in making the system even better and simpler to use for the ordinary person. Eventually, it was possible for any person to create an account on the prototype, create a new asset and have it tokenized on the Flow Blockchain as a one-of-one. A one-of-one non-fungible token meant that it only existed on the user's account and they would be the ones who could transfer it to another account.

In conclusion, from this study, it was found that it was possible to tokenize non-digital assets on the Flow Blockchain and allow them to exist in a digital form where anyone could verify them and would prevent any challenge faced by other processes. This was essential for the major parties involved such as the Ministry of Lands and Physical Planning as well as the National Transport and Safety Authority. The study showed that there exist many benefits of using an open and universally verifiable blockchain network to handle non-digital assets.

## **7.2 Recommendations**

This study presents a new solution to address the issue of securing and verifying assets in Kenya. However, for the maximum benefits of the technology to be reaped, the following recommendations are made:

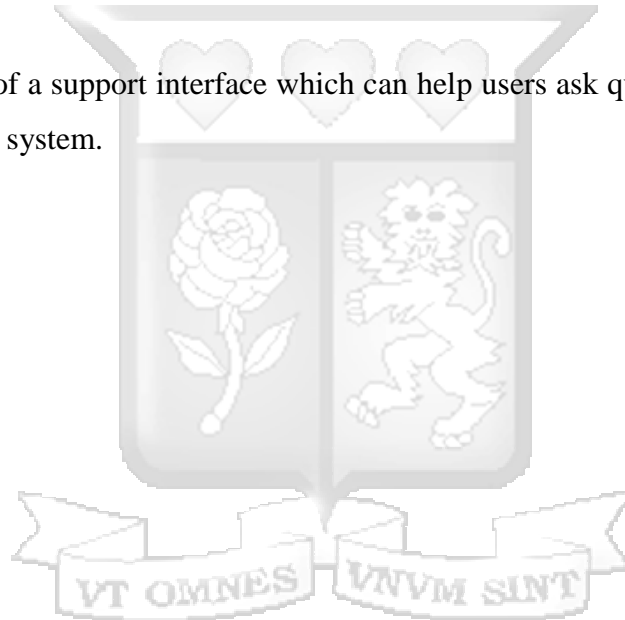
- i. To the Kenyan government and government bodies concerned:
  - a. The management of The Ministry of Lands and Physical Planning as well as the National Transport and Safety Authority should consider adopting blockchain technology in their various systems to allow for easy verification of asset by the relevant stakeholders.
  - b. The Distributed Ledgers Technology and Artificial Intelligence Taskforce report should be made a priority by the government as the emerging technologies such as blockchain can not only help in securing assets, but also in banking and tackling corruption.
  - c. The Central Bank of Kenya and the Parliament should accept blockchain technology and cryptocurrencies which would allow Kenyans to trade freely and experiment their ideas without fear.
- ii. To learning institutions:

- a. Blockchain technology is a real game changer and students should be encouraged to do research on it alongside other hot topics such as Artificial Intelligence and Internet of Thing.

### 7.3 Future Work

Below are some recommendations for future work relation to the prototype:

- i. The prototype can be scaled up and integrated to the existing systems of relevant stakeholders such as E-Citizen and ArdhiSasa.
- ii. Development of more features for the web application to cater for more asset categories and allow for more detailed explanations during asset creation.
- iii. Development of a mobile application for the prototype which increases the prototype's coverage.
- iv. Development of a support interface which can help users ask questions and be guided as they use the system.



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## Appendices

### APPENDIX A: REQUIREMENTS GATHERING QUESTIONNAIRE

This questionnaire is designed to help the researcher develop a prototype for securing non-digital assets using non-fungible tokens. Your organization has been purposively selected. The information you give will be used for the purpose of the study only. Therefore, do not write your name.

1. Kindly indicate your gender:

- Male
- Female

2. Kindly indicate your age in years:

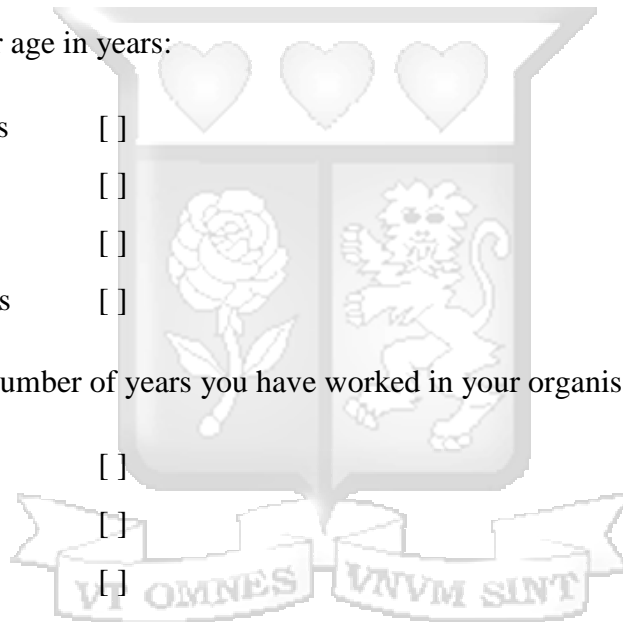
- Below 30 years
- 30 – 40 years
- 41 – 50 years
- Above 50 years

3. Please indicate the number of years you have worked in your organisation:

- Below 1 year
- 1 – 3 years
- 3 – 5 years
- Above 5 years

4. Kindly indicate the highest level of your education:

- Secondary Level
- Diploma Level
- Bachelor Level
- Master's Level
- PhD



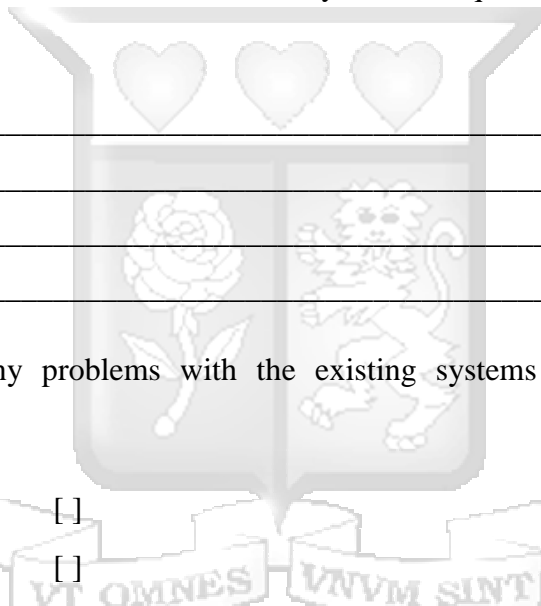
5. Do you directly take part in asset transactions such as purchase and transfer in your organisation?

- Yes
- No

6. If yes, how many asset transactions do you perform in a month on average:

- 0 - 10
- 10 - 20
- More than 20

7. Could you kindly list down the information you are required to fill during an asset transaction:



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8. Do you experience any problems with the existing systems when making an asset transaction?

- Yes
- No

9. If yes, could you kindly list down some of the problems you face while using the current existing systems?

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## **APPENDIX B: PARTICIPANT INFORMATION AND CONCENT FORM**

### **PARTICIPANT INFORMATION AND CONSENT FORM**

A Prototype for Securing Non-Digital Assets using Non-Fungible Tokens

#### **SECTION 1: INFORMATION SHEET**

Investigator: Brian Mwangi Kabiru

**Institutional affiliation:** Strathmore School of Computing and Engineering Sciences

#### **SECTION 2: INFORMATION SHEET–THE STUDY**

##### **2.1: Why is this study being carried out?**

The aim of this study is to develop a prototype for tokenizing non-digital assets in order to prove their ownership, authenticity and uniqueness. The history of the asset from creation will be tracked with new developments, such as transfers, being appended to the token.

##### **2.2: Do I have to take part?**

No. Taking part in this study is entirely optional and the decision rests only with you. If you decide to take part, you will be asked to complete a questionnaire to get information on the main challenges faced when securing digital assets and the techniques of detecting fraud in asset documentation. If you are not able to answer all the questions successfully the first time, you may be asked to sit through another informational session after which you may be asked to answer the questions a second time. You are free to decline to take part in the study from this study at any time without giving any reasons.

##### **2.3: Who is eligible to take part in this study?**

- Management and IT personnel at Ministry of Lands and Physical Planning
- Management and IT personnel at National Transport and Safety Authority

##### **2.4: What will taking part in this study involve for me?**

You will be approached and requested to take part in the study. If you are satisfied that you fully understand the goals behind this study, you will be asked to sign the informed consent form (this form) and then taken through a questionnaire to complete.

2.5: Are there any risks or dangers in taking part in this study?

There are no risks in taking part in this study. All the information you provide will be treated as confidential and will not be used in any way without your express permission.

2.6: Are there any benefits of taking part in this study?

The information will be used to improve the means through which assets are documented, safe-guarded and validated by using Blockchain technology.

2.7: What will happen to me if I refuse to take part in this study?

Participation in this study is entirely voluntary. Even if you decide to take part at first but later change your mind, you are free to withdraw at any time without explanation.

2.8: Who will have access to my information during this research?

All research records will be stored in securely locked cabinets. That information may be transcribed into our database but this will be sufficiently encrypted and password protected. Only the people who are closely concerned with this study will have access to your information. All your information will be kept confidential.

2.9: Who can I contact in case I have further questions?

You can contact me, Brian Mwangi Kabiru, at SCES, or by email (brian.kabiru@strathmore.edu), or by phone (+254716592266). You can also contact my supervisor, Prof. Ismail Ateya, at the Strathmore School of Computing and Engineering Sciences, Nairobi, or by email (iateya@strathmore.edu).

If you want to ask someone independent anything about this research please contact:

The Secretary–Strathmore University Institutional Ethics Review Board, P. O. BOX 59857, 00200, Nairobi, email [ethicsreview@strathmore.edu](mailto:ethicsreview@strathmore.edu) Tel number: +254 703 034 375

I, \_\_\_\_\_, have had the study explained to me. I have understood all that I have read and have been explained to me and had my questions answered satisfactorily. I understand that I can change my mind at any stage.

Please tick the boxes that apply to you;

Participation in the research study

I AGREE to take part in this research

I DON'T AGREE to take part in this research

**Storage of information on the completed questionnaire**

I AGREE to have my completed questionnaire stored for future data analysis

I DON'T AGREE to have my completed questionnaire stored for future data analysis

**Participant's Signature:**

\_\_\_\_\_

**Date:** \_\_\_\_/\_\_\_\_/\_\_\_\_

**DD / MM / YEAR**

**Participant's Name:**

\_\_\_\_\_

**Time:** \_\_\_\_/\_\_\_\_

**HR / MN**

*(Please print name)*

I, \_\_\_\_\_ (Name of person taking consent) certify that I have followed the SOP for this study and have explained the study information to the study participant named above, and that s/he has understood the nature and the purpose of the study and consents to the participation in the study. S/he has been given the opportunity to ask questions which have been answered satisfactorily.

**Investigator's Signature:**

\_\_\_\_\_

**Date:** \_\_\_\_/\_\_\_\_/\_\_\_\_

**DD / MM / YEAR**

**Investigator's Name:**

\_\_\_\_\_

**Time:** \_\_\_\_/\_\_\_\_

**HR / MN**

*(Please print name)*

## APPENDIX C: APPLICATION VALIDATION QUESTIONNAIRE

Please provide answers to the following questions to help get more insights on your opinion about the developed prototype.

Name .....

Occupation .....

Date .....

1. Did you find the prototype relevant?

- Yes
- No

2. Were you able to effectively create a new asset:

- Yes
- No

3. If no, please explain the problem you faced:

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4. Were you able to effectively transfer an asset:

- Yes
- No

5. If no, please explain the problem you faced:

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6. Were you able to view the assets history:

- Yes

- No

7.If no, please explain the problem you faced:

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8.Please rate the functionality of the system on a scale of 1 – 5 (1: Excellent, 2: Very Good, 3: Good, 4: Fair, 5: Poor)

- 1
- 2
- 3
- 4
- 5

9.Was the prototype easy to navigate?

- Yes
- No

10.If no, please state the challenge you experienced in navigating the system

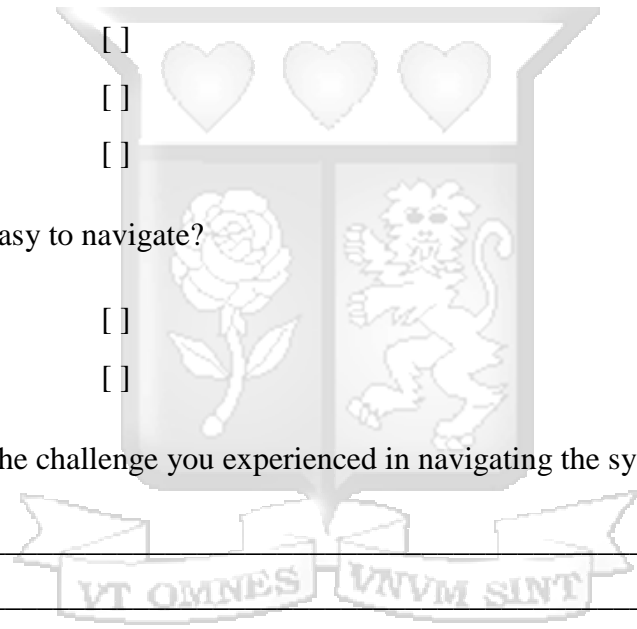
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11.Please rate the prototype's user interface (1: Excellent, 2: Very Good, 3: Good, 4: Fair, 5: Poor)

- 1
- 2
- 3
- 4
- 5



12. Please rate the prototype in terms of speed and accuracy.

- Good
- Average
- Poor

13. In your own view, does the prototype solve the problem of asset creation, tokenization and transfer?

- Yes
- No

14. If no, please explain what was lacking in the system.

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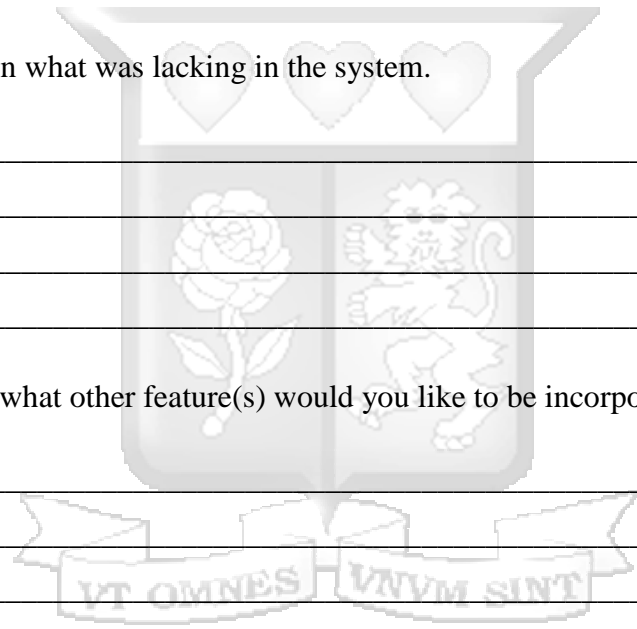
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15. In your own view, what other feature(s) would you like to be incorporated in the system.

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## APPENDIX D: ETHICAL APPROVAL



4<sup>th</sup> April 2022

Mr Mwangi Brian,  
brian.kabiru@strathmore.edu

Dear Mr Mwangi,

### **RE: A Prototype for Securing Non-Digital Assets using Non-Fungible Tokens**

This is to inform you that SU-IERC has reviewed and **approved** your above **SU masters'** research proposal. Your application reference number is **SU-IERC1245/21**. The approval period is **4<sup>th</sup> April 2022 to 3<sup>rd</sup> April 2023**.

This approval is subject to compliance with the following requirements:

- i. Only approved documents including (informed consents, study instruments, MTA) will be used
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-IERC.
- iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-IERC within 48 hours of notification
- iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-IERC within 48 hours
- v. Clearance for export of biological specimens must be obtained from relevant institutions.
- vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days upon completion of the study to SU-IERC.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) <https://research-portal.nacosti.go.ke/> and obtain other clearances needed.

Yours sincerely,

for: **Dr Ben Ngoye,**  
**Secretary; SU-IERC**

**Cc: Prof Fred Were,**  
**Chairperson; SU-IERC**



# APPENDIX E: NACOSTI RECEIPT

  
**REPUBLIC OF KENYA**

**Ref No: 290227**

**RESEARCH LICENSE**



**This is to Certify that Mr.. Brian Mwangi Kabiru of Strathmore University, has been licensed to conduct research in Nairobi on the topic: A Prototype for Securing Non-Digital Assets using Non-Fungible Tokens for the period ending : 09/April/2023.**

**License No: NACOSTI/P/22/16825**

**290227**  
Applicant Identification Number

  
**Director General**  
**NATIONAL COMMISSION FOR**  
**SCIENCE,TECHNOLOGY &**  
**INNOVATION**

Verification QR Code



**NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.**

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THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

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3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies
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8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

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Land line: 020 4007000, 020 2241349, 020 3310571, 020 8001077  
Mobile: 0713 788 787 / 0735 404 245  
E-mail: dg@nacosti.go.ke / registry@nacosti.go.ke  
Website: www.nacosti.go.ke





## APPENDIX F: OUR ORIGINAL REPORT



### Document Information

Analyzed document	94227 [K] - 21.3.22.docx (D132271421)
Submitted	2022-04-01T12:10:00.0000000
Submitted by	
Submitter email	Brian.Kabiru@strathmore.edu
Similarity	2%
Analysis address	library.strath@analysis.orkund.com

### Sources included in the report

<b>SA</b>	<b>HOOGLAND.pdf</b> Document HOOGLAND.pdf (D30560382)		1
<b>W</b>	URL: <a href="https://www.scriberlaw.com/value-digital-assets-estate-plan/#:~:text=Most%20digital%20assets%20derive%20their,have%20has%20little%20monetary%20value.The">https://www.scriberlaw.com/value-digital-assets-estate-plan/#:~:text=Most%20digital%20assets%20derive%20their,have%20has%20little%20monetary%20value.The</a> Fetched: 2022-04-01T12:22:00.0000000		2
<b>SA</b>	<b>NFT. The future of digital art and the end of the middleman.docx</b> Document NFT. The future of digital art and the end of the middleman.docx (D112331309)		4
<b>W</b>	URL: <a href="https://lands.go.ke/helpie_faq/is-ardhisasa-the-official-site-for-the-ministry-of-lands-and-physical-planning/">https://lands.go.ke/helpie_faq/is-ardhisasa-the-official-site-for-the-ministry-of-lands-and-physical-planning/</a> Fetched: 2022-04-01T12:10:00.0000000		4

