UNIVERSITY OF NAIROBI

FACULTY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF COMPUTING AND INFORMATICS

AN APPLICATION OF THE BLOCKCHAIN TECHNOLOGY IN CREDIT INFORMATION SHARING IN KENYA

JOB MARIGA

P54/38035/2020

SUPERVISOR

CHRISTOPHER A. MOTURI

A project report submitted in partial fulfilment of the requirements for the degree of Master of Science in Information Technology Management of the University of Nairobi.

May 2022

DECLARATION

This research project report is my original work and to the best of my knowledge has not been submitted for any other award in any University.

Signature___ ___ Date______May 11, 2022______

Mariga Job

P54/38035/2020

This research project report has been submitted for examination in partial fulfilment of the requirements for the Master of Science in Information Technology Management of the University of Nairobi with my approval as the university supervisor.

Christopher A. Moturi Date: *May 20, 2022*

Senior Lecturer

Department of Computing and Informatics

University of Nairobi

DEDICATION

I wish to dedicate this research project to beloved wife Sherriline Awidhi, my children Maya, Myles Harvey, and my parents for the support accorded to me in the course of this study.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my project mentor Mr. Christopher A. Moturi for his great guidance, patience, motivation, unending support and knowledge shared that culminated in the success of this research project

I wish to thank the faculty members of the Department of Computing and Informatics who formed the panel that guided and assessed my project: Prof. Agnes Wausi, Dr. Samuel Ruhiu, Dr. Stephen Mburu.

I acknowledge the respondents of the questionnaire survey, who were drawn from various stakeholders in the credit information sharing, for honestly sharing their insights.

Above all, I wish to thank the almighty God for the gift of strength and good health during the study.

ABSTRACT

Credit information sharing is a critical credit infrastructure that guarantees stability of the credit market by reducing the gap of information asymmetry between the lender and the customer. The credit information sharing mechanism involves an exchange of credit information amongst lenders through the credit reference bureaus (CRBs). For an effective credit information sharing mechanism, maintaining the integrity of the system is critical while considering privacy and security of data. As the CIS mechanism is continuously gaining in popularity in usage within the Kenyan credit market, there have been instances of malicious, unauthorised deletion and unlawful access to credit information that compromises the integrity of the system. To gain a comprehensive picture of the sentiments of the industry, a mixed-methods study was conducted with 93 respondents. The analysis of the results suggested there were instances of manipulation of data and unauthorised access and that use of blockchain technology would ensure security, the privacy of data and traceability on who accessed or made data changes. Through the findings of the study considering the importance of the mechanism to policymakers should consider adoption of the prototype for use in the credit market is recommended.

Keywords: {Blockchain technology, credit information sharing, credit market, integrity}

ABBREVIATIONS

CIS	Credit Information Sharing
CBK	Central Bank of Kenya
CRB	Credit Reference Bureau
DST	Data Specification Template
ETL	Extract, Transform and Load
IFC	International Finance Corporation
NACOSTI	National Commission for Science, Technology and Innovation

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

1.1. Background

The credit information sharing (CIS) mechanism involves an exchange of credit data amongst lenders through credit reference bureaus (CRBs). CIS is a critical financial infrastructure tool for ensuring the soundness and stability of the credit market by reducing the information asymmetry that exists between lenders and borrowers. It helps lenders objectively assess the capacity of an individual to repay a credit facility and acts as a tool to prevent individuals from overborrowing leading to over-indebtedness. CIS is also known as credit reporting addresses the asymmetry of information between borrowers and lenders(Jappelli & Pagano, 2002). In Kenya, CIS commenced in July 2010 (Central Bank of Kenya, 2010), following an amendment to section 31 of the Banking Act to allow for negative information sharing. The mechanism has since experienced tremendous growth by expanding the rich of credit information by including positive information sharing and inclusion of non-bank lenders to the mechanism through Banking CRB Regulations, 2020 which was promulgated in April 2020 (Central Bank of Kenya, 2020).

The blockchain technology is a digital distributed ledger that consists of a linked list of records in a particular sequence to form a chain. (Xia et al., 2017). It contains characteristics such as decentralisation, data transparency, tamper-proof, traceability and privacy and protection of data (Chang et al., 2020). Another key feature of blockchain is that aunthentication of transactions does not require a third-party (Yaga et al., 2019). The early uses of Blockchain technology have been in the implementation of cryptocurrencies but researchers have discovered the potential of its application in many other industries due to its characteristics of immutability and security. The fundamental functionalities of some sectors are intrinsically better suited to blockchain solutions. The main duties of verifying and transferring financial information and assets in financial services are quite comparable to blockchain technology's key revolutionary impact (Carson et al., 2018).

Blockchain is a technology that has the ability to completely revolutionize banks' payment clearing and credit information systems, allowing them to upgrade and transform as they seek new growth opportunities (Guo & Liang, 2016). Integrating blockchain technology extensively into credit reporting will ensure the security of credit information and reduce the cost of processing and acquiring data for credit decisioning (Zhang et al., 2020). CIS is a crucial infrastructure where quality, security, privacy and credibility of data is more important than the amount of data in the system. CIS Systems just like any other, face challenges of data accuracy and reliability of the data (Singh & Kim, 2018).

Zhang et al (2020), found that verification of ownership of data, integration of data, increased security for personal information notably in credit information exchange procedures can be achieved with the use of blockchain technology. Data in a blockchain cannot be easily changed as many records will have to be changed in the distributed ledger (Chowdhury et al., 2021) making blockchain technology viable for solving integrity issues bedevilling the CIS mechanism and further creating new business models to guarantee reliability (Carson et al., 2018).

As the CIS mechanism is growing in popularity and the wake of privacy laws enactment across the world, privacy and confidentiality have become key in its operations. In Kenya, the National Treasury and other state institutions realized the importance of data privacy and supported the enactment of Data Protection Act 2019, which defines how personal data should be managed. CIS in Kenya has had a positive impact on the management of credit portfolios in different financial institutions. Emergence of many credit products and credit providers that heavily rely on credit information in CRBs is evidence enough of the impact of credit reporting. Due to the positive impact of CIS mechanism on the economy with regard to accelerating the availability of credit to many sectors, regulators and policymakers have developed a keen interest in providing a framework that is reliable, credible and robust. Blockchain technology will best guarantee reliability and credibility which will lead to robustness and stability of the credit market.

1.2. Problem Statement

In Kenya, the submission of credit information is done on a daily and monthly basis to the centralised credit reference bureaus (CRBs) through the use of data submission portals of the three existing CRBs, a process that is deemed tedious and lengthy and affects availability of data in all the CRBs. Due to the manual nature of data submissions, individuals in the bank and CRBs deliberately remove default credit information of certain individuals maliciously to beat the system so that they can access credit from different lenders. Further with the current system, a lender can access credit information of a particular individual without following due process on data privacy rules (Zou et al., 2018). The use of blockchain technology in the CIS mechanism can safeguard data integrity, assure data availability, and protect fundamental privacy rights under the Data Protection Act, 2019.

1.3. Objectives

1. To review the effectiveness and reliability of ICT systems in use within the credit information systems in Kenya
2. To assess the capability of blockchain technology in addressing integrity issues in the credit information sharing mechanism
3. To develop a blockchain prototype for credit information sharing

1.4. Research Questions

1. What is the effectiveness of the current ICT technologies in the facilitation of credit information sharing?
2. What are the integrity issues identified in operating credit information sharing systems in Kenya?
3. What are the key features of Blockchain Technology?
4. How can Blockchain Technology be used to solve integrity issues in credit information sharing mechanisms?
5. How can a blockchain prototype help solve integrity issues in CIS mechanisms?
6. How is a blockchain prototype for CIS developed and tested?

1.5. Significance

Credit reporting is a crucial infrastructure in any credit market as it enables lenders to maintain the quality of loan portfolios and give consumers bargaining power based on data stored in the CRBs increasing access to credit with suitable credit terms. As such, implementing a system that is watertight of unauthorised manipulation and access would restore and uphold the lenders' confidence in using the mechanism to reach credit decisions which will then have a ripple effect in extending credit to the underserved.

1.6. Scope

This study focused on local lenders who are authorised to participate in the credit information-sharing mechanism.

1.7. Limitation

The study did not intend to address any legal shortfall in the CIS mechanism but on how to strengthen it based on the existing legal and regulatory framework.

CHAPTER TWO: LITERATURE REVIEW

This chapter outlines various research on the application of blockchain technology, credit information sharing and integrity issues in the credit information sharing mechanism in Kenya. This section serves as the conceptual underpinning for our study.

2.1. Credit Information Sharing mechanism in Kenya

Central Bank of Kenya (CBK) regulates the CIS mechanism as provided for under the CRB Regulations, 2020 issued under the Banking Act CAP 488 and Microfinance Act CAP 493D. The CRB Regulations, through an approval role of CBK, have allowed participation of non-bank credit providers who account for over 2,000 as of April 2021 (Central Bank of Kenya, 2019). The CRB Regulations regulate and maintain the integrity and soundness of the CIS mechanism. Different jurisdictions have implemented privately owned credit bureaus and others have implemented credit registries. The benefit of both systems depends on the purpose they intend to achieve. Privately owned credit reference bureaus are majorly serving the lenders to manage credit risk while public registries are majorly used to facilitate supervision of lenders. In their analysis of borrower and loan data sets from public credit registries, (Balakrishnan et al., 2019) discovered that registries' initiations and coverage improvements improve banks' loan loss recognition timeliness, i.e., how loan loss provisions capture subsequent non-performing loans (NPLs). From a comparison of the performance of credit markets performance using CBK's Bank Supervision reports from 2010 to 2020, the reports have rated highly the impact of CRBs on the quality of credit disbursed. Inclusion of data from other non-bank sources has expanded the information pool and positively made credit bureau products predictive enough to manage credit risk. The impact of credit bureaus has had a positive impact on management of the risk portfolios in credit markets and many countries in Africa are being encouraged to develop the CIS mechanism (Kusi et al., 2017). In the period 2010 to 2014 non-performing loans were reduced and banks increased in profitability (Mario Wairimu & Oliweny, 2015). To strengthen the implementation and rollout of this mechanism globally, the World Bank Group has put in place guidelines on how to develop a robust mechanism (World Bank Group, 2011) because credit information exchange methods are critical for improving financial inclusion and credit access. In seeking to strengthen the capacity of technology risk management in mobile money lending, Moturi & Ogoti (2020), for example, have proposed practices and strategies that integrates IT risk management essentials to protect the financial technology ecosystem in Kenya. The Kenyan credit bureau coverage is still at its nascent stage when compared to other developed nations for example the United

States and South Africa. The adult coverage to the credit bureau stands at 36.4% with 10,380,120 unique records of individuals and 330,783 for business firms (World Bank Group, 2020). With many non-bank credit providers joining the mechanism and the requirement to have them share both positive and negative information, it is expected to increase the number of unique profiles in the credit bureaus and also help other lenders objectively manage credit risk effectively.

2.2. Integrity issues in the CIS mechanism

Lagoze (2014) argues that Big data isn't just about size but rather how it impacts businesses by increasing efficiency and profits. (Lagoze, 2014) further records that data integrity is the ability to know the origin of the data, the responsible person in generating it, the ability to apply trust and integrity to them and to draw sensible conclusions from data. Data integrity is therefore a key attribute in credit information sharing as spelt out by (World Bank Group, 2011). The Banking CRB Regulations, 2020 require information to be shared with the CRBs to be both positive and negative loan portfolios, submitted promptly and follow provided data standards. World Bank Group (2011) reiterates the importance of data integrity so as not to compromise the contents of the database in the CRBs. They further encourage industry supervisors to consider putting in place enforcement tools such as monetary sanctions in cases of non-compliance. In Kenya, commercial and microfinance banks are required by law to report credit information; non-bank credit providers can submit credit information but must first obtain approval from the data subject. For enquiry of credit information, the law has provided stringent measures that are supposed to protect the privacy concerns of the consumer. A credit provider requires to state the purpose of accessing credit information as it accesses the information. Access to the credit report of the consumer requires one to have prerequisite consent to do so and a CRB needs to record reasons for access.

Credit information sharing has become a critical tool in stabilising the credit market performance in Kenya. Its importance has attracted the attention of policymakers who have developed necessary legislation to protect the lenders and consumers of credit in the process. The emphasis on the use of credit information has been cemented in the CRB Regulations that mandate commercial and microfinance banks to check a credit score of a borrower before extending credit to them. There are however, challenges that have persisted in the Kenyan microfinance sector such as increased credit risk, low visibility and poor understanding of emerging technology opportunities and risks, have been attributed to low levels of innovation and limited uptake of digital financial technologies (Ndungu & Moturi, 2020).

Due to the critical nature of information in the CRBs, some lenders without proper consent deliberately contravene privacy requirements for consumers. Access to credit information by lenders lowers the credit scores of consumers, affecting their ability to get cheaper credit terms from other lenders (Luthi, 2020). This is deemed to state the appetite of the consumer concerning access to credit which if many accessed without authority makes one a risky customer. As such, it is important to protect the system from unlawful access by credit providers probably shopping for one to give credit. Due to its increased use and reliance, it has been observed of unlawful temporary deletion of credit information to aid some customers access credit.

2.3. Key Features of Blockchain Technology

Blockchain technology is becoming more popular, and is being considered as a way to solve a several problems in the financial sector (Chang et al., 2020). Blockchain technology has since its first application in 2008 exhibited several characteristics that make it attractive for researchers to explore its application in areas such as health, banking and information sharing. Characteristics of blockchain include decentralisation, data transparency, tamper-proofing, traceability, privacy protection and open-sourcing (Zhang et al., 2020). Blockchain technology as data management technology is characterised by security, anonymity and data integrity without the involvement of a third party (Yli-Huumo et al., 2016). Decentralization enables distributed transactions without the need for a third party to act as a middleman to approve the transactions (Chang et al., 2020) preventing unauthorized data manipulation because it replicates data throughout a network and if anything needs to be changed, every node in the network must accept the change. Tamper-proofing is key in protecting the integrity of data stored in credit information sharing systems as any change unless all the nodes accept to make any changes ensures reliability of the system (Andoni et al., 2019). In ensuring trustworthiness in the CIS mechanism, blockchain with its decentralisation feature can ensure traceability enhancing the transparency of the system and privacy and general security of data stored (Andoni et al., 2019). On the other hand, blockchain technology implements asymmetric encryption using hashes that guarantee security, ownership of credit data and reliability of the data (Guo & Liang, 2016) leading to a robust credit information system.

2.4. Capabilities of Blockchain Technology in Credit Information Sharing

Whereas ICT has had enormous changes in financial services, it has also experienced several problems when it comes to security and the interests of customers (Drigă & Isac, 2014). However, there are several advances in finding the solutions emerging due to the current digitization process. Credit information systems have been plagued with integrity issues that threaten their very existence. The turnaround time of the credit process has greatly reduced with the emergence of digital credit and internet-based credit products. To ensure availability and currency of data to make the crucial decision will guarantee sustainability of the credit market. The use of Blockchain has been identified as one of the solutions that will assist in restoration of integrity of credit information systems for support of the fast growing and advancing credit market. Ortlepp (2019) concluded that it is feasible to use Blockchain in credit information sharing due to its benefits in the speed of processing, security of data and the cost implication in the management of the system. In terms of security, blockchain has features that allow peering points and secure communication, point-to-point transmission, consensus, and encryption algorithm to link individual credit bureau references or credit providers to each other (Liu & Chen, 2019) and guarantee trust, consumer privacy and restore confidence in the system (Guo & Liang, 2016). To ensure that the data formats across the network are uniform, blockchain with the key characteristic of decentralisation controls the content added to it until the format of the entry is agreed upon by other peers in the network using the consensus protocols (Hasselgren et al., 2020). Hasselgren et al. (2020) further report that blockchain enables ease of audit and traceability by linking a new block to the previous one with attributes of who made the change and the reason for that. In the case of credit information sharing, the consortium approach of permissioned blockchain will be employed which requires access by authorised and invited users, a design that will guarantee accountability as a log of each of their actions is kept in the blockchain (Xia et al., 2017).

Credit information contains personal financial information of credit customers from different sectors of the credit market (World Bank Group, 2011). Protection of personal information has become one of the key focus across nations in the world to protect citizens against unethical use of their data. Kenya has currently enacted the Data Protection Act, 2019 which requires data controllers and processors to ensure data is protected. Using blockchain will give power to the consumer to track the users of their data and guarantee security (Zyskind et al., 2015). Users can know which entities or individuals accessed their credit records in the blockchain. In compliance with blockchains as privacy-friendly, Schwerin, S. (2018) notes that developers can be helpful due to their traceability feature. Blockchain systems guarantee integrity by ensuring that every node agrees with the values entered based on the consensus algorithms set (Schwerin, S., 2018). Data is stored in different block in a blockchain linked to the parent block and secured using a unique fingerprint known as a hash which is a cryptographic function for mapping the size of data (Schwerin, S., 2018).

Credit information sharing (CIS) involves the integration of private credit information from different credit providers to solve information asymmetry when granting credit (Jappelli et al., 2005). Private data requires a high level of confidentiality due to privacy laws that have been enacted by different jurisdictions. It is therefore important to employ private preserving record linkage approaches to guarantee information privacy from unauthorized users and blockchain has been found to provide a strong linkage between privacy and ethical information sharing (Nóbrega et al., 2021). The kind of blockchains that can be developed, private and consortium, where private blockchain stores the actual data and the consortium blockchain stores the indexes of the various data points this ensures that data is securely stored, access control and privacy preservation during the search process (Zhang & Lin, 2018). Blockchain through the use of Ethereum will be able to implement smart contracts that will require execution and verification through the Ethereum network (Goharshady et al., 2018) thus maintaining the security of transactions. Smart contracts contain a characteristic that removes control from a centralised entity or a third-party entity for making decisions (Goharshady et al., 2018) making it ideal for use in a credit information sharing environment.

2.5. Analysis of Legal, Ethical, Social and Political Issues in Blockchain

Like many countries, blockchains are not regulated in Kenya nor backed by the Government but the government established a task force to look into their use cases in the Kenyan economy(Ministry of Information Communication and Technology, 2019). The task force concluded that blockchain technology can be used as a digital locker that can store securely credit reports and prevent them from malicious access by individuals or entities. Concluding that the technology is usable in the CIS mechanism to securely store and disseminate credit information to relevant individuals. Implementation of blockchain systems presents a regulatory challenge due to its decentralised nature in which regulators should develop Sandboxes that can be used to assess the potential risks that can threaten stability of the financial industry (Guo & Liang, 2016).

2.6. Review of Existing Credit Information Sharing Systems

Credit information sharing is critical infrastructure in the management of the knowledge equilibria between stakeholders in a credit-debtor relationship (Wyk & Boraine, 2017). Wyk & Boraine (2017), further claim that ineffective implementation of systems can result in flawed credit decisions by the lenders and therefore recommend execution of a functional system that supports consumer protection with a keen consideration of the privacy of data.

The credit bureau system works by accumulation of data from different lenders (Wyk & Boraine, 2017). Comprehensiveness, accuracy, consistency and accessibility of credit data need to be keenly considered to guarantee reliability of it for the benefit of the economy, lenders and consumers of credit. Credit bureau systems should be able to have a framework to correct erroneous data as guided by World Bank Principles of Credit Reporting as a redress mechanism to the consumers to ensure accurate data about themselves is shared.

CRB systems are not off-the-shelf solutions that can be easily acquired and installed into computer systems but have to be customized based on the data to be collected (IFC, 2006). However, based on the roles that they have been given there exist key features that such systems should have that include collecting, validating, merging data, generating and distributing credit reports and most importantly providing security and backup solutions to ensure availability at all times (IFC, 2006). Whereas the systems owned by the CRBs can manage the process of referencing and receiving data, they are prone to manipulations from bank and credit bureau staff and institutions participating in the mechanism compromising truthfulness and reliability of the information and violating the principles of data privacy as stipulated by the CRB Regulations and the Data Protection Act.

World Bank Group (2019) guides that credit information systems need to be developed to perform collection, validation and merging of data; processing and dissemination of credit reports and other products to credit providers; ensure data security and backup, and ensure system performance and monitoring of reports.

Blockchain-based credit reporting systems are being researched across the world to determine viability. The systems guarantee the traceability of the participant from where the information was acquired and that data is transparent, open, and ensures data privacy (Zhu, 2020). Credibility is one of the key requirements of the CIS systems, Zhu (2020) argues that user information, transactions conducted and operations are stored and monitored by the entire network, which helps track the behaviour of a particular lender to flag any unusual conduct. Wust & Gervais (2018) concur with the findings of (Zhu, 2019) that using blockchain technology protects data storage integrity and transparency for entities participating in a network. A study by Rathee et al (2019) on securing connected vehicles using blockchain technology a concept related to that of CIS shows that there was a 79% success rate in solving issues of compromising the whole ecosystem leading to loss of secrecy and privacy by users of the system.

Credit information systems in Kenya are based on relational databases that are developed using the industry data specification and validation template that is used to guide ETL credit information to the CRBs databases. The data specification template (DST) guides both the credit providers and CRBs in designing ETL solutions. SWOT analysis of the current system is shown in Table 1.

Table 1:SWOT Analysis of the current system

Strengths i. The system has bridged the information asymmetry	**Weaknesses** i. Compromised data quality ii. Centralised system
Opportunities i. Include timestamps and footprints on access to data ii. Enhance security through hashing algorithms iii. Decentralise the database to enhance security	**Threats** i. Privacy and confidentiality ii. Unauthorised manipulation of data iii. Unavailability in instances of attack

2.7. Proposed Blockchain-based Solution

The conceptual framework proposes a 5-layer conceptual model for the blockchain, (Zhang et al., 2020) as shown in Figure 1.

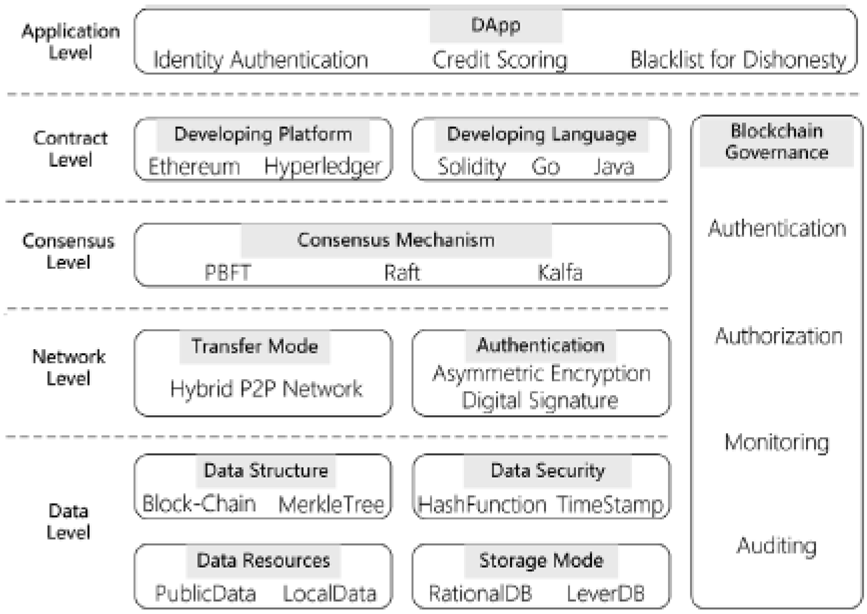


Figure 1:CIS Data Exchange Model

Source: (Zhang et al., 2020)

Data Level layer for organising data and storing transaction data of credit reporting

Network Layer made up of nodes within the blockchain network with no central authority

Consensus layer for creating trust for nodes to transact with each other

Contract layer is used to write the business logic of a blockchain system

Application layer is the interface layer that can be interacted with by the users of the system

CHAPTER THREE: RESEARCH METHODOLOGY

This chapter discusses the overall tenets of research philosophy, research design, target population, sampling techniques, data collection and analysis methods.

3.1. Research Philosophy

The study adopted a pragmatist worldview approach. (Johnson & Onwuegbuzie, 2004) advocates for this philosophy due to its ability to trace practical consequences to the phenomenon.

3.2. Research Design

The study focused on all credit information providers in Kenya and was taken between November 2021 and January 2022. We focused on Questionnaires that provided quantitative data and a literature review of reports and policy documents for qualitative research. The choice of the two approaches was to give the breadth and depth of an inquiry into blockchain technology and its potential use in credit information sharing (Johnson & Onwuegbuzie, 2004).

3.3. Target Population

This study targeted credit information providers being Commercial Banks, Microfinance banks, Saccos, Leasing Companies, State Lenders/corporations, PayGo Solar companies and credit-only Microfinance Institutions.

3.4. Study Sample

The study employed stratified random sampling on all credit information providers with a target population of 100 respondents. The sampling technique choice was to ensure that all the sectors participating in the mechanism are well captured (Etikan & Bala, 2017).

3.5. Data Collection

Commercial banks, microfinance banks, SACCOs, leasing companies, state lenders/corporations, PayGo solar companies and credit-only Microfinance Institutions were targeted in the study and the distribution is as per Table 2.

Table 2: Distribution of respondents by Sector

Target	**Sample Size**
Commercial Banks	25
Microfinance Banks	13
SACCOs	13
Digital Lenders	18
State Lenders/Corporations	6
Other (Lease Finance Companies, PayGo Solar companies)	18
Total	**93**

The primary source of data was use of questionnaires circulated to respondents of various financial institutions. Secondary data was collected from various journals on Blockchain technology, reports of the Ministry of ICT (2019), National Treasury National CIS policy CBK Bank Supervision Reports (2010 – 2020) and the Data Protection Act 2019.

3.6. Data Analysis and Presentation

We tested the designed questionnaire for its validity and reliability using SPSS and we noted that the internal consistency was at a consistency level of 0.860. SPSS was used for coding data and cleanup for any errors. The findings were presented using the frequency tables.

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter presents the results of data collection and maps them to the research objectives. It involves a presentation of findings using tables, charts and graphs.

4.1. Data Analysis and Results

A response rate of 93% attained out of the target of 100 is considered satisfactory, being above 50% (Mugenda & Mugenda, 2003).

4.2. Demographic Information

The distribution of demographic information shows that 69.9% of respondents were male and the majority of the respondents had a working experience of more than 5 yrs experience making them aware of the operations of the financial institution. 53.8% of the respondents were drawn from the credit department since they form the main users of the credit information-sharing mechanism. This dataset is reliable in conducting this study.

Table 3:Demographic Information

		Full Data set	
		Frequency	**Percentage (%)**
Gender	Female	28	30.1
	Male	65	69.9
Years of operation	Below 5yrs	25	26.9
	5-10yrs	14	15.1
	10-20yrs	7	7.5
	Above 20yrs	47	50.5
Work Experience	Less than a year	0	0
	1-5yrs	28	30.1
	5-10yrs	31	33.3
	Above 10yrs	34	36.6
Level of Education	PhD	0	0
	Master's	45	48.4
	Bachelor's	45	48.4
	Diploma	3	3.2
Department of operation	Credit	50	53.8
	ICT	13	14
	Finance	0	0
	Risk	10	10.8
	Operations	10	10.8
	Customer Care	0	0
	Other	10	10.8
Level of Management	Top	26	28
	Middle	52	55.9
	Operations	15	16.1
	Total	93	100

4.3. Blockchain technology

From the study, it was noted that none of the institutions had adopted the use of blockchain technology but 43% are considering implementation of Blockchain technology.

4.3.1. Use of Blockchain technology and faster processing of data

Table 4 shows that 78.5% of the respondents believe that adoption of blockchain technology results in faster data processing while 11.8% disagree.

Table 4:Blockchain technology results in faster data processing

Blockchain technology leads to faster processing of data					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	6	6.5	6.5	6.5
	Disagree	5	5.4	5.4	11.8
	Neither Agree nor Disagree	9	9.7	9.7	21.5
	Agree	19	20.4	20.4	41.9
	Strongly Agree	54	58.1	58.1	100.0
	Total	93	100.0	100.0	

4.3.2. Blockchain technology can improve data accuracy

82.8% of the respondents believe that blockchain technology does improve data accuracy essential in credit information sharing mechanism for increased reliability. 10.8% disagree to have any significant change as illustrated in Table 5.

Table 5:Blockchain technology improves data accuracy

Blockchain technology improves data accuracy					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	5.4	5.4	5.4
	Disagree	5	5.4	5.4	10.8
	Neither Agree nor Disagree	6	6.5	6.5	17.2
	Agree	18	19.4	19.4	36.6
	Strongly Agree	59	63.4	63.4	100.0
	Total	93	100.0	100.0	

4.3.3. Blockchain technology will improve the correctness of credit data

86.1% of respondents feel that the implementation of blockchain technology would increase the accuracy of data, whereas 10.8% disagree. Table 6 illustrates the findings.

Table 6: Blockchain technology can enhance the correctness of credit information.

Blockchain technology can enhance the correctness of credit information					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	5.4	5.4	5.4
	Disagree	5	5.4	5.4	10.8
	Neither Agree nor Disagree	3	3.2	3.2	14.0
	Agree	30	32.3	32.3	46.2
	Strongly Agree	50	53.8	53.8	100.0
	Total	93	100.0	100.0	

4.3.4. Blockchain technology and security of data

From Table 7, it can be deduced that 84.9% of respondents believe that the use of blockchain technology would enhance security of data and will lead to ease of compliance with the strict legal requirement.

Table 7:Blockchain technology and security of data

Blockchain technology enhances the security of data					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	5.4	5.4	5.4
	Disagree	2	2.2	2.2	7.5
	Neither Agree nor Disagree	7	7.5	7.5	15.1
	Agree	27	29.0	29.0	44.1
	Strongly Agree	52	55.9	55.9	100.0
	Total	93	100.0	100.0	

4.3.5. Blockchain technology and data protection and privacy

81.8% of the respondents believe that the use of blockchain technology would uphold data protection and privacy of credit data subjects while 11.8% disagree that it will offer any significant change as illustrated in Table 8.

Table 8: Blockchain technology and data protection and privacy

Blockchain technology upholds data protection and privacy					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	5.4	5.4	5.4
	Disagree	6	6.5	6.5	11.8
	Neither Agree nor Disagree	6	6.5	6.5	18.3
	Agree	26	28.0	28.0	46.2
	Strongly Agree	50	53.8	53.8	100.0
	Total	93	100.0	100.0	

4.3.6. Blockchain in credit processes with improved credit risk management

88.1% of the respondents agree that the use of blockchain technology will significantly improve credit risk management processes while 5.4% disagree with the contribution as shown in Table 9.

Table 9:Blockchain technology will improve credit risk management

Blockchain technology will improve credit risk management					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	2	2.2	2.2	2.2
	Disagree	3	3.2	3.2	5.4
	Neither Agree nor Disagree	6	6.5	6.5	11.8
	Agree	31	33.3	33.3	45.2
	Strongly Agree	51	54.8	54.8	100.0
	Total	93	100.0	100.0	

4.3.7. Blockchain technology would solve unauthorised manipulation of data

91.4% of the respondents believe that blockchain technology can solve issues on unauthorised manipulation of data. 8.6% of the respondents disagree with any significant change if the technology is used as illustrated in Table 10.

Table 10:Blockchain technology would solve unauthorised manipulation of data

Blockchain technology would help solve unauthorised manipulation of data					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	5.4	5.4	5.4
	Disagree	3	3.2	3.2	8.6
	Agree	34	36.6	36.6	45.2
	Strongly Agree	51	54.8	54.8	100.0
	Total	93	100.0	100.0	

4.3.8. Blockchain technology will restore trust and confidence in credit bureau products

86% of the respondents believe that blockchain will restore trust and confidence in the use of credit bureau products. 11.8% of the respondent disagree that blockchain technology can restore trust.

Table 11:Blockchain technology will restore trust and confidence in credit bureau products

Blockchain technology can restore trust and confidence in credit bureau products					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	5	5.4	5.4	5.4
	Disagree	6	6.5	6.5	11.8
	Neither Agree nor Disagree	2	2.2	2.2	14.0
	Agree	33	35.5	35.5	49.5
	Strongly Agree	47	50.5	50.5	100.0
	Total	93	100.0	100.0	

4.4. Credit Information Sharing

Out of 93 respondents from various institutions, 84 (90.3%) are actively participating in the credit information sharing mechanism while 9 (9.7%) are not due to the regulatory constraints.

4.4.1. Institutions Participating in Credit Information Sharing

83.9% of the respondents to a large extent participate in credit information sharing and a paltry 5.4% do not completely participate due to regulatory sanctions that were effected on some non-bank credit providers as highlighted in Table 12 below.

Table 12: Extent of participation in CIS mechanism

The extent of participation in the CIS mechanism					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	5	5.4	5.4	5.4
	Moderate Extent	10	10.8	10.8	16.1
	Great extent	22	23.7	23.7	39.8
	Very Great Extent	56	60.2	60.2	100.0
	Total	93	100.0	100.0	

4.4.2. Use credit information to reach credit decisions

78.5% of the respondents greatly use credit information in reaching credit decisions. While 3.2% use it only to a small extent. As illustrated in table 13.

Table 13: Use of credit information to reach credit decisions

Use of credit information to reach credit decisions					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	3	3.2	3.2	3.2
	Moderate Extent	17	18.3	18.3	21.5
	Great Extent	39	41.9	41.9	63.4
	Very Great Extent	34	36.6	36.6	100.0
	Total	93	100.0	100.0	

4.4.3. Credit information use has reduced bad loans and increased profitability

43% of the respondents attribute to great extent profitability and reduced bad loans to credit information sharing. 15.1% of the respondents claim CIS has contributed to the reduction of bad loans and increased profitability per table 14 below.

Table 14: CIS and impact on profitability

CIS and profitability					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	14	15.1	15.1	15.1
	Moderate Extent	39	41.9	41.9	57.0
	Great Extent	32	34.4	34.4	91.4
	Very Great Extent	8	8.6	8.6	100.0
	Total	93	100.0	100.0	

4.4.4. Credit information contribution to financial inclusion and new product offering

24.7% of the respondents claim that the input of Credit information towards financial inclusion was to a small extent while 12.9 % to a very great extent. 33.3% suggest that they have had a significant impact on financial inclusion while 29% to a moderate extent.

Table 15: CIS on Financial Inclusion

CIS on financial inclusion					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	23	24.7	24.7	24.7
	Moderate Extent	27	29.0	29.0	53.8
	Great Extent	31	33.3	33.3	87.1
	Very Great Extent	12	12.9	12.9	100.0
	Total	93	100.0	100.0	

17.2% of the respondents claim that CIS has greatly impacted the development of new products and 39.8% have contributed a great deal. However, 43% of the respondents claim that they have either contributed moderately or to a small extent.

Table 16: CIS contribution to new product offerings

CIS contribution to new product offerings					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	15	16.1	16.1	16.1
	Moderate Extent	25	26.9	26.9	43.0
	Great Extent	37	39.8	39.8	82.8
	Very Great Extent	16	17.2	17.2	100.0
	Total	93	100.0	100.0	

4.4.5. Credit information in CRBs is accurate and reliable for lending decisions

44.1% of the respondents believe that data stored in the CRBs is not accurate and reliable for lending decisions. 55.9% believe that information is accurate to a great and large extent.

Table 17:CRBs Data accuracy and reliability

CRBs Data accuracy and reliability					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	9	9.7	9.7	9.7
	Moderate Extent	32	34.4	34.4	44.1
	Great Extent	33	35.5	35.5	79.6
	Very Great Extent	19	20.4	20.4	100.0
	Total	93	100.0	100.0	

4.4.6. Captures all credit information from credit providers

A large pool of data in credit bureaus leads to the development of very predictive models. As per Table 18, credit information does not collect data from all credit data with 54.8% of the respondents claiming that they moderately cover all the credit providers and 45.2% which is quite significant believe that CRBs cover a small extent of data providers

Table 18: CRBs capture credit information from all credit providers

CRBs capture credit information from all credit providers					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	42	45.2	45.2	45.2
	Moderate Extent	51	54.8	54.8	100.0
	Total	93	100.0	100.0	

4.4.7. CRBs have compromised the integrity of data

41.9% of the respondents believe that CRB data is compromised to a moderate extent while 58.1% believe it is compromised to a small extent. This has a big impact on the reliability of the data.

Table 19: CRB Data is compromised

CRB Data is compromised					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	54	58.1	58.1	58.1
	Moderate Extent	39	41.9	41.9	100.0
	Total	93	100.0	100.0	

4.4.8. Highest standard of data security and footprints on who accessed

From Table 20, 23.7% and 22.6% of respondents believe that the CRBs maintain a significant level of security and keep footprints on who accessed their data. However, 53.8% believe that this effort to secure data is to a small and moderate extent. This impacts greatly on credit providers truthfully sharing data consistently.

Table 20: Highest standard of data security and footprints on accesses

Highest standard of data security and footprints on who accessed					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	18	19.4	19.4	19.4
	Moderate Extent	32	34.4	34.4	53.8
	Great Extent	21	22.6	22.6	76.3
	Very Great Extent	22	23.7	23.7	100.0
	Total	93	100.0	100.0	

4.4.9. Data availability in case of a link failure

Table 21 illustrates that 60.2% of the respondents believe or are aware that CRBs don't have a backup plan in case a link fails which is bound to happen occasionally. 39.8% believe that CRBs have in a moderate view put in place measures in case of link failures.

Table 21:Data availability in case of link failure

Data availability in case of link failure					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	56	60.2	60.2	60.2
	Moderate Extent	37	39.8	39.8	100.0
	Total	93	100.0	100.0	

4.4.10. CRBs Maintains confidentiality and privacy of data

36.6% and 41.9% of the respondents believe that CRBs have put in place measures that ensure that data stored in the CRBs are kept confidentially and disclosure is strict as stipulated in the law. 3.2% of the respondents are however sceptical about the effort employed by CRBs to secure data and 18.3% give a moderate view of the efforts.

Table 22:Confidentiality and privacy of data

Confidentiality and privacy of data					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	3	3.2	3.2	3.2
	Moderate Extent	17	18.3	18.3	21.5
	Great Extent	39	41.9	41.9	63.4
	Very Great Extent	34	36.6	36.6	100.0
	Total	93	100.0	100.0	

4.4.11. Data stored is tamper-proof making it more reliable

Data Stored in the CRBs is 54.8% to a small extent tamper-proof and 45.2% moderate extent. This makes the data in the CRBs to be partially relied on in reaching credit decisions. Table 23 illustrates the extent to which data stored is tamper-proof.

Table 23:Data stored in CRBs is tamper proof

Data stored in CRBs is Tamper-proof					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Small Extent	51	54.8	54.8	54.8
	Moderate Extent	42	45.2	45.2	100.0
	Total	93	100.0	100.0	

4.5. The Blockchain-based Prototype for CIS

The prototype developed is required to simulate the credit information sharing environment by use of blockchain technology. It demonstrates characteristics of blockchain that guarantee the integrity of data shared across the network. The system demonstrates the removal of third-party involvement in facilitating credit information sharing which creates an avenue for distortion and unauthorized manipulation of credit information.

4.5.1. Features of the Prototype

The system is made up of three modules the Borrowers module, Lenders module and Referencing module. The borrowers' module allows one to seek a loan facility. The Lender module approves a loan and gives the terms of the loan to the borrower. The referencing module assists lenders to find out the level of customer exposure.

As a blockchain network, the system has several nodes representing different lenders. The prototype has been developed using Solidity Object oriented programming language, Truffle Framework, Ganache, Metamask and React 17.0.2. Truffle Framework offers tools for developing Ethereum smart contracts. It offers tools such as smart contract management, deployment and migration, network management, and development console. The ganache on the other hand mimics the behaviour of public blockchain but for local development
Testing of the prototype was conducted by 5 individuals working in the commercial banks. The purpose of the testing was to check the main functionalities that the system proposes which are to prevent unauthorized manipulation and access to credit information sharing. Due to the sensitivities of financial institutions and the complexity of installation of the prototype, the testing process opted to take the respondents through the prototype and get their feedback. Generally, it was felt that the system if fully implemented will offer much value to the mechanism and instil more confidence in information use.

4.5.2. Top-Level diagram of the functionalities of the prototype

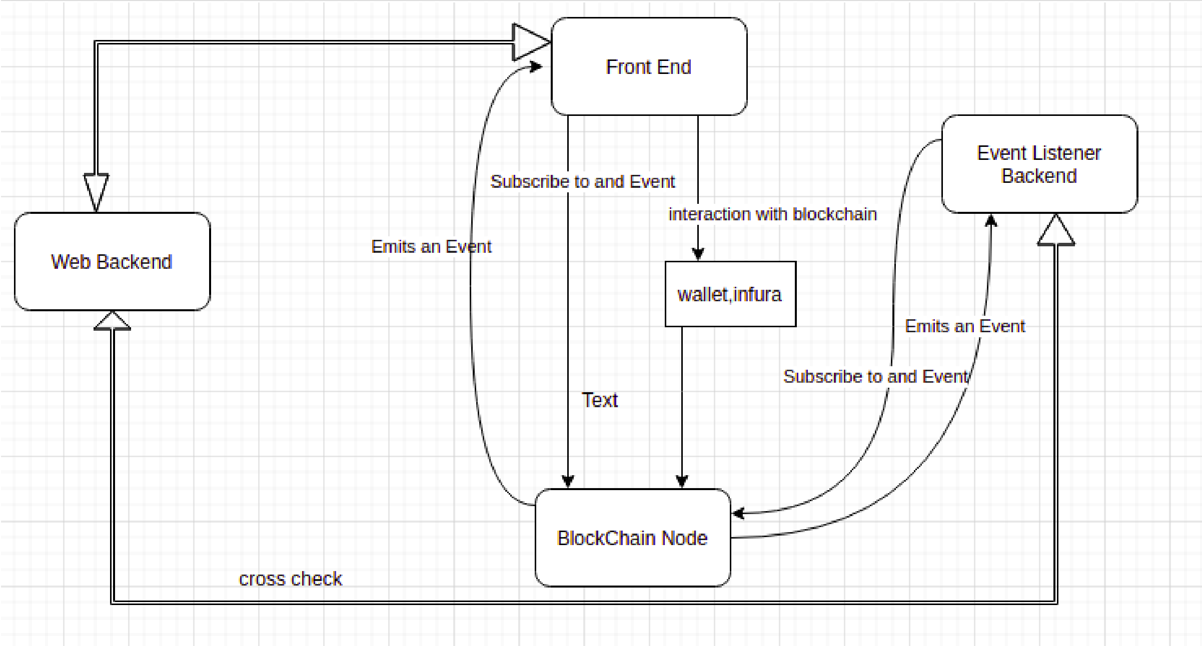


Figure 2: System Architecture

As a form of collateral, a borrower submits a digital mortgage to the lender. In addition, he sets a deadline for repaying the loan, beyond which he loses his home. A reputable government portal can be used to verify the ownership of a digital mortgage. Lenders that are interested in the mortgage will examine it and then make a recommendation to the borrower about the loan amount and interest rate they want. The borrower examines the bids and accepts the ones that are most likely to help them meet their financial goal.

4.5.3. System flow

The system is started by bashing the application and starting ganache.

NOTE: The ganache configuration is localhost**:7545**

The system is accessed using **127.0.0.1:8080** this is the landing page of the system.

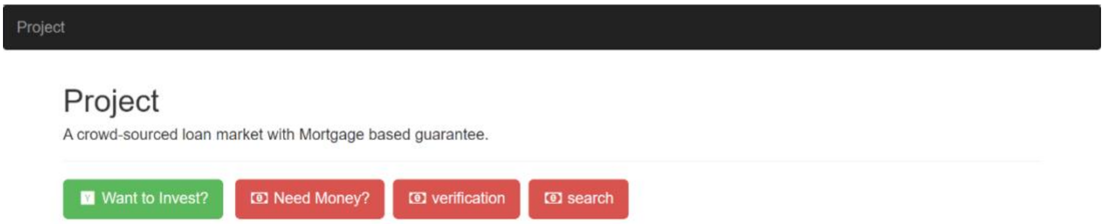


Figure 3: Main Window

Loan Application window

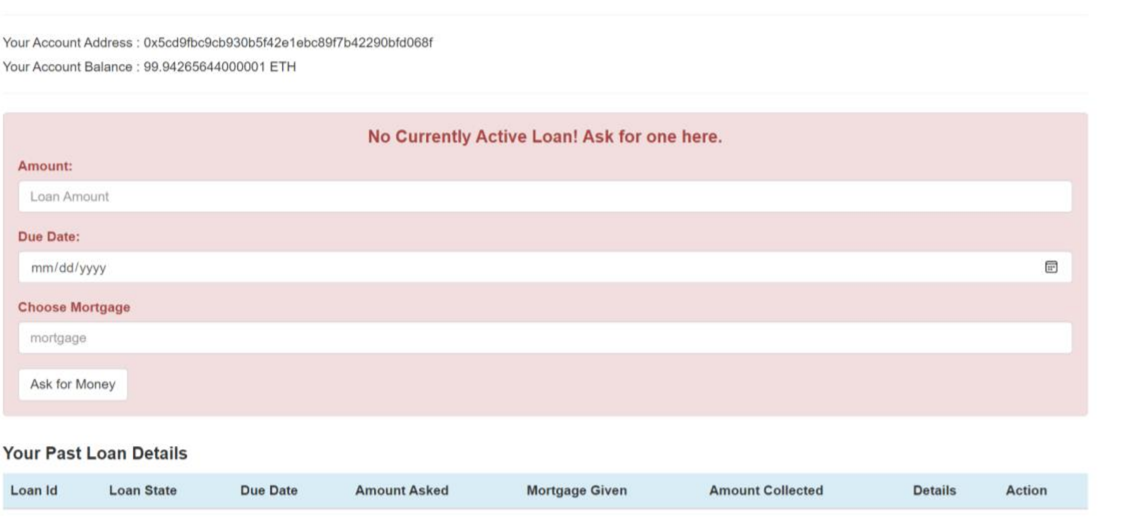


Figure 4: Loan Application Window

This is the window where the loan applicant applies for a loan.

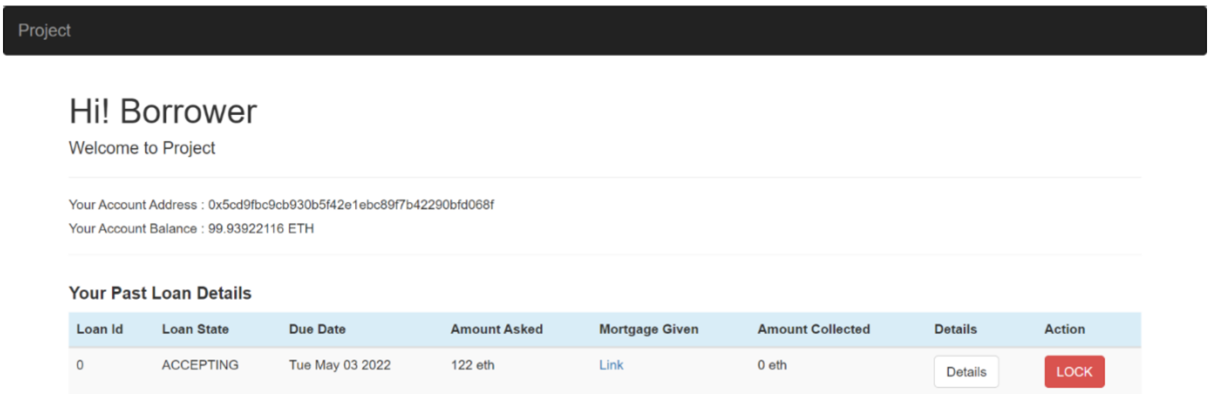


Figure 5: Loan disbursement window

Lenders Window

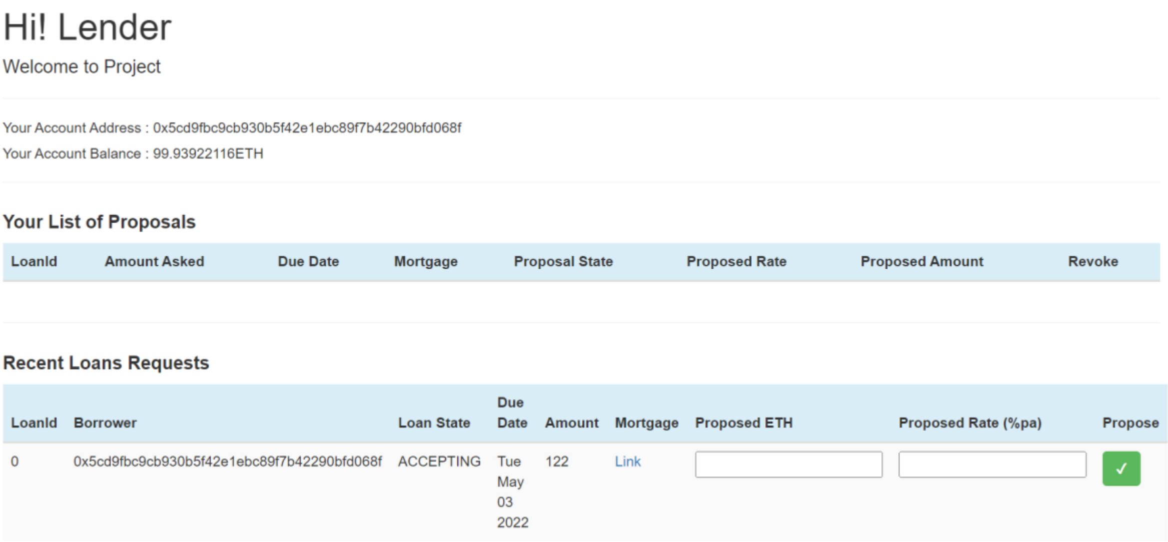


Figure 6: Lender proposal window

This is the lender's screen where the lender can key in the interest rates.

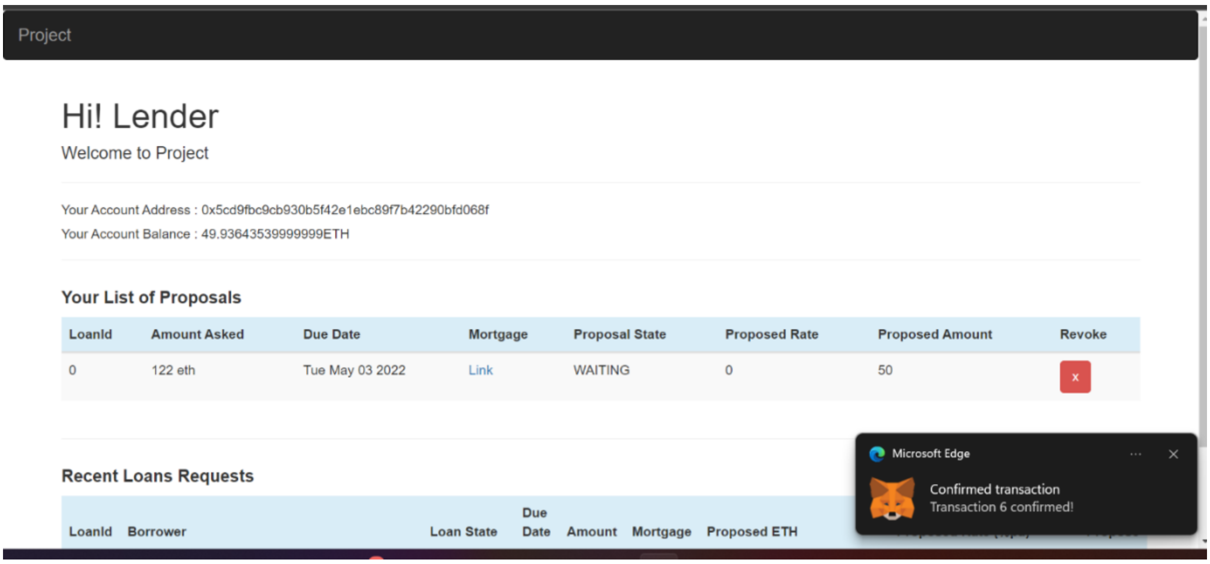


Figure 7:Lender Approval

This window shows how the lenders will be approving and viewing the progress of already issued loans.

4.6. Discussion

Zhang et al. (2020), and (Ortlepp, 2019) found that the integration of blockchain technology in a credit information sharing system ensures the safety of credit data shared across a channel and the efficiency of the whole mechanism. This finding was affirmed by this study where a majority of the respondents believe that the use of blockchain technology will enhance security of information and the processing time. Guo & Liang (2016) found that in instances of mistrust, and consumer privacy issues, blockchain technology can be used to restore confidence which coincides with findings made in the study where respondents believe that the use of blockchain technology restores confidence amongst the users of the information since information in a blockchain is tamper-proof, decentralised and traceable. These characteristics of blockchain will help in solving integrity issues identified by the study such as unauthorised data manipulation and unauthorised access of data which is against data protection principles.

Every credit provider is concerned about the reliability of data used in reaching credit decisions. The study shows that a significant percentage of credit providers use credit information to reach credit decisions which has greatly contributed to financial inclusion. However, some entities believe that information stored in the CRBs can easily be altered hampering the accuracy of the information. Considering the importance of the mechanism and its reliance on it, it is necessary to employ available advanced technologies to manage all these issues. With Hasslegren et al. (2020) finding that blockchain technology will enhance auditability and traceability, issues with manipulation of data will be solved and increase reliance on the data to make credit decisions. Chang et al. (2020) further state that the decentralisation nature of blockchain technology removes the requirement of a third party as an intermediary to approve transactions making unauthorised manipulation of data difficult thus increasing reliability a finding which (Yli-Huumo et al., 2016) concurs with.

From the findings blockchain technology as one of the advanced technologies will greatly improve trust and confidence in the system due to its ability to solve unauthorised access and altering of credit information, improving the correctness and security of data. Schwerin, S. (2018), claims that the blockchain technology will guarantee the integrity of data as every node will have to agree on a certain format of data to be shared maintaining the correctness and uniform interpretation of the data and further claims that the fact that blockchain stores each activity in a block using a hash function, it makes the information of information in the blockchain secure from access by unauthorised users a finding that (Nóbrega et al., 2021) attests to.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

This chapter contains the achievements, conclusions and recommendations from the study.

5.1. Achievements

Objective 1: To review the effectiveness of ICT systems currently in use within the credit information systems in Kenya

Findings from the study reveal the importance of credit information in the decision-making process of credit providers. Due to the prevailing condition of the current systems especially on the unauthorised temporary deletion of credit information to beat the system, unauthorised access of data against the approved procedures under the Data Protection Act, 2019 and CRB Regulations, 2020.

Objective 2: To assess the capability of blockchain technology in addressing integrity issues in the credit information sharing mechanism

From the assessment of the responses received, respondents, believe that blockchain technology due to its characteristics of decentralisation, data transparency, tamper-proofing, traceability, privacy protection and open-sourcing will enhance the security, privacy and correctness of data essential in credit decisions. Integrity issues will be solved

Objective 3: To develop a blockchain prototype for credit information sharing

The study findings led to the development of a prototype that would simulate the actual process of credit information sharing. It followed an approach of developing, implementing and testing DApp using a ganache simulator. Solidity objected-oriented software was used to develop smart contracts. The developed prototype proved that it can be able to be used in management of the CIS mechanism to maintain integrity.

5.2. Value of the study

The importance of this study was to evaluate the applicability of blockchain technology in terms of resolving integrity issues that are hurting credit information-sharing mechanism. The soundness of the credit market is dependent on a reliable system that is key in the management of the credit portfolios of credit providers. The reliability and integrity of this system will lead to easy forecasting of credit trends and interventions that cushion customers in case of distress.

5.3. Conclusions

The study on how blockchain technology can be used to solve integrity issues in credit information sharing has been necessitated by the wide usage of the system by attracting non-traditional players including retailers, higher purchase traders and emerging lending companies on different products and services. This surge in the number of users of the system can be attributed to successes the system has had in credit risk management and product development. In the past 5yrs, the credit market has seen an increase in the number of product offerings by financial institutions and the emergence of digital lenders who rely on reputational collateral offered through CRBs to extend credit to their customers. This has had a big impact on enhancing financial inclusion among the underserved population. Based on this, it is necessary for system supervisors, regulators and lenders to find solutions to uphold the integrity of the system to guarantee sustainability and growth of the credit market.

Despite the existence of regulatory and industry standards set to ensure that elaborate measures are taken to secure and safeguard the integrity of the system, there still exist loopholes that if not sealed can jeopardise the reliability of the system. The Taskforce set out by the Ministry of ICT to investigate the impact of various emerging technologies in the economy documented that blockchain technology is a viable technology that is used in credit information sharing. As such, it is important that based on this research relevant policymakers, regulators and industry players begin a conversation about its implementation.

5.4. Recommendation

The developed prototype prove that a blockchain-based system would be able to manage integrity and restore public confidence in handling of privacy issues. To actualise this, policy makers should adopt the prototype and subject it to live testing with the aim of deploying it to the industry. This will guarantee reliability of the system and its effectiveness in credit risk management. However, further research should be conducted to ensure products on the system are predictive enough for different credit products.

REFERENCES

1. Adèr, H.J. & Mellenbergh, G.J. (2008). Advising on research methods: a consultant's companion. Huizen, the Netherlands: Johannes van Kessel Publishing.
2. Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., McCallum, P., & Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. Renewable and Sustainable Energy Reviews, 100, 143–174. https://doi.org/10.1016/J.RSER.2018.10.014
3. Balakrishnan, K., & Ertan, A. (2019). Credit information sharing and loan loss recognition. Available at SSRN 2964138.
4. Carson, B., Romanelli, G., Walsh, P., & Zhumaev, A. (2018). Blockchain beyond the hype: What is the strategic business value. McKinsey & Company, 1-13.
5. Central Bank of Kenya. (2010). *Bank Supervision Annual Report 2010*. Retrieved from https://www.centralbank.go.ke/images/docs/Bank%20Supervision%20Reports/Annual%20Reports/bsd2010
6. Central Bank of Kenya. (2020). *Bank Supervision Annual Report 2020*. Retrieved from https://www.centralbank.go.ke/uploads/banking_sector_annual_reports/468154612_2020%20Annual%20Report.pdf
7. Central Bank of Kenya. (2021). *Approved Third-party Credit Information Providers*. Retrieved from https://www.centralbank.go.ke/wp-content/uploads/2021/05/Approved-Third-Party-Credit-Information-Providers-30042021.pdf
8. Chang, V., Baudier, P., Zhang, H., Xu, Q., Zhang, J., & Arami, M. (2020). How Blockchain can impact financial services – The overview, challenges and recommendations from expert interviewees. Technological Forecasting and Social Change, 158. https://doi.org/10.1016/j.techfore.2020.120166
9. Chowdhury, M., Suchana, K., Alam, S., & Khan, M. (2021). Blockchain Application in Banking System. *Journal Of Software Engineering And Applications*, *14*(07), 298-311. https://doi.org/10.4236/jsea.2021.147018
10. Drigă, I., & Isac, C. (2014). E-banking services–features, challenges and benefits. Annals of the University of Petroşani. Economics, 14, 49-58.
11. Guo, Y., & Liang, C. (2016). Blockchain application and outlook in the banking industry. Financial Innovation, 2(1). https://doi.org/10.1186/s40854-016-0034-9

12. Guo, Y., & Liang, C. (2016). Blockchain application and outlook in the banking industry. Financial innovation, 2(1), 1-12.
13. Hasselgren, A., Kralevska, K., Gligoroski, D., Pedersen, S. A., & Faxvaag, A. (2020). Blockchain in healthcare and health sciences—A scoping review. International Journal of Medical Informatics, 134(December 2019). https://doi.org/10.1016/j.ijmedinf.2019.104040
14. International Finance Corporation (IFC). (2006). Credit Bureau Knowledge Guide.
15. Jappelli, T., & Pagano, M. (2002). Information sharing, lending and defaults: Cross-country evidence. Journal of Banking & Finance, 26(10), 2017–2045. https://doi.org/10.1016/S0378-4266(01)00185-6
16. Jappelli, T., & Pagano, M. (2006). 10 The Role and Effects of Credit Information Sharing. The economics of consumer credit, 347.
17. Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. Educational researcher, 33(7), 14-26.
18. Kafshdar Goharshady, A., Behrouz, A., & Chatteriee, K. (2018). Secure Credit Reporting on the Blockchain. *2018 IEEE International Conference On Internet Of Things (Ithings) And IEEE Green Computing And Communications (Greencom) And IEEE Cyber, Physical And Social Computing (Cpscom) And IEEE Smart Data (Smartdata)*. https://doi.org/10.1109/cybermatics_2018.2018.00231
19. Kusi, B. A., Agbloyor, E. K., Ansah-Adu, K., & Gyeke-Dako, A. (2017). Bank credit risk and credit information sharing in Africa: Does credit information sharing institutions and context matter?. Research in International Business and Finance, 42, 1123-1136.
20. Kwambai, K. D., & Wandera, M. (2013). Effects of Credit Information Sharing on Nonperforming Loans : the Case of Kenya Commercial Bank Kenya. European Scientific Journal, 9(13), 168–193.
21. Lagoze, C. (2014). Big Data, data integrity, and the fracturing of the control zone. Big Data and Society, 1(2), 1–11. https://doi.org/10.1177/2053951714558281
22. Liu, C., & Chen, C. (2019). Application and Challenges of Blockchain Technology to Big Data-Based Credit Reference in China. In J.-L. Chen, A.-C. Pang, D.-J. Deng, & C.-C. Lin (Eds.), Wireless Internet (pp. 148–155). Springer International Publishing.

23. Luthi. (2020). *Does Checking My Credit Lower My Score?*. Experian.com. Retrieved 3 March 2022, from https://www.experian.com/blogs/ask-experian/does-checking-your-credit-score-lower-it/.
24. Ministry of ICT and Technology. (2019). *Emerging digital Technologies for Kenya: Exploration & analysis*.
25. Moturi, C., & Ogoti, G. (2020). Strengthening technology risk management in mobile money lending. International Journal of Financial Services Management, 10(3), 217-238.
26. Mugenda, O.M., & Mugenda, A.G. (2003).Research methods.(3rd Ed.). Nairobi: Act Press publication.
27. Mugwe, M. W., & Oliweny, T. (2015). The Effect of credit information sharing on the performance of commercial banks in Kenya. International Journal of Business and Commerce, 5(3), 41-63.
28. Ndungu, J. M. & Moturi, C. A. (2020). Determinants of Mobile Fintech Uptake in Kenyan Microfinance Sector. Current Journal of Applied Science and Technology, 39(28), 102-114.
29. Nóbrega, T., Pires, C. E. S., & Nascimento, D. C. (2021). Blockchain-based Privacy-Preserving Record Linkage: enhancing data privacy in an untrusted environment. Information Systems, 102. https://doi.org/10.1016/j.is.2021.101826
30. Ortlepp, B. (2019). A Feasibility Study on Using the Blockchain to Build a Credit Register for Individuals Who Do Not Have Access to Traditional Credit Scores.
31. Rathee, G., Sharma, A., Iqbal, R., Aloqaily, M., Jaglan, N., & Kumar, R. (2019). A blockchain framework for securing connected and autonomous vehicles. Sensors, 19(14), 3165.
32. Rowlands, B. (2005). Grounded in Practice: Using Interpretive Research to Build Theory. The Electronic Journal of Business Research Methodology, 3(1), 81–92.
33. Schwerin, S. (2018). Blockchain and Privacy Protection in the Case of the European General Data Protection Regulation (GDPR): A Delphi Study. The Journal of the British Blockchain Association, 1(1), 1–77. https://doi.org/10.31585/jbba-1-1-(4)2018
34. Singh, M., & Kim, S. (2018). Blockchain Based Intelligent Vehicle Data Sharing Framework. *Computer Networks*. https://doi.org/10.1016/j.comnet.2018.08.016
35. Van Wyk, J., & Boraine, A. (2017). Credit bureaus in South Africa and Namibia: a comparative analysis of the regulatory frameworks evaluated against the World Bank's

principles for credit reporting—part I. Comparative and International Law Journal of Southern Africa, 50(2), 147-195.

36. World Bank Group. (2011). FINANCIAL INFRASTRUCTURE SERIES CREdIT REpoRTINg poLICy ANd RESEARCh General PrinciPles for credit rePortinG. September.
37. World Bank Group. (2019). Credit Reporting Knowledge Guide 2019. Credit Reporting Knowledge Guide 2019. https://doi.org/10.1596/31806
38. Wust, K., & Gervais, A. (2018). Do you need a blockchain? In Proceedings - 2018 Crypto Valley Conference on Blockchain Technology, CVCBT 2018 (pp. 45–54). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/CVCBT.2018.00011
39. Xia, Q., Sifah, E. B., Smahi, A., Amofa, S., Zhang, X., Au, M. H., Han, J., Liu, J. K., & Kaafarani, A. El. (2017). information BBDS: Blockchain-Based Data Sharing for Electronic Medical Records in Cloud Environments. https://doi.org/10.3390/info8020044
40. Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2019). Blockchain Technology Overview. https://doi.org/10.6028/NIST.IR.8202
41. Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K. (2016). Where Is Current Research on Blockchain Technology?—A Systematic Review. PLOS ONE, 11(10), e0163477. https://doi.org/10.1371/journal.pone.0163477
42. Zhang, A., & Lin, X. (2018). Towards Secure and Privacy-Preserving Data Sharing in e-Health Systems via Consortium Blockchain. Journal of Medical Systems 2018 42:8, 42(8), 1–18. https://doi.org/10.1007/S10916-018-0995-5
43. Zhang, J., Tan, R., Su, C., & Si, W. (2020). Design and application of a personal credit information sharing platform based on consortium blockchain. Journal of Information Security and Applications, 55(2019), 102659. https://doi.org/10.1016/j.jisa.2020.102659
44. Zhu, X. (2020). Blockchain-Based Identity Authentication and Intelligent Credit Reporting. Journal of Physics: Conference Series, 1437(1). https://doi.org/10.1088/1742-6596/1437/1/012086
45. Zou, Y., Mhaidli, A. H., McCall, A., & Schaub, F. (2018). " I've Got Nothing to Lose": Consumers' Risk Perceptions and Protective Actions after the Equifax Data Breach. In *Fourteenth Symposium on Usable Privacy and Security ({SOUPS} 2018)* (pp. 197-216).

46. Zyskind, G., Nathan, O., & Pentland, A. 'Sandy'. (2015). Decentralizing Privacy: Using Blockchain to Protect Personal Data. 2015 IEEE Security and Privacy Workshops, 180–184. https://doi.org/10.1109/SPW.2015.27

APPENDICES

Appendix I:
<u>Interview Guide</u>

University of Nairobi

Department of Computing and Informatics

Blockchain Technology Application in Credit Information Sharing in Kenya

My name is Job Mariga graduate student pursuing an MSc. IT Management at the University of Nairobi Department of Computing and informatics. I am undertaking a research study Titled "Blockchain Technology Application in Credit Information Sharing in Kenya" under the supervision of Mr. Christopher A. Moturi. The purpose of this study is to explore the potential of blockchain technology to solve integrity issues around unauthorised manipulation of data in the credit reference bureaus and in protection of consumer security and privacy. I will like to request that you take a between 10-15mins of your time and participate in this survey. All information collected in this survey will only be used for academic purposes. The survey does not collect information that will be identifying you and the responses will remain anonymous and data treated with the highest level of confidentiality.

Blockchain Technology Application in Credit Information Sharing mechanism in Kenya

SECTION I: GENERAL INFORMATION

1. Name of financial institutions ________________________________
2. The type of financial institution
    - Commercial Bank
    - Microfinance Bank
    - SACCO
    - Digital Lender
    - Leasing company
    - Microfinance Institution

- Credit Reference Bureau

3. The number of employees in the institution
    - Below 20
    - 21- 50
    - 51-100
    - Above 100
4. How long has the financial institution been operational in Kenya?
    - Below 5yrs
    - 5-10yrs
    - 10-20yrs
    - Above 20yrs
5. Gender of the respondent
    - Male
    - Female
6. Work Experience in the financial institution
    - Less than a year
    - 1-5yrs
    - 5-10yrs
    - Above 10yrs
7. Level of education
    - PhD
    - Master’s Degree
    - Bachelor’s Degree
    - Diploma
8. Department of operation within the financial institution
    - Credit Department
    - IT Department
    - Finance Department
    - Risk Department
    - Operations department
    - Customer care and front office department
    - Other
9. Level of Management within the financial institution
    - Top Level Management

- Middle Level Management
- Operational Level management

SECTION II: BLOCKCHAIN TECHNOLOGY

10. Has your organization adopted the use of blockchain Technology?
    - Yes
    - No
11. If Yes, how successful has the blockchain technology enabled credit processes?
    - Not Successful at all
    - Not successful
    - Somewhat Successful
    - Successful
    - Very Successful
12. If No, has the institution considered in its strategy to employ the blockchain technology?
    - Yes
    - No
13. Indicate to what extend embracing Blockchain would enhance Credit Information Sharing. Use the following scale 1= Strongly Disagree; 2=Disagree; 3=Slightly disagree; 4= Neither Agree nor Disagree; 5=Strongly Agree; Tick (✓) where appropriate.

	1= Strongly Disagree; 2=Disagree; 3=Slightly disagree; 4= Neither Agree nor Disagree; 5=Strongly Agree				
Blockchain Technology	**1**	**2**	**3**	**4**	**5**
Using Blockchain technology will assist in faster data processing					

Blockchain technology will improve the data accuracy					
Blockchain technology will improve the correctness of credit data					
Blockchain technology will enhance security of data					
Blockchain technology will improve help upheld data protection and privacy					
Application of Blockchain technology in credit processes will improve credit risk management					
Blockchain technology will help solve unauthorized manipulation of data					
Blockchain technology will help restore trust and confidence in credit bureau products					

SECTION III: CREDIT INFORMATION SHARING

14. Does your institution participate in credit information sharing mechanism?
    - **Yes**
    - **No**
15. What mechanisms does your institution apply to enhance participation in CIS?
16. State the name of CRB systems used to ensure effectiveness in participation in CIS mechanism?

    ____

    ____

17. To what extent has the financial institution embraced CIS and has been beneficial to the credit process. Use the following scale: 1 = Not at all; 2=Small extent;

3=Moderate extent; 4= Great extent; 5 = Very great extent; Tick (✓) where appropriate

Credit Information Sharing	**1**	**2**	**3**	**4**	**5**
Participating in credit information sharing					
Use credit information to reach credit decisions					
Credit information has reduced bad loans					
Impact of Credit information on the institution's profitability					
Credit information has enabled us the organisation reach the underbanked and underserved					
Credit Information impacted development of new products					
Credit information in CRBs is accurate and reliable for lending decisions					
Captures all credit information from credit providers					
Has compromised integrity of data					
Highest standard of data security and footprints on who accessed					
Data availability in case of a link failure					
Maintains confidentiality and privacy of data					
Data stored is tamper-proof making it more reliable					

Appendix II: User Manual

Step 1: Right click on the document that bears the solidity system and open windows terminal and run the command npm install to install the npm package.

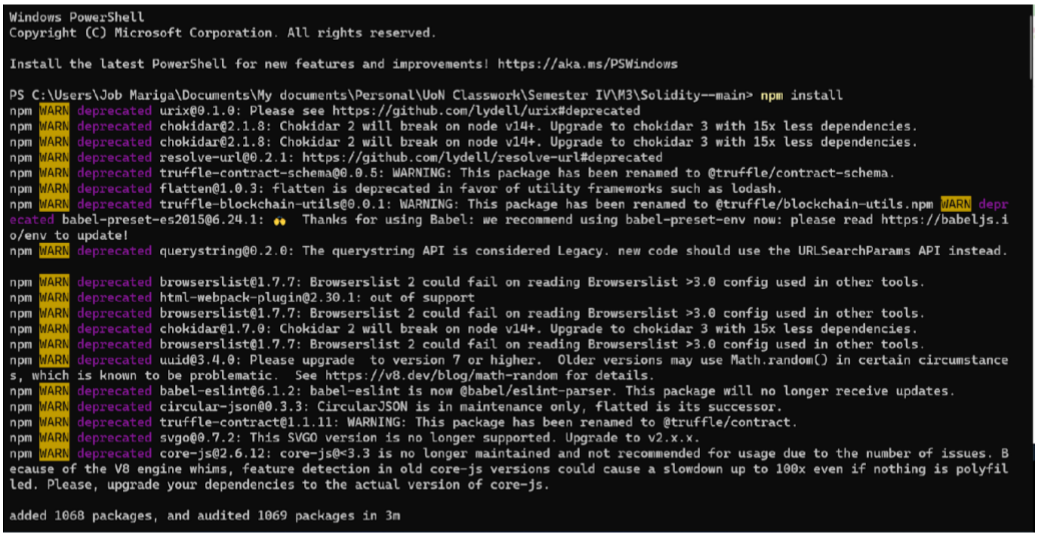


Figure 5: Install npm package

Step 2: Start Ganache software that is used to set up Ethereum Blockchain for testing solidity contracts and create a workspace.

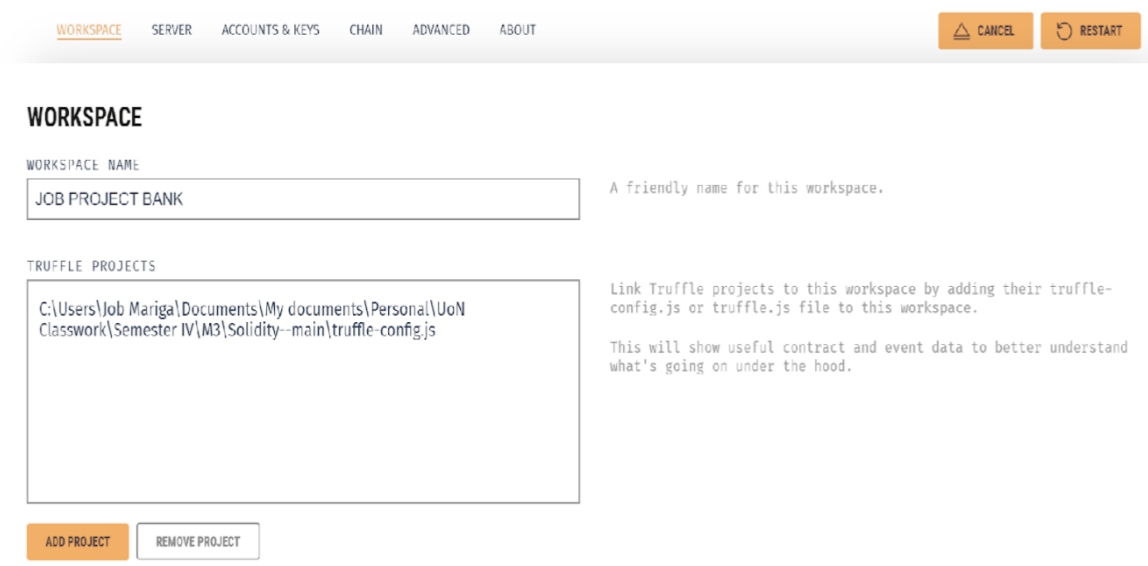


Figure 6: Ganache workspace setup

Step 3: Run *truffle migrate* command on the command prompt window. The command migrates all the contracts to deploy contracts. Then run run dev command to compile all the smart contract assets.

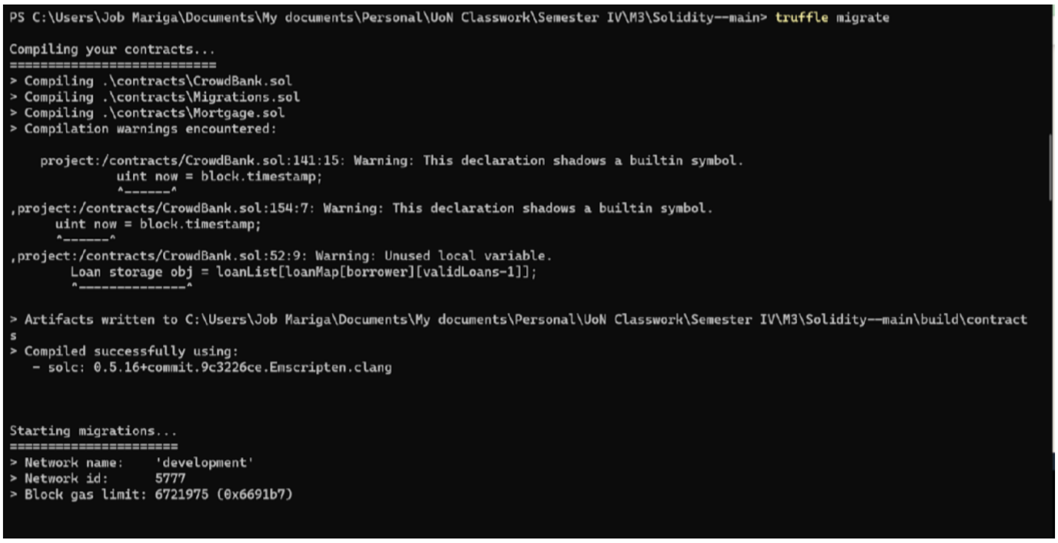


Figure 7: truffle migrate window

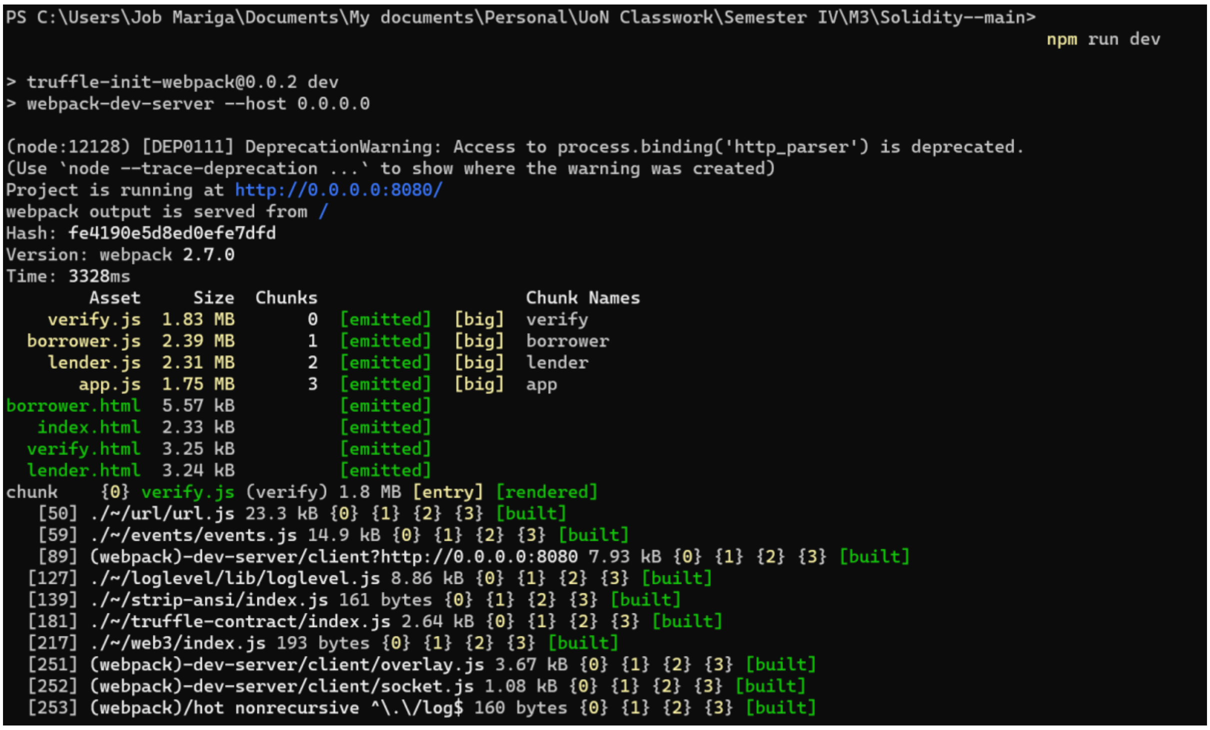


Figure 8: npm run dev command

Step 4: Open browser and add Metamask extension. Metamask helps one connect to a decentralised web. Then run 127.0.0.1: 8080 to interact with the web interface.

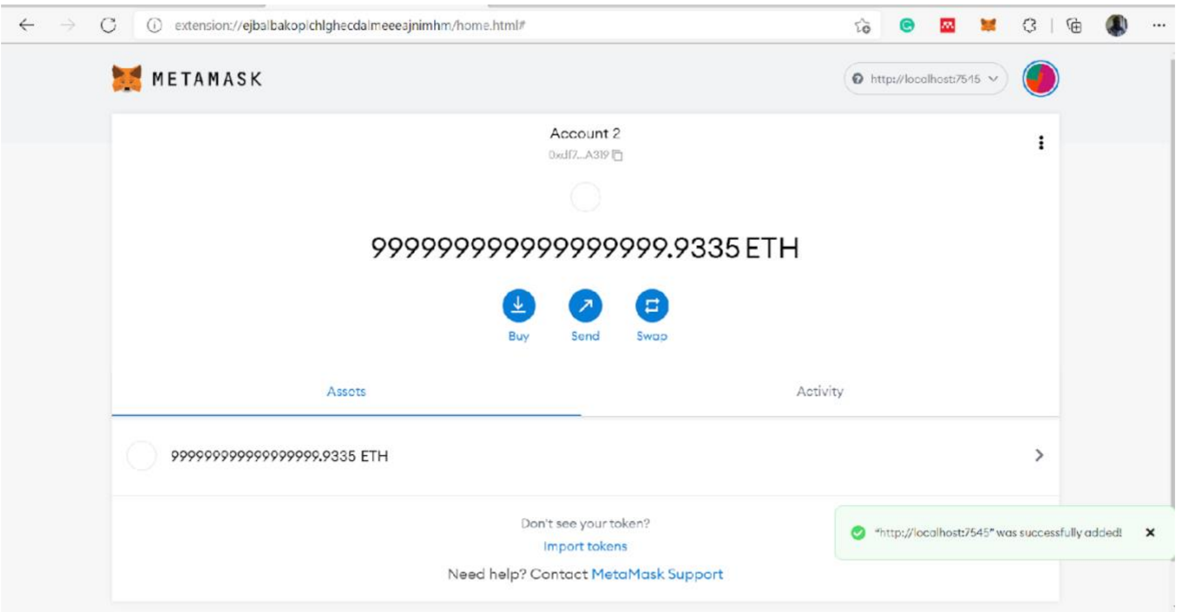


Figure 9: Metamask page

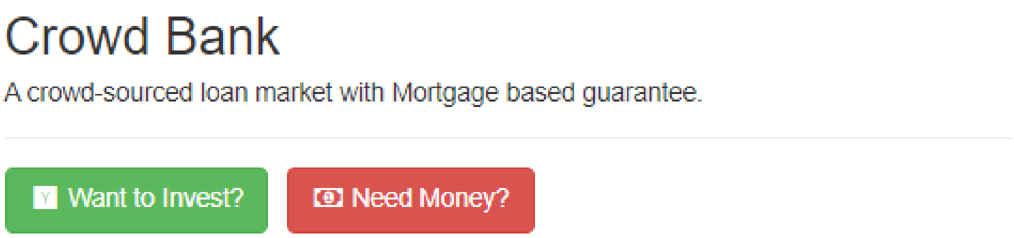
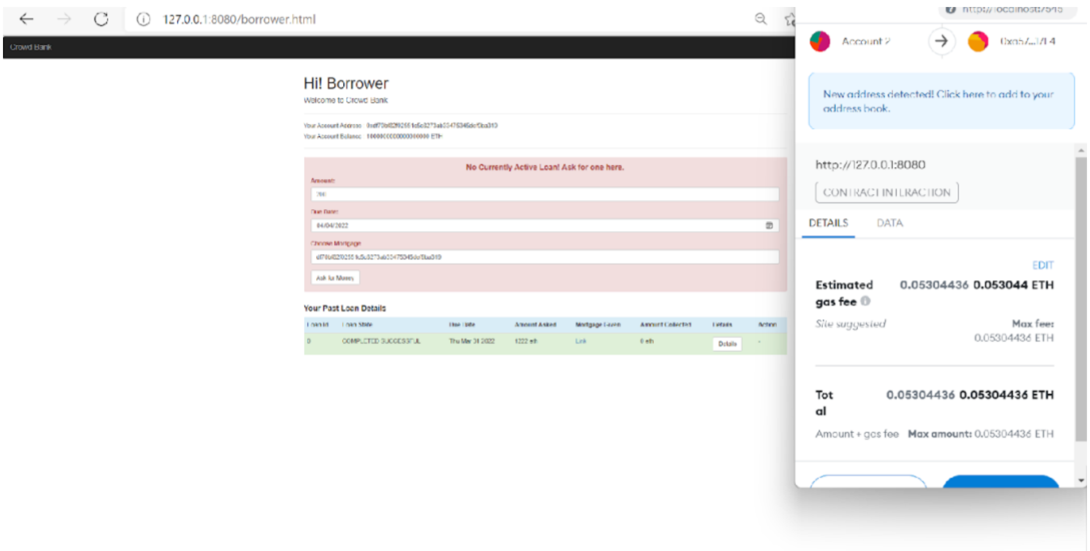


Figure 10: Web interface to borrow and approve loans

Step 5: Click on need money button and apply to borrow money and click on Confirm when metamask pops up.



Step 6: Login in as a lender by getting to the home page and click on invest. From the window below you will see the amount applied you need to accept or reject the transaction and confirm on the Metamask pop-up.

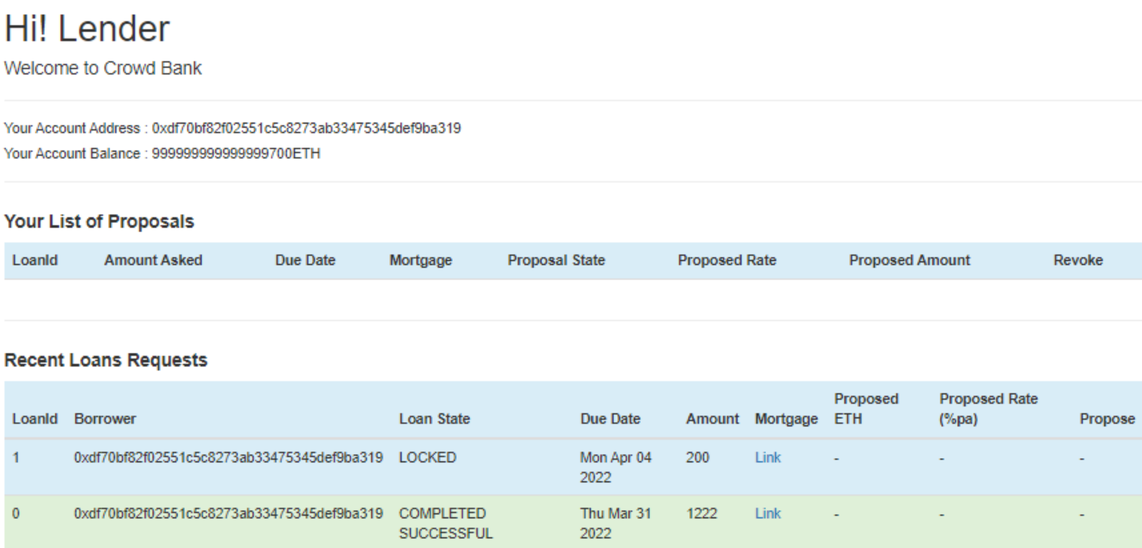
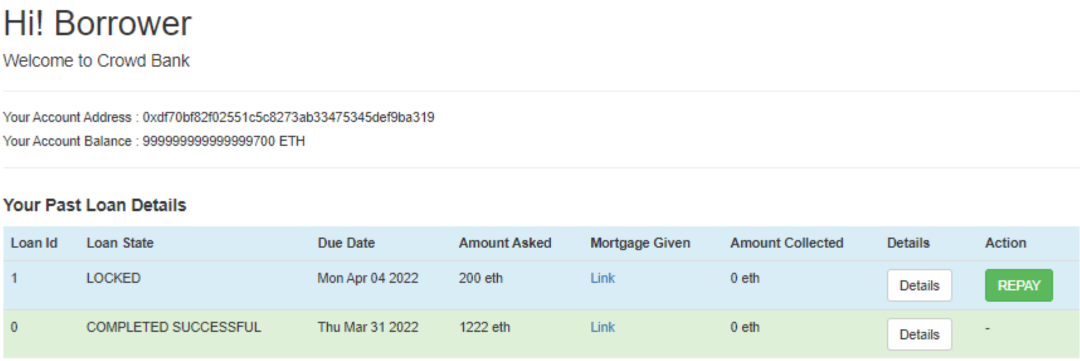


Figure 11: Lender's window for approval/rejection of loan

Step 7: On the borrower side, if you wish to repay amount you click on the button below and confirm.



Repaid loans will appear as;

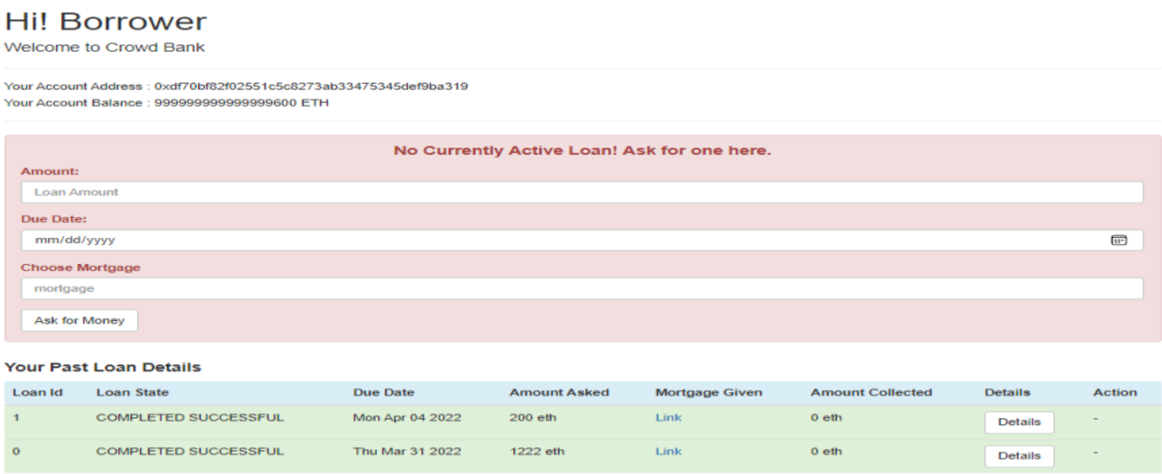


Figure 12: Loan repayment by the customer

To confirm on the transactions done on the application, open Ganache which will display blocks of transactions that have taken place. The blocks cannot be altered as they are system generated.

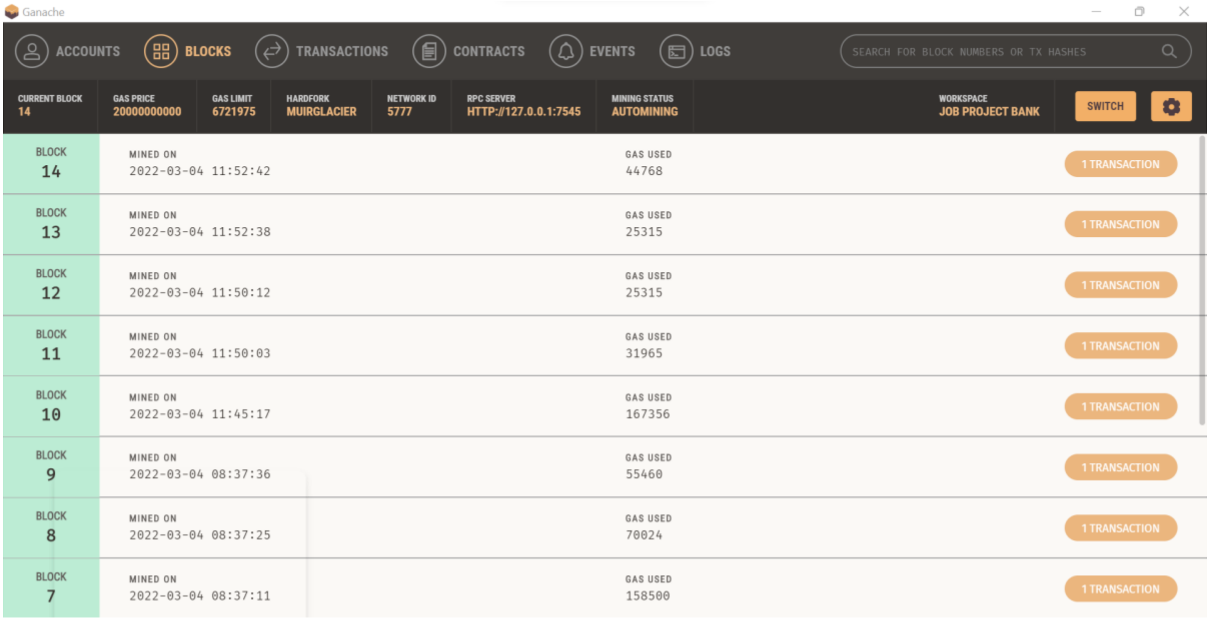


Figure 13: Confirmation of transactions in Ganache

Appendix II: Sample Solidity Code

<u>CrowdBank Contract</u>

```
pragma solidity ^0.5.0;

contract CrowdBank {


    address public owner;


    enum ProposalState {
        WAITING,
        ACCEPTED,
        REPAID
    }


    struct Proposal {
        address payable lender;
        uint loanId;
        ProposalState state;
        uint rate;
        uint amount;
    }


    enum LoanState {
        ACCEPTING,
        LOCKED,
        SUCCESSFUL,
```

```
    FAILED
}

struct Loan {
    address borrower;
    LoanState state;
    uint dueDate;
    uint amount;
    uint proposalCount;
    uint collected;
    uint startDate;
    bytes32 mortgage;
    mapping (uint=>uint) proposal;
}

Loan[] public loanList;
Proposal[] public proposalList;

mapping (address=>uint[]) public loanMap;
mapping (address=>uint[]) public lendMap;

constructor() public{
    owner = msg.sender;
}
```

```
    function hasActiveLoan(address borrower) public view returns(bool) {
        uint validLoans = loanMap[borrower].length;
        if(validLoans == 0) return false;
        Loan storage obj = loanList[loanMap[borrower][validLoans-1]];
        if(loanList[validLoans-1].state == LoanState.ACCEPTING) return true;
        if(loanList[validLoans-1].state == LoanState.LOCKED) return true;
        return false;
    }

    function newLoan(uint amount, uint dueDate, bytes32 mortgage) public {
        if(hasActiveLoan(msg.sender)) return;
        uint currentDate = block.timestamp;
        loanList.push(Loan(msg.sender, LoanState.ACCEPTING, dueDate, amount, 0, 0, currentDate, mortgage));
        loanMap[msg.sender].push(loanList.length-1);
    }

    function newProposal(uint loanId, uint rate) public payable {
        if(loanList[loanId].borrower == address(0) || loanList[loanId].state != LoanState.ACCEPTING)
            return;
        proposalList.push(Proposal(msg.sender, loanId, ProposalState.WAITING, rate, msg.value));
        lendMap[msg.sender].push(proposalList.length-1);
```

```
    loanList[loanId].proposalCount++;
    loanList[loanId].proposal[loanList[loanId].proposalCount-1] = proposalList.length-1;
}

function getActiveLoanId(address borrower) public view returns(uint) {
    uint numLoans = loanMap[borrower].length;
    if(numLoans == 0) return (2**64 - 1);
    uint lastLoanId = loanMap[borrower][numLoans-1];
    if(loanList[lastLoanId].state != LoanState.ACCEPTING) return (2**64 - 1);
    return lastLoanId;
}

function revokeMyProposal(uint id) public {
    uint proposeId = lendMap[msg.sender][id];
    if(proposalList[proposeId].state != ProposalState.WAITING) return;
    uint loanId = proposalList[proposeId].loanId;
    if(loanList[loanId].state == LoanState.ACCEPTING) {
        // Lender wishes to revoke his ETH when proposal is still WAITING
        proposalList[proposeId].state = ProposalState.REPAID;
        msg.sender.transfer(proposalList[proposeId].amount);
    }
    else if(loanList[loanId].state == LoanState.LOCKED) {
        // The loan is locked/accepting and the due date passed : transfer the mortgage
        if(loanList[loanId].dueDate < now) return;
```

```
        loanList[loanId].state = LoanState.FAILED;
        for(uint i = 0; i < loanList[loanId].proposalCount; i++) {
            uint numI = loanList[loanId].proposal[i];
            if(proposalList[numI].state == ProposalState.ACCEPTED) {
                // transfer mortgage
            }
        }
    }
}

function lockLoan(uint loanId) public {
    //contract will send money to msg.sender
    //states of proposals would be finalized, not accepted proposals would be reimbursed
    if(loanList[loanId].state == LoanState.ACCEPTING)
    {
      loanList[loanId].state = LoanState.LOCKED;
      for(uint i = 0; i < loanList[loanId].proposalCount; i++)
      {
        uint numI = loanList[loanId].proposal[i];
        if(proposalList[numI].state == ProposalState.ACCEPTED)
        {
          msg.sender.transfer(proposalList[numI].amount); //Send to borrower
        }
        else
```

```
          {
            proposalList[numI].state = ProposalState.REPAID;
            proposalList[numI].lender.transfer(proposalList[numI].amount);    //Send    back    to
lender
          }
        }
      }
      else
        return;
    }


    //Am uint time = loanList[loanId].startDate;
      uint paid = msg.value;
      if(paid >= toBePaid)
      {
        uint remain = paid - toBePaid;
        loanList[loanId].state = LoanState.SUCCESSFUL;
        for(uint i = 0; i < loanList[loanId].proposalCount; i++)
        {
          uint numI = loanList[loanId].proposal[i];
          if(proposalList[numI].state == ProposalState.ACCEPTED)
          {
            uint original = proposalList[numI].amount;
            uint rate = proposalList[numI].rate;
            uint interest = (original*rate*(now - time))/(365*24*60*60*100);
```

```
        uint finalamount = interest + original;
        proposalList[numI].lender.transfer(finalamount);
        proposalList[numI].state = ProposalState.REPAID;
      }
    }
    msg.sender.transfer(remain);
  }
  else
  {
    msg.sender.transfer(paid);
  }
}

 function acceptProposal(uint proposeId) public
{
    uint loanId = getActiveLoanId(msg.sender);
    if(loanId == (2**64 - 1)) return;
    Proposal storage pObj = proposalList[proposeId];
    if(pObj.state != ProposalState.WAITING) return;

    Loan storage lObj = loanList[loanId];
    if(lObj.state != LoanState.ACCEPTING) return;

    if(lObj.collected + pObj.amount <= lObj.amount)
```

```
        {
          loanList[loanId].collected += pObj.amount;
          proposalList[proposeId].state = ProposalState.ACCEPTED;
        }
    }

    function totalProposalsBy(address lender) public view returns(uint) {
        return lendMap[lender].length;
    }

    function getProposalAtPosFor(address lender, uint pos) public view returns(address, uint, ProposalState, uint, uint, uint, uint, bytes32) {
        Proposal storage prop = proposalList[lendMap[lender][pos]];
        return (prop.lender, prop.loanId, prop.state, prop.rate, prop.amount, loanList[prop.loanId].amount, loanList[prop.loanId].dueDate, loanList[prop.loanId].mortgage);
    }

// BORROWER ACTIONS AVAILABLE

    function totalLoansBy(address borrower) public view returns(uint) {
        return loanMap[borrower].length;
    }
```

```
    function getLoanDetailsByAddressPosition(address borrower, uint pos) public view returns(LoanState, uint, uint, uint, uint,bytes32) {
        Loan storage obj = loanList[loanMap[borrower][pos]];
        return (obj.state, obj.dueDate, obj.amount, obj.collected, loanMap[borrower][pos], obj.mortgage);
    }

    function getLastLoanState(address borrower) public view returns(LoanState) {
        uint loanLength = loanMap[borrower].length;
        if(loanLength == 0)
            return LoanState.SUCCESSFUL;
        return loanList[loanMap[borrower][loanLength -1]].state;
    }

    function getLastLoanDetails(address borrower) public view returns(LoanState, uint, uint, uint, uint) {
        uint loanLength = loanMap[borrower].length;
        Loan storage obj = loanList[loanMap[borrower][loanLength -1]];
        return (obj.state, obj.dueDate, obj.amount, obj.proposalCount, obj.collected);
    }

    function getProposalDetailsByLoanIdPosition(uint loanId, uint numI) public view returns(ProposalState, uint, uint, uint, address) {
        Proposal storage obj = proposalList[loanList[loanId].proposal[numI]];
        return (obj.state, obj.rate, obj.amount, loanList[loanId].proposal[numI],obj.lender);
```

```
    }


    function numTotalLoans() public view returns(uint) {
        return loanList.length;
    }

}
```

Migrations Contract

```
pragma solidity ^0.5.0;

contract Migrations {
  address public owner;
  uint public last_completed_migration;

  modifier restricted() {
    if (msg.sender == owner) _;
  }

  constructor() public {
    owner = msg.sender;
  }

  function setCompleted(uint completed) public restricted {
```

```
    last_completed_migration = completed;
  }

  function upgrade(address new_address) public restricted {
    Migrations upgraded = Migrations(new_address);
    upgraded.setCompleted(last_completed_migration);
  }
}
```

Mortgage Contract

```
pragma solidity ^0.5.0;
contract Mortgage {

  address public owner;

  mapping (bytes32=>address[]) public ownerMap;
  mapping (address=>bytes32[]) public mortgageMap;

  constructor() public {
      owner = msg.sender;
  }

  function addData(bytes32 document) public {
    address[] storage owners = ownerMap[document];
```

```
  uint i;

  for(i=0;i<owners.length; i++)

  {

    if(owners[i] == msg.sender)

      return;

  }

  ownerMap[document].push(msg.sender);

  uint count = mortgageMap[msg.sender].length;

  for(i=0;i<count; i++)

  {

    if(mortgageMap[msg.sender][i] == document)

      return;

  }

  mortgageMap[msg.sender].push(document);

}


function getMortgageCount(address person) public view returns(uint) {

  return mortgageMap[person].length;

}


function getOwnerCount(bytes32 hash) public view returns(uint) {

  return ownerMap[hash].length;

}
```

```
 function getOwnerByPosition(bytes32 hash,uint index) public view returns(address) {
  return ownerMap[hash][index];
 }



}ount to be Repaid
    function getRepayValue(uint loanId) public view returns(uint) {
      if(loanList[loanId].state == LoanState.LOCKED)
      {
        uint time = loanList[loanId].startDate;
        uint finalamount = 0;
        for(uint i = 0; i < loanList[loanId].proposalCount; i++)
        {
          uint numI = loanList[loanId].proposal[i];
          if(proposalList[numI].state == ProposalState.ACCEPTED)
          {
            uint original = proposalList[numI].amount;
            uint rate = proposalList[numI].rate;
            uint now = block.timestamp;
            uint interest = (original*rate*(now - time))/(365*24*60*60*100);
            finalamount += interest;
            finalamount += original;
          }
        }
```

```
      return finalamount;
    }
    else
      return (2**64 -1);
}

 function repayLoan(uint loanId) public payable {
  uint now = block.timestamp;
  uint toBePaid = getRepayValue(loanId);
```