

The Use of Block Chain in the Informal Distributed Manufacturing Industry in Kenya

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Abstract

In the last decade, research and development around distributed ledger technology (DLT) has grown exponentially. The financial services industry has been revolutionized by the explosion of cryptocurrencies like Bitcoin and Ethereum. Researchers have taken the principles used in these cryptocurrencies and are using them to develop other DLTs in various fields. This study explores how blockchain can be used to provide traceability, visibility, and transparency in the Kenyan informal distributed manufacturing industry. SOKO, an aggregator of artisans spread all over Nairobi, was the case study used. Purposive and convenience-based were the sampling methods used. 48 SOKO supply chain employees and active artisans were the sample population. Interviews and observations were data collection methods used. Content analysis, a qualitative data analysis method, was used to capture emerging and predetermined themes. Google sheets and Dovetail were the tools used for this study. This paper finds that the use of the immutability and proof of origin features of blockchain greatly enhances traceability within a supply chain. It is imperative that the granular information collected should be intuitive and accessible to all parties to enhance visibility. Amplified traceability and visibility greatly improved transparency and accountability within the SOKO ecosystem. A pivotal recommendation for future research is the usage of unit-based tagging technologies e.g. barcodes, QR codes, or RFID. The combined use of such technologies and blockchain would achieve the highest level of traceability, especially when working with diverse producers who produce similar products.

Keywords

Distributed Ledger Technology (DLT), Blockchain, Distributed Manufacturing, Aggregator, Supply Chain (SC)

1. Introduction

In the early 90s, Haber & Stornetta proposed a cryptographically secured chain of blocks whereby no one could tamper with the timestamps of documents. This paper marked the inception of Distributed Ledger Technology (DLT). 17 years later, Satoshi Nakamoto wrote the first Bitcoin white paper proposing the use of the using a peer-to-peer network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work (Nakamoto, 2008) and formed the genesis Bitcoin block. After that, the open-source code was modified to create better cryptocurrencies, and some projects also tried to alter the idea of Blockchain beyond the use case of P2P money.

One of the sectors where Blockchain technology has been widely discussed, most probably because of the Bitcoin hype, is the financial services industry. Startups, organizations, and governments have begun exploring implementations in various areas such as energy supply, electronic health records, voting, ownership management, supply chain, etc. (Xu et al., 2017). Some countries such as Sweden have already implemented the use of blockchain in their land registry systems (Chavez-Dreyfuss, 2016).

Globally, the manufacturing sector has the most organizations with at-scale deployments, compared to the retail and consumer products industry (Capgemini, 2018). However, looking at their usability and costs of setup, it is clear that the technologies developed so far do not cater to distributed manufacturing in developing countries.

While traditional manufacturing is characterized by centralized manufacturing (Bamber & Dale, 2000), developing markets such as Africa, Central, and South America have missed out on opportunities because the majority of the workforce is distributed. The Kenyan distributed manufacturing sector, in particular, is largely informal, and heavily interconnected, with real-time transactions ongoing at every moment. To solve this, pooling together the resources available has given the markets a chance to enter the global market. Taking the Kenyan agricultural sector as an example, farmers have formed cooperatives that allow them to consolidate their produce and make the logistics of getting the produce to the end consumer easier.

While this approach offers a level playing field, it brings its fair share of challenges. The aggregators need to have visibility of data of all their producers, their location as well as keeping track of any processes that the product goes through. We are also in the age of the conscious consumer, with customers asking to have more transparency regarding the sourcing of their goods and the manufacturing process. Buyers are keen to understand the true value of what they are purchasing or reselling. 66 percent of global consumers are willing to pay more for sustainable goods, and specifically 73 percent of Millennials (Curtin, 2018). Satisfying these requests is quite difficult in the existing distributed manufacturing setup. In agriculture, it would require consolidation of data from several coopera-

tives, logistics companies, and processing companies if any were used, and tracing all the activities back to their origin.

Providing a technology that enables organizations in the Kenyan informal distributed manufacturing industry to have transparency into their operations while having the elusive traceability and visibility will boost the Kenyan economy and allow local manufacturers to compete on a global market. It will also help the informal manufacturers have better access to financial services such as loans and grants as their data will be in a centralized location that is trustworthy due to the immutability of records. The scope of this study was limited to the informal Kenyan craft industry and organizations within the industry that act as consolidators or aggregators. The study sought to investigate: how can uniform data on informal producers be provided using a DLT system; can a DLT system be developed that has features that support the provision of visibility and traceability in the Kenyan informal distributed manufacturing industry; will the DLT system provide traceability and visibility of data to aggregators in the Kenyan informal distributed manufacturing industry and what is the impact of the use of the system in terms of transparency of processes to the artisans and aggregators in Kenyan informal distributed manufacturing industry?

This study sought to answer the following questions:

- 1) How does blockchain enhance traceability in the Kenyan informal distributed manufacturing industry?
- 2) How does blockchain facilitate visibility in the Kenyan informal distributed manufacturing industry?
- 3) What is the influence of blockchain in enhancing transparency in the Kenyan informal distributed manufacturing industry?

This article has five sections. Section one is the introduction, Section two has the literature review, Section three is the methodology, Section four is the findings and Section five is the conclusions.

2. Literature Review

2.1. The Informal Sector in Developing Economies

Based on traditional industrial manufacturing standards, Africa is not considered a manufacturing hub. Apart from South Africa and a few other African countries, large-scale industrial manufacturing continues to be very minimal. However, distributed manufacturing booms in the African economy. This consists of workers in small unregistered factories or workshops, and industrial workers who work from their homes (also called homeworkers) (Chen, 2005).

Classified as a key player in the informal sector, the local craft/manufacturing industry, popularly known as Jua Kali which literally means fierce sun in Swahili, is a sector that contributes heavily to Kenya's GDP. Kenya's 2014 Economic Survey indicated 80 percent of the 800,000 jobs created in 2014 were in the informal and/or Jua Kali sector that is dominated by small and medium enterprises (SMEs). Jua Kali employs more than 14 million people translating to 83.4

percent total jobs in the country and contributes 34.3 percent of the country's Gross Domestic Product (GDP), making it one of the most intense sectors in the Kenyan economy.

2.2. Aggregators

The cooperatives movement in Kenya has grown over the years since the first cooperative society was established in 1908 under the colonial government, to 18,573 cooperatives in 2016 (Ministry of Industry, 2017). Cooperatives offer members a chance to optimize their economic, social and cultural needs. In the last decade, Kenya has seen other members of the informal sector such as the transport industry and craftsmen also registering 57 and 211 cooperatives respectively. While this is only above 1% of the number of existing SACCOs, this indicates that informal workers are realizing the benefits of being a large entity.

External partners are also coming into distributed manufacturing as aggregators. They bring together groups of producers and provide them with access to funding and local and international markets. An example of this is Lynk, a Kenyan company that brings together informal service providers such as carpenters, plumbers, etc. and the final consumers.

Once the cooperatives or aggregators purchase goods from the producers, some choose to do more value addition processes on the products to get them to a global standard. This creates a supply chain that is dependent on distributed producers, which brings about a different set of challenges. Producers would like to have product data which will help them improve their product offerings in the global market. Consumers are also interested in knowing how the product was made.

2.3. Role of Technology

In Kenya, Policy documents that have been created recently such as Sessional Paper No. 2 of 2005 on Development of Micro and Small Enterprises for Wealth and Employment Creation for Poverty Reduction, which have highlighted the need for development of the technological capacity of MSEs. The aim is to grow the ability of MSEs to adopt and adapt to new technologies as well as to enhance their access to available technology.

Apart from the changes in policy, distributed manufacturing is further empowered by modern infrastructural ICT developments. The emergence and usage of mobile technology in Sub-Saharan Africa has grown dramatically over the last two decades, with Kenya leading by having 91% penetration of mobile subscriptions compared to Africa's 80%. 3 G network coverage has increased from 67% in 2014 to 85% in 2017, with a bigger proliferation of 4 G, now reaching more than a third of the population (Islam, 2019). With the establishment of mobile money, businesses can track their financial transactions and the records used to request for financial resources.

It is imperative that technologists continue to develop human-centered products that aim to solve the sector's needs. Connecting informal producers with the

global market can be made possible by providing visibility and traceability into the value chain. This would include capturing the producer data, any value addition done on the product, logistics companies used, up to reception by the final consumer. Emerging technologies like Distributed Ledger Technologies can be explored to provide these solutions.

2.4. Distributed Ledger Technology

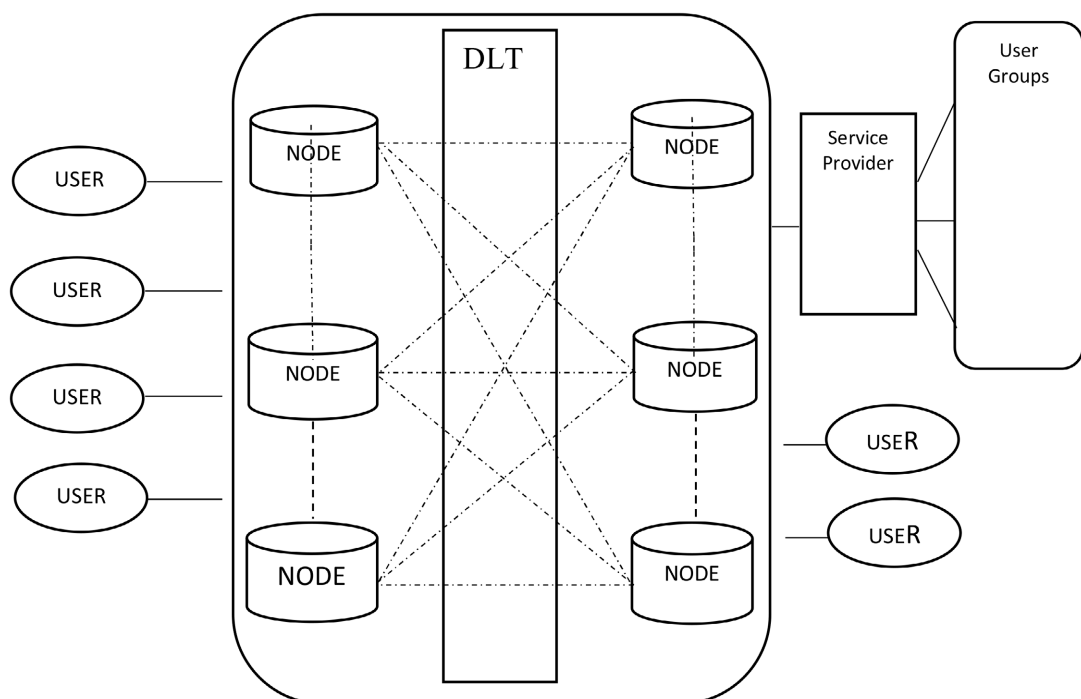
The International Telecommunication Union (ITU) in 2019 defined a distributed ledger as a type of ledger that is shared, replicated, and synchronized in a distributed manner. A distributed ledger is a public ledger that is accessible to every participant of a network, and records transactions between peers in a chronological order by using time stamps.

The ITU-T (2019) identifies the DLT components as user, DLT node, DLT service provider, and user groups. **Figure 1** below shows a simple illustration of the components of the distributed ledger technology.

DLTs can have two different access control structures: permission-less/public or permissioned/private. In permission-less anyone can participate in the consensus protocol of the ledger and propose data to add to it, while in permissioned only a set of known entities can propose data to be added. Permissioned ledgers are mostly used by private industries (Voshmgir, 2019).

2.5. DLT Features

Given that any participant can make new entries, the issue of data validation in



Source: ITU-T (2019).

Figure 1. A typical example of DLT actors and components.

distributed ledgers brought about some of the most notable features of DLTs below:

- **Immutability (append only).** The record is added to the database using hash functions and time stamps for new data entries. An attempt to change the data later would destroy the chronological order and logical consistency of the chain of information and would immediately be flagged (Lenz, 2019).
- **Proof of origin.** The distributed ledger infrastructure uses asymmetric private and public digital keys when writing into the database to ensure that every new piece of information is uniquely linked to the sending participant (Lenz, 2019).
- **Consensus mechanism.** DLTs have an algorithm whose role is to ensure that information is only recorded once in the base to prevent duplication of records (Lenz, 2019).
- **Shared/Decentralized record keeping.** Multiple parties can collectively create, maintain and update the shared ledger (Rauchs et al., 2018). The shared result of the reconciliation/consensus process i.e. the 'ledger' serves as the authoritative version for these records.

2.6. Blockchain

The most prominent implementation of DLT shared over a network is blockchain. It is a type of distributed ledger which is composed of digitally recorded data arranged as a successively growing chain of blocks with each block cryptographically linked and hardened against tampering and revision (ITU-T, 2019).

A blockchain is a data structure which consists of an ordered list of blocks, with each block containing a list of transactions. The blocks of data are linked to each other, where each block is 'chained' to the previous block as it carries a hash representation of the previous block. The data (set of blocks) is managed redundantly in a distributed network. (Lenz, 2019; Xu et al., 2017).

The financial services industry was revolutionized by Bitcoin. Bitcoin is the most used DLT based system, using public Blockchain infrastructure. It is very controversial as it helped enable a multi-billion dollar industry of anonymous transactions that lacked any government control (Crosby et al., 2016). Ethereum is another popular cryptocurrency that is described as a Blockchain with a built-in Turing-complete programming language, allowing anyone to write smart contracts and decentralized applications where they can create their own arbitrary rules for ownership, transaction formats and state transition functions. (Buterin, 2013).

2.7. Conceptual Framework

Figure 2 below details the key variables in the research study.

2.8. Conceptual Model

The proposed approach comprises a decentralized distributed system that uses a

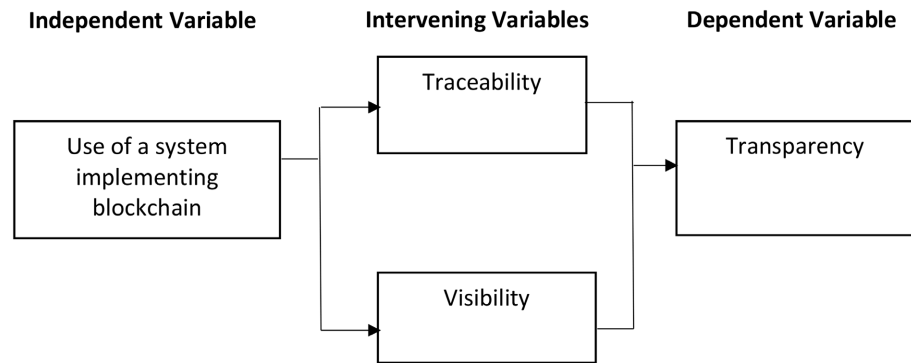


Figure 2. Conceptual framework.

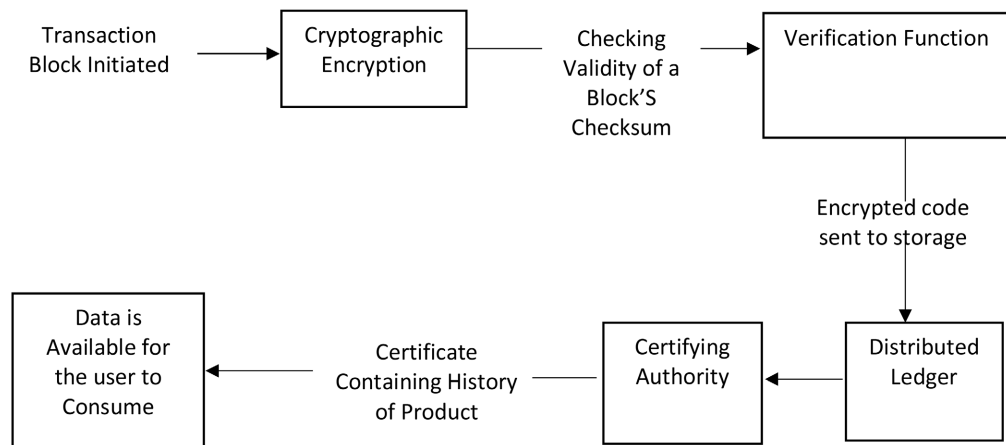


Figure 3. Conceptual model outlining the components.

private permission less blockchain to collect, store and manage key product information of each product throughout its life cycle. This will create a secure, shared trail of data for each product as well as specific product information. As displayed in **Figure 3**, the proposed tool should contain the following components; the distributed ledger, cryptographic encryption, verification function, and the certifying authority.

The distributed ledger is the base storage and will contain the encrypted transaction blocks. Cryptographic encryption generates an encrypted key based on a transaction and will continue to build on previous transactional blocks. The block and its encrypted data are sent to the ledger and shared across nodes. The verification function ensures validity of a blocks checksum to confirm that the transaction chain has not been broken. A certificate should be issued by the certifying authority on completion of the process, which can confirm the chain of history of transactions on the block. This certificate should contain the checksums, key and the product details.

3. Methodology

3.1. Software Development Methodology

Agile software development methodology as illustrated in **Figure 4** was used as

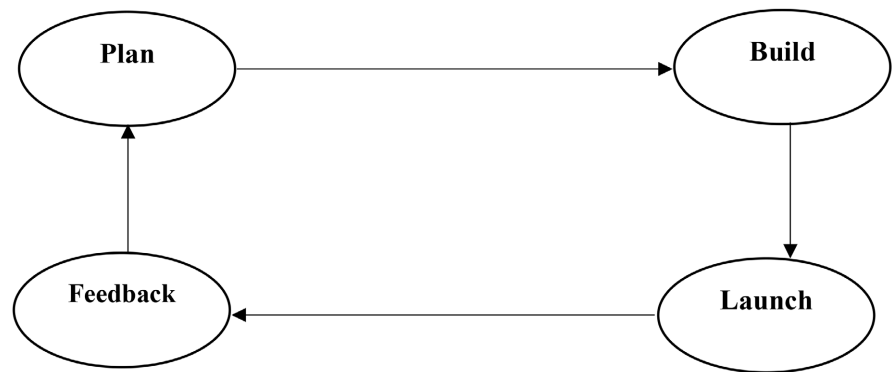


Figure 4. Agile software development methodology.

it allows software to be developed in iterations and gain feedback, as the development process is ongoing. This agile process was composed of one-month sprints (iterations). In these iterations, the researcher was involved in generating user requirements, building software, releasing the software to the end user, getting interactions with the end user, gaining feedback and implementing that feedback.

The system is built using python programming language on the Django framework which offers high scalability and a fast-prototyping environment. MySQL database is used for information storage. Blockchain technology is used in encryption and verification and a hyper ledger used for transaction storage.

The additions to the system were the following components; the distributed ledger, cryptographic encryption, verification function, and the certifying authority. Cryptographic encryption generates an encrypted key based on a transaction and will continue to build on previous transactional blocks. The encryption function is triggered by users moving a product through the supply chain. The verification function ensures validity of a blocks checksum to confirm that the transaction chain has not been broken. The verified block and its encrypted data are sent to the ledger and shared across nodes. The distributed ledger is the base storage and contains the encrypted transaction blocks.

Unit tests, integration tests and user acceptance tests were carried out with the systems users to ensure that the system met the required expectations and that it was working well.

3.2. Research Design

In this study, the researcher used exploratory research design with a leaning towards using the analysis of ‘insight-stimulating’ examples. A prototype was also designed and developed; the prototype was later evaluated in order to evaluate whether the afore-stated objectives had been met. To test the prototype, the researcher used the single case study methodology with the group selected in the case study being the organization SOKO Inc. SOKO was ideal for this situation because the organization has an internal supply chain and for manufacturing, works with artisans who make jewelry and are distributed all over Nairobi.

The researcher used SOKO Inc., as a focus firm, an organization that works as an aggregator of artisans. This organization was selected as it is representative of the typical scene in the distributed manufacturing sector. Also, it is convenient to the researcher since the researcher has an established relationship with the organization and the artisans.

3.3. Data Gathering

The organization has access to a network of over 2000 artisans with more than 250 workshops spread all over Nairobi, mostly in Kibera, Dandora and Rongai areas. SOKO also has 80 employees in the Kenya office. The sampling methods used in this study were purposive and convenience-based sampling. Only artisans who were actively working with SOKO over the last year participated. **Table 1** below describes the numbers of the total population and the sampled population. The total target population was 187 and a sample of 48 was selected. This was slightly above 20 percent of the target population hence was considered adequate for the study.

Two rounds of data collection took place, in March 2020 and May 2020. The first round involved observation and in person interviews with the respondents to capture information on the usage of the technology that was already existing. This first round of data was used to inform the development of software. During the second round of data collection, phone interviews were incorporated, in addition to the methods used during the first round. This was due to the Covid 19 pandemic, which hindered the movement of the researcher.

The researcher used the content analysis method and was looking to find any patterns and themes that would emerge. Predetermined themes based on the research objectives were; traceability, visibility, transparency and how they were achieved as each iteration went by data. Axial coding was done in order to find relationships or connections within these patterns or themes.

4. Findings

4.1. Traceability

Traceability on the first round of data collection was given an average rating of 2.67, with the problems stated being that it took too long and it required opening

Table 1. Target population and sampling.

Area	Description	Total Population	Sampled Population
Kibera	Artisans	59	15
Rongai	Artisans	36	5
Dandora	Artisans	28	5
SOKO Office	Artisans	7	5
SOKO Office	SC Operators	54	16
SOKO Office	SC Management	3	2

so many pages. After viewing the changes added, the average rating for traceability awarded went up to 4.8. **Figure 5** below shows the spread of ratings during the second round.

The study established that 75% of artisans were interested in information regarding the quality of their product, even after they had been paid for it. However, due to the lack of technology that could be tagged to a specific product and follow it through its lifecycle, this was not possible.

4.2. Visibility

Results on visibility revealed that 61.9% of the artisans interviewed in the first round of data collection indicated that they would like more visibility into SOKO processes e.g. SOKO's customers and where they are from and how SOKO arrives at product pricing. For the study, the name and country of origin were added to the app. Due to SOKO's business reasons, pricing was not addressed during this study. 86% of the artisans were happy to see this information.

Within the supply chain, visibility of the solution was rated at 4.3 with the lowest rating being a 3. This was after a single page that contains all the chains, blocks and the index of the transactions was created and made accessible to all. **Figure 6** below shows the spread of ratings.

4.3. Transparency

The study sought to establish whether the system could be able to deliver transparency. The results as presented in **Figure 7** below shows how the respondents rated transparency on the system, during the second round of data collection. On a scale of 1 - 5 where 1 is poor and 5 is excellent, an average rating of 4.5 was given. 55% of the respondents gave a rating of 5 and the other 45% rated it at a 4.

Concerning production **Figure 8** below reveals that 66.7 % of the artisans interviewed in the first round indicated that they were interested in the SOKO's customer. After the information was added, 88.5% of the respondents were happy to

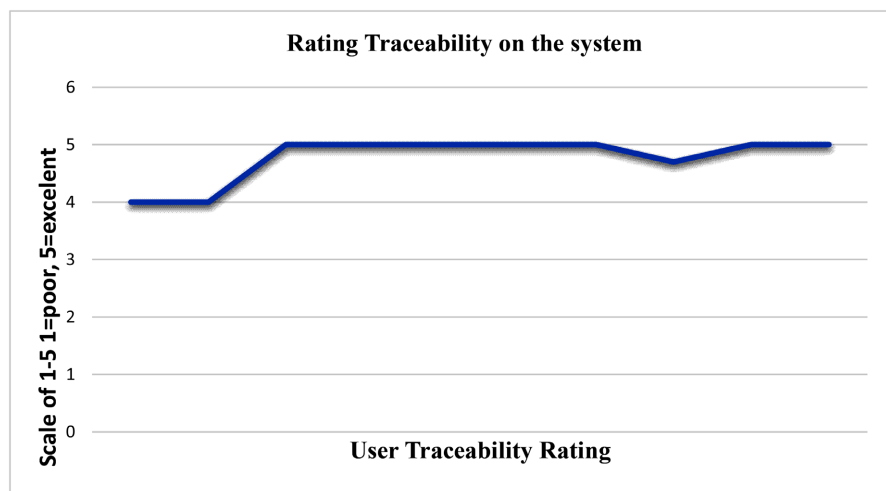


Figure 5. System traceability rating.

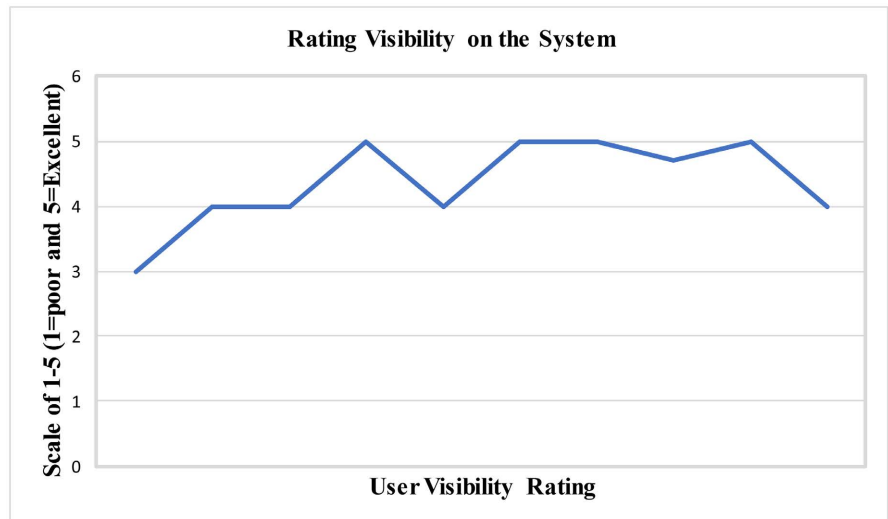


Figure 6. System visibility rating.

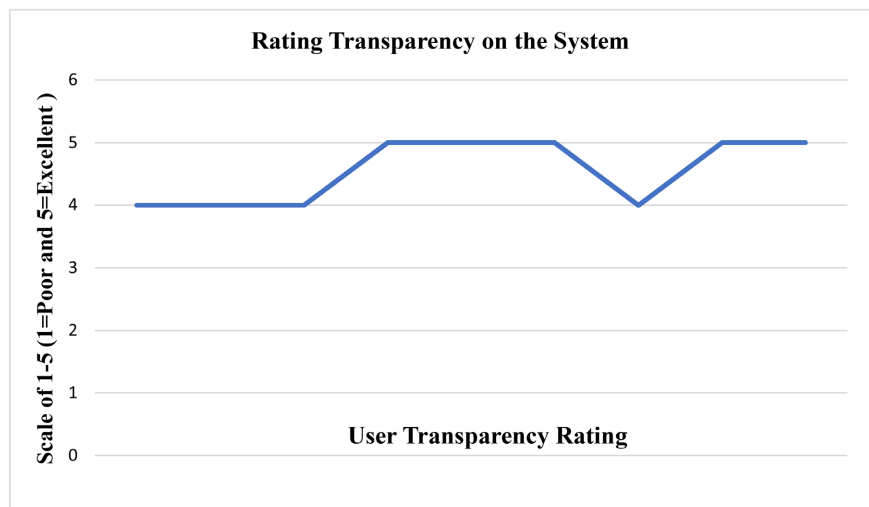


Figure 7. Transparency rating of the system.

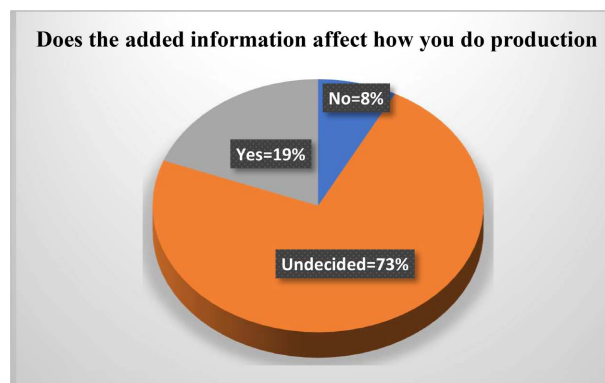


Figure 8. The effect of having additional customer Information on artisans.

see the information, and the other 11.5% were undecided. Interestingly though as shown in Figure 9 below, only 19% of the respondents admitted that the added

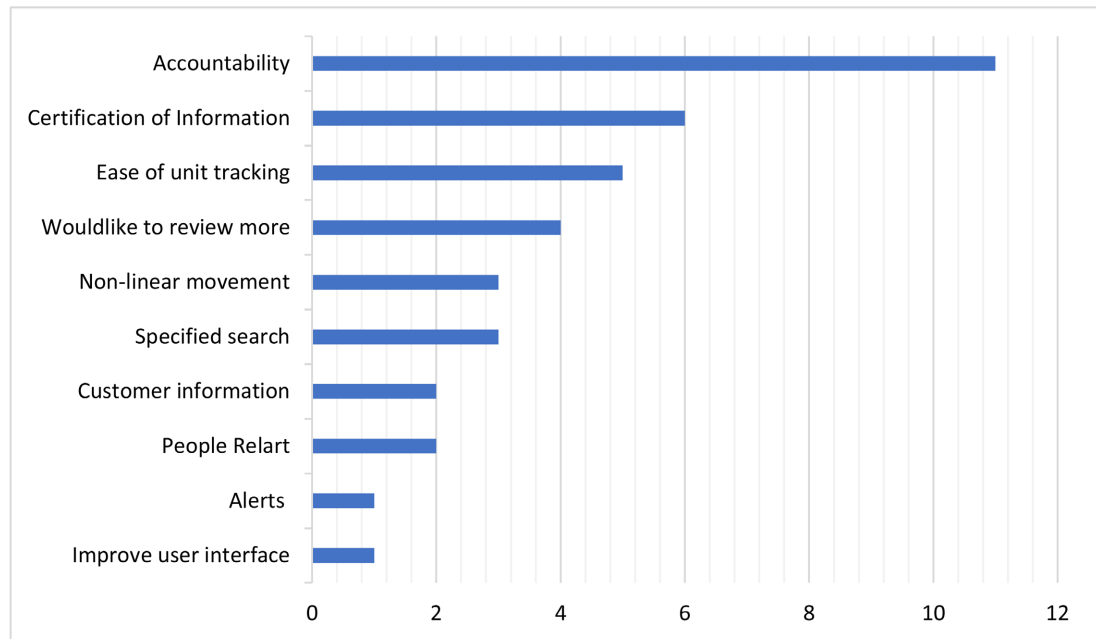


Figure 9. Results from axial coding in the 2nd round of data collection.

knowledge would affect how they did production. The other 81% indicated that they would continue production as usual since they put in the same amount of care in their work, despite the customer.

4.4. Accountability

This was a theme that came by surprise. It was especially apparent in the SOKO internal operations, once the blockchain system was implemented. As shown in **Figure 9**, out of the 37 tags of appearing themes, accountability and ownership appeared 11 times in the SOKO employees.

5. Conclusion

By setting up a secure, reliable, and immutable log of transactions and information that provided traceability and visibility, the study's main objective of addressing the lack of transparency in informal distributed manufacturing was tackled. To capture security, reliability, and immutability, blockchain technology was the DLT technology used. As stipulated earlier in the literature review, blockchain provides immutability and proof of origin by hashing and timestamping each transaction. These features provided much-needed traceability and visibility. The use of SOKO as the case study gave the researcher an opportunity to view firsthand the challenges faced before and the results after adding blockchain technology into the ecosystem.

From the research findings, it was clear that traceability and visibility are key to building transparency and accountability within the distributed manufacturing ecosystem. While the SOKO artisans were independent entities, they were still interested in the information about their customers SOKO. Increased visibility

and transparency create trust between both parties. Operators within the supply chain were able to retrieve information that they previously did not have access to and they were able to do this faster. Due to the improved access to secure and reliable information, individuals and departments within the supply chain can now hold each other accountable for the organization's operations and goals. It will be interesting to see the long-term effects of the provision of transparency within this sector.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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