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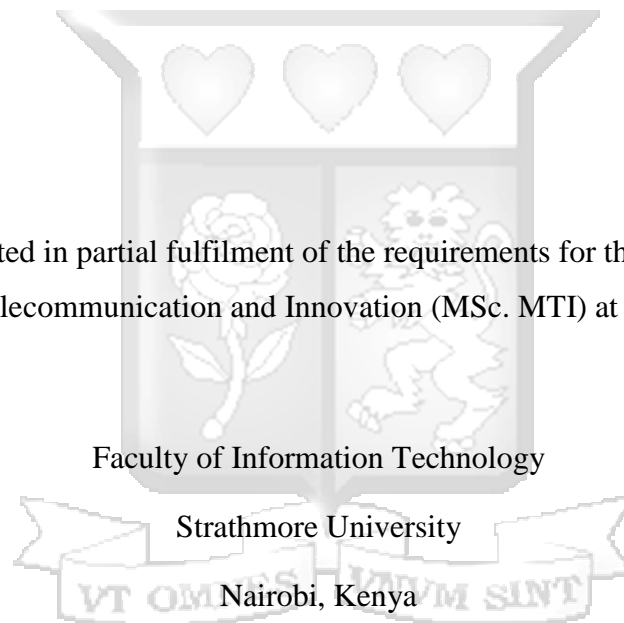
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**A MOBILE APPLICATION FOR TRACKING AND VERIFICATION OF COBALT
ORES IN ARTISANAL MINES: A CASE STUDY OF DEMOCRATIC REPUBLIC OF
CONGO**

Destin Nsarhaza Kakira

A Dissertation submitted in partial fulfilment of the requirements for the Degree of Masters of
Science in Mobile Telecommunication and Innovation (MSc. MTI) at Strathmore University



Faculty of Information Technology

Strathmore University

Nairobi, Kenya

June, 2018

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Destin Nsarhaza Kakira

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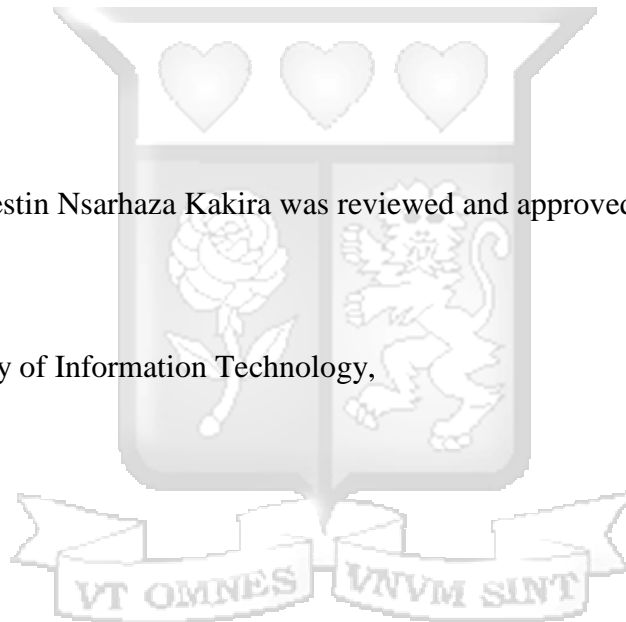
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Dedication

To my Father for all his love and support and putting me through the best education possible. I appreciate his sacrifice and I would not have been able to get to this stage without him.



Acknowledgements

I would like to acknowledge the Almighty God for granting me the opportunity to pursue this Master's program. A special gratitude to my supervisor Dr Vitalis Ozianyi for his guidance and assiduous support. I would like to recognise the contribution of my family members particularly Pacific Baderhehuguma and Divine Nsarhaza for their incessant support and encouragement.



Abstract

Tracking and verification of Cobalt in artisanal mines is enormously challenging in the Democratic Republic of Congo. Several artisanal mining companies have been disseminated throughout the country, some of these companies are involved in illegal exports and branding of Cobalt ores. Consequently, these unlawful activities are leaching a fifth of all Cobalt revenue away from the state budget. It is estimated that between 2013 and 2016, over \$1.3 billion of payment by mining companies to Congo's tax agencies never reached the national treasury.

This research used an online questionnaire that was distributed to 95 mine inspectors and mining officers to give a comprehensive study of characteristics of a licit Cobalt ores bag, methods and technology currently used to track and verify Cobalt ores bags and how a mobile application for tracking and verification of Cobalt bags can be designed, developed and tested. Google analytics tools were used to collect data from respondents. The results were used to attain the system requirements and design of an Android application for tracking and verification of Cobalt ores in artisanal mines. Agile software development methodology was used because it allows iteration and gets the user involved in the entire process of development. The Android application was integrated with a back-end application which gives a synopsis of Cobalt ores bags legally extracted and vetted artisanal mines. Testing and validation was done on the final prototype by the potential users of the application. Mine inspectors, mining officers and ultimately the government tax collector agencies stand to gain by using the mobile application to ensure that a Cobalt ores bag has been extracted from a vetted artisanal mine. It allows the government to maximise the revenue from tax on Cobalt extracted from artisanal mines and minimise significantly the illegal exports and rebranding of Cobalt ores in artisanal mining sector.

The proposed system achieved imposing results in terms of functionalities. Respondents stated that the system solved the problem related to tracking and verification of Cobalt ores in artisanal mines. 100 % of respondents were able to scan or generate the QR code. It crucial to note that if the system is adopted by the government through the Ministry of mines, illegal exportation and branding of Cobalt ores can be significantly reduced.

Keywords: Android, Verification, Cobalt, Tracking.

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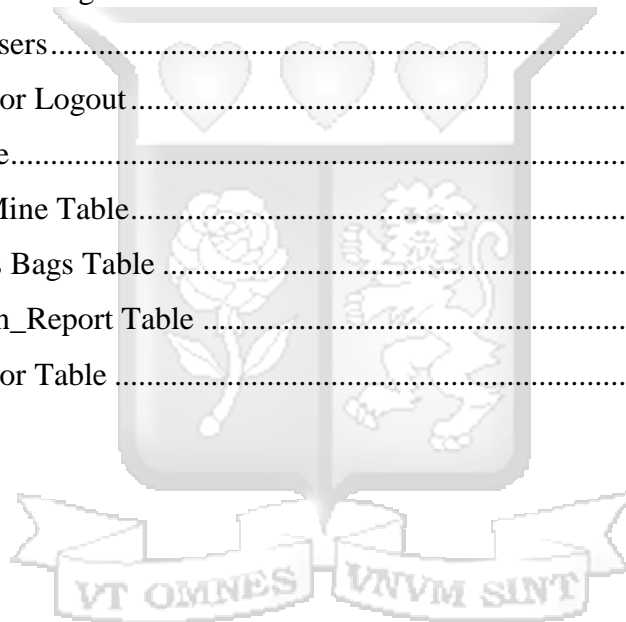
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List of Abbreviations/Acronyms

- ASM - Artisanal and Small-Scale Mining
- DRC - Democratic Republic of Congo
- GDP - Gross domestic product
- ICGLR - International Conference on the Great Lakes Region
- ISS - International Slab Sales
- NGO - Non-governmental Organisation
- OECD - Organization for Economic Cooperation and Development
- QR Code - Quick Response Code
- SADC - Southern African Development Community



CHAPTER 1: INTRODUCTION

1.1 Background of the Study

The Democratic Republic of Congo (DRC) is endowed with remarkable Cobalt reserves. Over the past few decades Cobalt which initially was mined as a by-product of Copper has become a highly demanded mineral. Cobalt is an essential mineral used in high-performing lithium-ion batteries, laptops, smartphones and hybrid cars (Frankel, 2016). Statistics on Cobalt production are particularly difficult to obtain, it is estimated about 8,000 metric tonnes per annum, with a total export value of \$48 million. However, a significant quantity produced in artisanal mines is illegally procured and transported from the DRC to Rwanda. Cobalt ores extracted from unregistered mining companies are subsequently smuggled out of the country. These practices lead to revenue loss through unregistered, untracked and therefore untaxed Cobalt ores movements. The two methods generally used by artisanal miners to export illicit Cobalt ores are smuggling and false declaration (James, Herman & Howe, 2006). Smuggling and false declaration of Cobalt ores in the Democratic Republic of Congo distort trade statistics and are economically and financially harmful to the country. The illicit exports of Cobalt deprives the DRC of the developmental value of Cobalt resources due to diminished revenues (Smillie, 2005).

A Research conducted by the ISS in Zambia during 2010 found that the mining sector was affected by theft, corrupt business practices, tax evasion and smuggling. Tax evasion and corrupt practices occur at all levels, informal to large-scale, of the mining sector. In recent years, some SADC countries have been seriously affected by predatory activities in the mining sector, with DRC being a particularly ravaged territory (Huebschle, 2010), especially in the precious metal and Cobalt sectors. While large mining companies employ highly complex and often opaque mining production systems that create a formidable challenge to revenue collectors, numerous other small-scale mining producers occupy a sector replete with unregistered and informal operators. Clandestine activities prejudicial to tax collection also occur in the artisanal and small-scale sector. Trade in illicitly acquired minerals by registered and unregistered groups continues to cause costly fiscal challenges in the Democratic Republic of Congo.

This research focuses on tracking and verification of Cobalt extracted from artisanal mines. Artisanal mining and small-scale mining (ASM) grew significantly in Democratic Republic of Congo since 1990s. There are approximately 11,000 to 15,000 artisanal mines South-Kivu which operate alongside much larger industrial operators. It is difficult to estimate the extent to which artisanal miners supply Cobalt chain due to the small scale and unregulated nature of artisanal mining (Perks, 2011). Therefore, there is clearly a need for a significant formalisation of artisanal mining sector in the Democratic Republic of Congo.

Tracking and verification of Cobalt mineral extracted from artisanal mines is beneficially important as it contribute to the original resource of Cobalt used by large business around the world (Louise & Mistry, 2012). Verification in this particular context means that mine inspectors should be able to verify whether the Cobalt ores were legally extracted from a vetted artisanal mine, while tracking means that mining officers should be able to track the Cobalt ores from extraction site to the smelting site. The mine inspectors use the mobile application to scan the QR code which should provide them with all the information about the Cobalt ores bag.

1.2 Problem Statement

Cobalt mining in Democratic Republic of Congo (DRC) has been extremely rowdy and inefficient. It is characterised by illegal exports, rebranding of Cobalt ores bags and uncertified extraction of Cobalt ores. Artisanal miners in DRC are prone to corruption and violence since Cobalt mined by artisans is often a conduit through which armed groups are financed. This inevitably leads to exploitation of mining communities and loss of revenue for government when Cobalt is smuggled. The application can enable the government and actors involved in artisanal mining activities to track and verify Cobalt ores bags from the production site to the smelting site.

1.3 Research Objectives

- i. To analyse the Characteristics of a licit Cobalt ores bag in artisanal mining sector.
- ii. To analyse the technologies currently used to support tracking and verification of Cobalt ores in artisanal mining sector.
- iii. To investigate how tracking and verification of Cobalt ores is currently done in artisanal mining sector.

- iv. To design, develop and test a mobile application for tracking and verification of Cobalt ores in artisanal mining sector.
- v. To validate the efficacy of the mobile application for tracking and verification of Cobalt ores in artisanal mining sector.

1.4 Research Questions

- i. What are the characteristics of a licit Cobalt ores bag?
- ii. Which technologies are available to support tracking and verification of Cobalt ores in artisanal mining sector?
- iii. How is tracking and verification of Cobalt ores currently done in artisanal mining sector?
- iv. How can a new system be designed, developed and tested?
- v. Does the system address tracking and verification of Cobalt ores issue through the proposed solution?

1.5 Justification of the Study

The study should be handy to mine inspectors and mining officers. Mine inspectors would use the application by scanning the QR code to verify if Cobalt ores were extracted from a vetted artisanal mine. The QR code generator would be helpful when it comes to track Cobalt ores bags. The mining officer from Ministry of mines would use the backend dashboard to store artisanal mines and Cobalt bags details in the database which will substantially reduce smuggling and illegal exports of Cobalt and help the government to generate more revenue from royalties and taxes.

1.6 Scope of the Study

QR code technology was used in this research to develop a mobile application for tracking and verification of Cobalt ores in artisanal mines. The institution selected for the purpose of this research is the Ministry of mines of the Democratic Republic of Congo. Since most of the mine inspectors and mining officers use Android smartphones, the mobile application was designed to run on Android platform.

1.7 Limitations of the Study

Internet connection must be accessible for the mine inspectors to get the Cobalt ores bags details after scanning the QR code. The mobile application will be deployed on Android phones, therefore users using phones running on other platforms are left out.

1.8 Summary

This research focuses on developing an Android application for tracking and verification of Cobalt ores in artisanal mines. Cobalt mining in artisanal mines is an important source of revenue for artisanal mineworkers in the Democratic Republic of Congo. Nevertheless, Cobalt mining needs to be monitored to avoid illegal exports and smuggling. In the next chapter, a review was carried out on what other researchers have done to help deal with the issues that occur in the process of tracking and verification of Cobalt ores.



CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter begins by covering what has already been done by other researchers. The subjects discussed include an overview of existing mineral management mechanisms, a review of characteristics of a licit Cobalt ores bag, methods currently used in tracking and verification of Cobalt ores and technologies available to carry out tracking and verification of Cobalt ores. Finally, it gives a review of QR technology.

2.2 Overview of Existing Mineral Management Mechanisms

Regulation of the mining sector in SADC may be broken up into regulation of the large-scale industrialised, the semi-industrialized and the formal and informal small-scale sectors. In some countries such as Malawi and the Democratic Republic of Congo, informal, small-scale sectors preponderant. In all countries, all mining sectors are required by law to be licensed, but degrees of acquiescence are unequal (Dreschler, 2002). The main purpose of the licensing regime for small-scale miners is to be facilitative, to enable the licensees to access mining sites, mine in a safe and environmentally comprehensive manner and to market their output.

A study on organised crime in SADC revealed that mineral output from the informal sector is sold to intermediaries within the country, at the origin or across the border. Smuggling of unprocessed minerals affects most countries, facilitated by porous frontiers and encouraged by the incentives offered by the intermediaries. Disposal of minerals to networks of Nigerian and Lebanese buyers is common in Mozambique, as is the smuggling of gold from the DRC and Zimbabwe into Zambia for export to Zurich. It is suspected that more than 90 per cent of the gemstones produced in Tanzania are smuggled out of the country (Hubschle, 2010). There are indications that licensing legislation does not prevent illicit practices in mining. Evidently, some illicit mining is conducted by persons holding work and investor permits corruptly obtained from immigration departments (Hubschle, 2010). Even more insidious is exploitation by traditional leaders, including chiefs who purchase or lease mineral-bearing plots of land. Such transactions occur without the involvement of the relevant minerals departments.

The trading chain along which tanzanite passes from the major sources such as the Merani area in Tanzania prior to its export involves three phases. The gems are first sold to a broker at the point of extraction. The broker then carries the tanzanite to a long-distance broker who in turn sells it to a branch office in town from where the tanzanite is exported. The semi-industrialized or medium-level mining sector is better regulated than the informal sector for such factors as capital investment and labour regulations. However, this does not insulate it from criminal activities. The diamond, copper and cobalt sectors have proved attractive to unscrupulous dealers in various parts of the region.

2.3 Characteristics of a Licit Cobalt ores Bag

A licit Cobalt ores bag can be identified by the artisanal mine approval number which represent the mine where the Cobalt ores were extracted , the Cobalt bag serial number, weight, smelting place, transportation method and in some case the buyer.

2.3.1 Artisanal Mine Approval Number

In artisanal mining industry only vetted artisanal mine are allowed to extract and process Cobalt ores. The artisanal miner is given a certificate which holds the approval number and the operating sector (Lasker, 2015).

2.3.2 Cobalt ores Bag Serial Number

Under the guidance of the Congolese authorities and with assistance from foreign NGO, the artisanal miners bag and tag their Cobalt ores in a large clear and sealed plastic bag. The Cobalt ores bag bears the name of the vetted artisanal mine and a barcode which hold the Cobalt ores bag serial number (Lasker, 2015).

2.3.3 Weight

Artisanal miners bag and tag Cobalt ores in a clear plastic bag with a tag on it. To determine the net content of a plastic bag, the artisanal miner look for the tare weight which is the weight of the plastic bag, then he deducts the tare weight from the weight of the Cobalt ores bag. The weight varies depending on each artisanal mine.

2.4 Methods Currently used in Tracking and Verification of Cobalt ores

The Regional Initiative against the Illegal Exploitation and export of the Natural Resources, also known as the Protocol against the Illegal Exploitation of the Natural Resources, was adopted by the ICGLR members at the Lusaka Conference on 15 December 2010. The main aim of the Lusaka Declaration was to develop a joint, regional approach to stop the illegal exploitation and export of natural resources in the Great Lakes Region.

2.4.1 Regional Certification Mechanism

The Certification Mechanism enables the custody chain tracking of four minerals (cassiterite, wolframite, Cobalt and gold) to prevent the mining and trading of conflict minerals. An independent mineral chain auditor supervises the mechanism. This is one of the tools used by ICGLR to fight against the illegal exploitation and export of natural resources. The Regional Certification Mechanism ensures that neither mine site nor channels of trade within the country as well the region are in predatory control of armed groups or criminal networks. The mechanism is supervised by an independent mineral chain auditor (Blore & Ian, 2011).

2.4.2 Mine Site Inspection and Certification

The ICGLR Mine Site Inspection and Certification Standards are designed to ensure that Designated Minerals are sourced only from mine sites that are conflict free and meet minimum social standards (for example, no child labour). Mine sites inspection is conducted annually by a government inspector as required by the ICGLR scheme. These government inspections are cross-checked by annual Independent Third Party Audits carried out by an ICGLR accredited auditor. On-going risk assessment of mine sites is provided by the office of the ICGLR Mineral Chain Auditor standards (Blore & Ian, 2011).

Artisanal mines are classified in three categories, Certified Green Flagged, the artisanal mine meets all standards, no conflict, no child labour and it can produce minerals for certified export. Yellow Flagged means infractions of one or more important criteria, in this case the mine operator has six months to resolve the problem and can still produce minerals for certified export.

Un-certified Red Flagged represents grave infractions of one or more critical criteria, the artisanal mine is prohibited from producing minerals for a minimum of six months and it remains Red Flagged until a further inspection shows the infractions to have been resolved.

2.4.3 Chain of Custody Tracking Within Member States

The ICGLR Chain of Custody Tracking Standards are designed to ensure that Designated Minerals are fully traceable and conflict-free from the mine site to the point of export. Member State governments are responsible for implementing and supervising the chain of custody tracking system within their own borders. The integrity of Member States' chain of custody systems are verified annually via ICGLR Third Party Audits. Mineral flows are tracked and analysed via an ICGLR Regional Database using the data on individual shipments collected and transmitted to the ICGLR by each Member States' Chain of Custody system. Member States can have more than one type of chain of custody tracking system in operation for different minerals, or different regions (Atanasijevic, 2016).

2.4.4 Export and Certification Procedures

The ICGLR Certificate serves as the assurance to purchasers that a mineral shipment is conflict free, and meets all other ICGLR standards. Member State governments must examine each export of Designated Material, including all the supporting documentation concerning the chain of custody and mine of origin, before issuing a Certificate (Atanasijevic, 2016).

2.5 Technologies Available to Carry out Tracking and Verification of Cobalt ores

Tracking of Regional Mineral Flows via a public ICGLR Database is one of the main pillars of the ICGLR Certification scheme. Tracking and reconciling mineral flows within and between Member States assures all stakeholders (Member State governments, local and international NGOs, private sector end users and others) of the integrity of certified mineral flows from the region (Smith, 2017).

2.5.1 Regional Mineral Tracking Database Unit

The ICGLR Regional Database on mineral flows is the repository of data first generated and stored at the Member State level. Member States collect mineral data from their respective mineral supply chains and store it in national databases.

The data are then transferred up to populate the Regional Database on a regular basis. The ICGLR adopted a model where the unique data format for all the Member States is set by the ICGLR Secretariat in order to facilitate data transfers (Rutherford, 2017). The Regional Database consists of three sub-databases, a regional mine site database, a regional mineral tracking database and a regional mineral exporters database.

The Regional Mine Sites Database

Each Member State constitutes its own mining sites database for mine sites which produce designated minerals within its territory. The database records the identity information of the mine site (identity number, location, etc.) and the status of the mine site (certified, uncertified, yellow side). Regular inspections by Member State inspectors establish and verify the status of each mine site. Inspections of the Member States are subject to crosschecks and checks during third party audits and are supported by risk assessments conducted by the Independent Mineral Chain Auditor. The mine site database in Member States is linked to the ICGLR Regional mining site database and associated protocols on periodic updates to ensure that the information on the situation are held up to date at both national and regional level.

The Regional Mineral Tracking Database

The mineral tracking database is the most complicated of the three sub-databases making up the Regional Database. The Regional Certification Mechanism requires that certified mineral supply chains have in place a traceability system capable of tracking mine site lots, negotiant lots and exporter lots, thus tracking mineral flows from mine site to point of export. The Regional Mineral Tracking Database stores and analyses the data generated by the various traceability systems established in the region to track these certified mineral supply chains.

The Regional Mineral Exporters' Database

The Regional Mineral Exporters' Database is used to record information about all the mineral exporters in each of the Member States, including their location, ownership and status. Under the standards of the Regional Certification Mechanism each exporter must be audited once per year by an accredited third party auditor. The database of exporters keeps a record of the audits, including a copy of the audit report in PDF and Microsoft Word format that can be viewed or downloaded by users.

2.5.2 Bar Codes

According to the Tin Supply Chain Initiative, the bar code allows them to track Cobalt ores' weight, the date of extraction, initial and subsequent buyers, transportation method and routes, and finally the place where the minerals were processed.

However, the challenge in terms of tracking Cobalt ores is that much of it is smuggled out of the country by militias and sold to middlemen who ship it to smelters. Fraudulent tags keep reaching certified smelters and people create their own tags with the same barcode number. Militias circumvent the bag and tag program and it was discovered that copycat or fake duplicates of the tags were circulating through the eastern DRC and Rwanda (Harrison & Marie, 2010).

2.6 QR Code Technology

A Quick Response (QR) code is a matrix barcode readable by smart phones and mobile phones with cameras. They are sometimes referred to as 2d codes, 2d barcodes, or mobile codes. The QR code typically appears as a small white square with black geometric shapes, though coloured and even branded QR codes are now being used. QR codes can hold much more information than a regular barcode. The information encoded in a QR code can be a URL, a phone number, an SMS message, a V-card, or any text. They are referred to as QR because they allow the contents to be decoded at high speed (Tan, 2008).

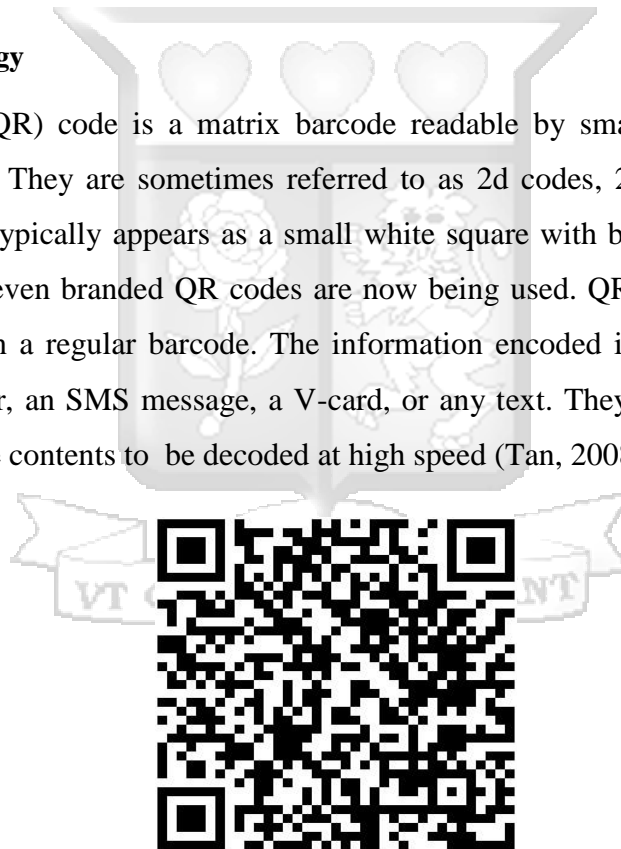


Figure 2.1 QR Code (Fleishman, 2017)

2.6.1 Implementing QR Codes on Mobile

There are several ways to implement QR code on mobile, the preeminent approach is to use a library that is already built and integrate it into the application.

Generation and Scanning of QR code

When provided a message string, the encoder changes the message into a byte string embedded with general QR code header information, error correction bytes and a masking element. The modified byte string is then changed to a 2-dimensional matrix of 1's (white) and zeroes (black) which can be transformed into an image. When this image is scanned by a phone camera, the byte string is recovered and converted to the intended message, viewable by the person who initiated the scan (Qiao & Brackins, 2017).

Figure 2.2 gives a description of the regular process of generating a QR code from a provided message and scanning the code with a smart phone.

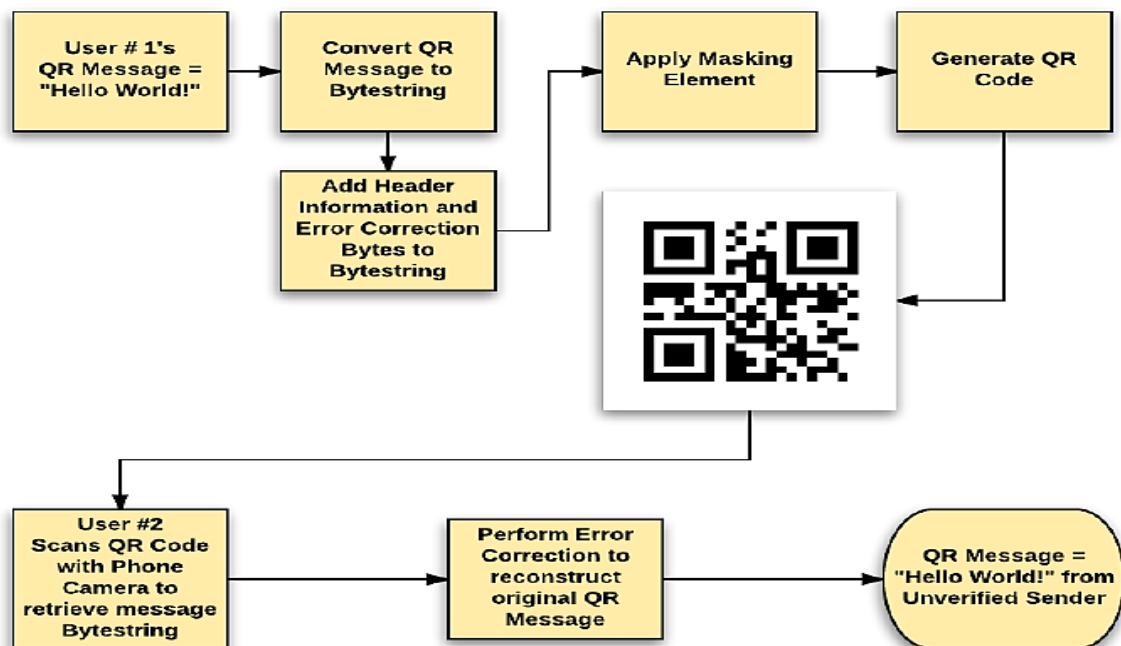


Figure 2.2 Generation and Scanning of a QR code (Qiao & Brackins, 2017)

2.6.2 QR Code Benefits

Users do not need special knowledge for using QR code, only required smart phones like iPhone, Android phone with QR code scanner. The speed of decoding the QR code can be made 20 times faster than that of other matrix symbols. QR codes are cost effective. By making the relationship between the character type and the saved data peculiar for special use, QR Code can be easily encrypted. With the use of web analytics and peculiar codes for various placements, marketers can get some valuable facts about how well campaigns are going, as well what works and what does not. To correct distortion in symbols, QR Code has alignment patterns arranged at a regular interval within the range of the symbol that make the distorted symbols readable (Isaac, 2015).

QR Code has a linking functionality which enables one symbol to be represented in several symbols by dividing it. This allows the entire information to be edited and submitted to the computer regardless of what order the symbols had been read by the reader (Peng, 2014).

2.7 Gaps and Limitations

The readability of barcodes is determined by how well a barcode reader can decode the data stored in the symbol. It can be impacted by a number of technical and environmental factors which are temperature, low contrast, quiet zone violations and mark inconsistency. In case of any distortion or damage, the code becomes permanently unreadable (Luke, 2004).

Currently, there is no system for tracking and verification of Cobalt ores in the Democratic Republic of Congo. To fill the gaps and limitations that exist in the process of tracking and verification of Cobalt ores, this research takes advantage of online verification and QR code technology to improve the process of tracking and verification of Cobalt ores in artisanal mining sector.

2.8 Summary

Previous researchers have used tagging and bagging methods to track and verify Cobalt ores bags. However, this study makes use of QR codes to achieve the same. The reason is that, QR code technology is more advantageous than any other technology previously discussed, smartphones and mobile phones with cameras can be used to read the codes. The next chapter explains the methodology that was used in this research.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodology which was used for conducting this research with the purpose of answering the research questions. Agile software development methodology was used in this study.

3.2 Agile Software Development Methodology

Agile model believes that every project needs to be handled differently and the existing methods need to be tailored to best suit the project requirements. In Agile, the tasks are divided to small time frames to deliver specific features for a release. It is people-focused communications-oriented, flexible, speedy, focuses on shortening timeframe and cost, reacts appropriately to expected and unexpected changes (Sonia & Amandeep, 2013).

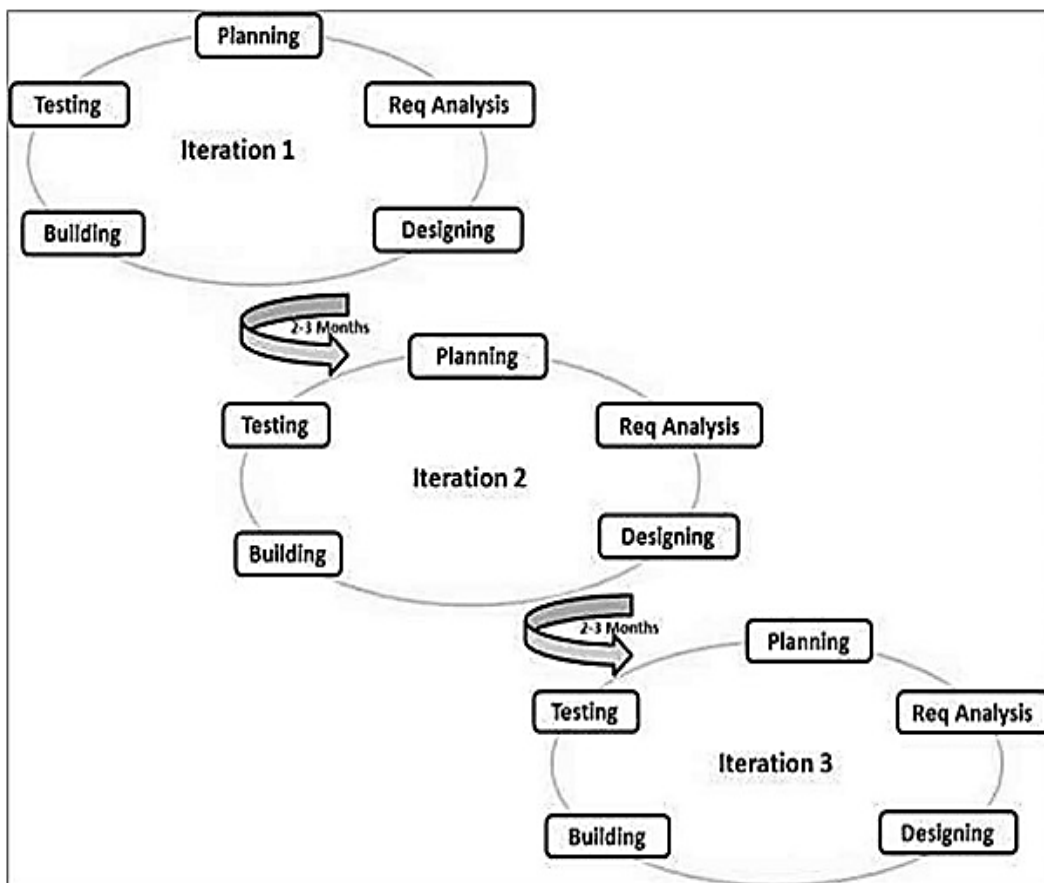


Figure 3.1 Agile Software Development Methodology (Steljes, 2012)

Agile methodology fit this research because it gives the ability to make and respond to change. Furthermore, users are involved in the entire development process. Figure 3.1 above illustrates the phases of Agile development methodology. These phases include planning, requirements analysis, design, implementation and testing.

3.2.1 Planning Phase

This is the first phase of Agile methodology in which planning of the entire process was tackled. Planning was used to determine the resources that were needed to build the system.

3.2.2 Requirements Analysis Phase

This phase consists of specifying what the system requires to meet users expectations (Brian, Daniel, Juergen & Arnold, 2009). This research used both primary and secondary sources of data as instruments of data collection, it used questionnaires, observation and document survey to collect data. It also made use of quantitative research using questionnaires and problem quantified using numerical data. 95 people who would prefer to use the new system or believe the new system is an innovative idea were identified in this regard. Google forms were used to distribute the user requirements questionnaire and reach a large population. Qualitative research was done using non-participant observation which was carried out to validate the data provided through questionnaires (Creswell, 2014). The purpose of qualitative research is to obtain a clear understanding of the problem that exists using sincere reporting, direct experience and quotations of real conversations (Neuman, 2003). It was used to get a clear understating of the current systems and processes of tracking and verification of Cobalt ores in artisanal minig. These methods were used because they provide accurate data which were convenient when trying to interpret the situation on the ground.

Target Population and Sampling

This research exclusively gathered its findings from South Kivu, in Democratic Republic Congo. According to the government's own estimation, 20% of Cobalt ores currently exported from Democratic Republic of Congo, come from southern part of the country. There are approximately 11000 to 15000 artisanal mines in the region which operate alongside much larger industrial operators.

In this research random sampling technique was used. The sample population was selected randomly among mine inspectors and mining officers assigned to each one of the artisanal mines. Equation 3.1 demonstrates the formulae applied to get the sample population so that every person would get an equivalent chance to be part of the sample population.

$$n = \frac{NZ^2 * 0.25}{[d^2 * (N - 1)] + (Z^2 * 0.25)}$$

n= Sample size

d = Precision level (mostly 0.10 or 0.5

N= Total population

Z = Statistic for level of confidence (for example, 1.96 for 95% confidence level)

n = 95.4353218

Data Collection Process

In this research primary and secondary data were used. Questionnaires were used to collect Primary data which helped to determine the user requirements. The advantage of using primary data is its originality and relevance to the research study, therefore the degree of accuracy is very high. Secondary data was collected from books in the library and online books which hold information from work of past researchers with the intent of finding the gaps that need to be filled. The advantage of using secondary data is its affordability, and it also provides a way to access the work of the best researchers all over the world.

Questionnaires

Questionnaires were prepared and distributed using Google document (Google docs), they were used to collect data from the target sample population regarding challenges faced in tracking and verification of Cobalt ores in artisanal mining . Furthermore, they were used to test whether the Android application developed met the required functionalities in tracking and verification of Cobalt ores.

Data Analysis

The researcher made use of Descriptive analysis. An online survey was done using a questionnaire which was sent and answered via email. Google analytics was used to analyse the data collected. The information was displayed using charts and graphs which provided a clear finding representation for interpretation and analysis of results. It was then used to draw conclusions with regards to whether the new system would resolve the current issues faced by mine inspectors and mining officers in the process of tracking and verification of Cobalt ores.

3.2.3 Designing Phase

When designing a system, different approaches can be used, it can either be object-oriented, data-oriented or process-oriented. In this study, the researcher used object-oriented because it combines both, processes and data into a single entity which is called object (Francoise, 2011).

Use Case Diagram

Use Cases were used to determine and classify the system actors and processes. The actors of the proposed system were mine inspectors and mining officers interacting to make the Cobalt ores tracking and verification system a success. The Use Case illustrates the influence the user has on the system (Bittner & Spence, 2003).

System Sequence Diagram

The System Sequence Diagram was used to show interaction of objects. It demonstrates the flow of events generated by an external actor, how those events follow each other and any other interaction with external systems (Gopal & Patil, 2011).

Entity Relationship Diagram (ERD)

The entity relation diagram was used to design the Database. It identifies different Entities and their attributes, the relationship between these entities with their cardinality.

Design Class Diagram

The Design Class diagram was used to illustrate the characteristics and functions of the system. The Design Class diagram is used to visually, describe the problem domain in terms of types of objects or classes related to each other in different ways (Chebanyuk & Markov, 2015).

3.2.4 Implementation Phase

The Android Application was developed using Zxing library and Java in xml to implement the QR code scanner. The Web backend dashboard used, PHP and Bootstrap Model. PHP was preferred because it is fast and platform independent (Samra, 2016), MySQL as used as the relational database management system. MySQL was preferred because it is open source and across platform. PHP QR Code library was used to develop the QR code generator in the backend dashboard.

3.2.5 Testing Phase and Validation

This phase involves ensuring that the system achieves its objectives. Different types of testing were done. Usability Testing was used to verify the usability of the developed mobile application. To achieve this, a total of 15 respondents were used, sampled to test the proposed solution and gave their feedback for any improvement. Functional Testing was used to ensure that everything was functioning properly on the entire system, that is, the application and the backend dashboard. The application was tested to see whether a component like QR code scanner was functioning and backend was tested to see whether a component like QR code generator was functioning correctly. To validate if the developed mobile application solved the issues faced in the artisanal mining industry, Alpha acceptance testing which checks if end user requirements are met and Beta acceptance testing checks which if the system works on different android phones were used (Hambling & Goethem, 2013).

3.3 Summary

This chapter has discussed the processes and methods that were used to come up with the mobile application for tracking and verification of Cobalt ores in artisanal mines. It described how the objectives were attained. The next chapter outlines the Requirements Analysis and System Design.

CHAPTER 4: REQUIREMENTS ANALYSIS AND SYSTEM DESIGN

4.1 Introduction

This section details the requirements analysis and the system desing. In the requirements analysis, findings that derive from the research that was carried out, are described. Responses from the online questionnaire were analysed using Google forms analysis tools. Graphs and Charts were used to depict the responses from respondents. Research questions were answered using the results from the data collected which provided the requirements needed to come up with the application.

4.2 Results from Requirements Questionnaire

The questionnaire were distributed to 95 respondents and all of them answered the questions which form 100 % rensponse rate. 15.7 % of these respondents formed the sample class that facilitated in later evaluations of the prototypes that led to the development of the final solution.

4.2.1 Respondent Job Position

From all the respondents of sampled target users, 44.2 % were mine inspectors and 55.8 % were mining officers.

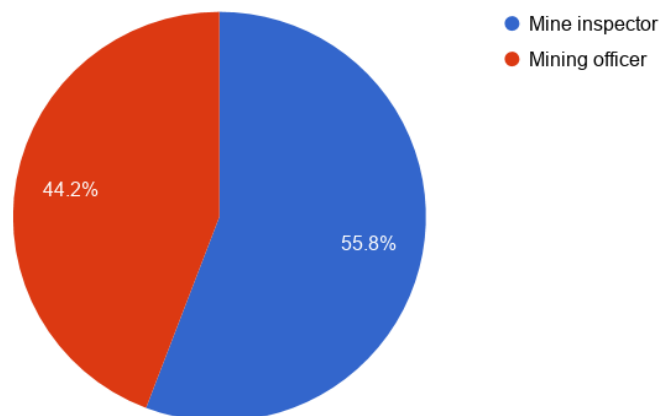


Figure 4.1 Respondents Job Position

4.2.2 Respondents Job Rotation Period

All Ministry of mines employees, mine inspectors and mining officers have to switch their work position after three, six or one year as required by the Ministry of mines policy. From all the responses of sampled target users, 24.2 % switch their work position every three months, 30.5 % every six months and 45.3 % after 1 year as shown on Figure 4.2.

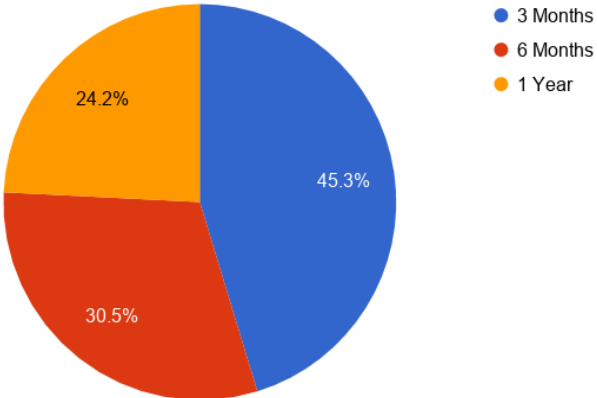


Figure 4.2 Respondents Job Rotation Period

4.2.3 Mobile Phone Ownership

Mobile phone ownership was an important aspect of the proposed solution, which focused on users of Android enabled phones. From the respondents, 98.9 % own a mobile phone as shown on Figure 4.3.

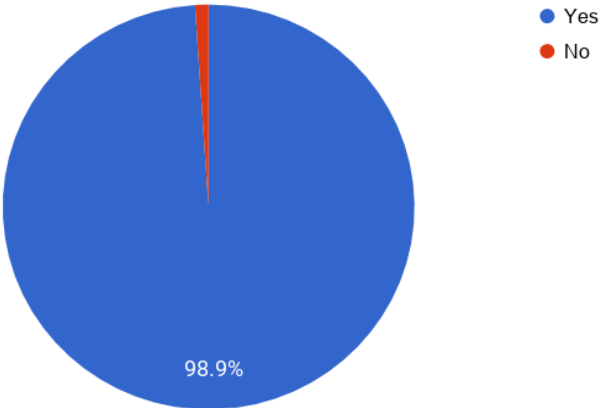


Figure 4.3 Mobile Phone Ownership

4.2.4 Operating System of Respondent's Mobile Phones

Results from the questionnaire demonstrate that 84.2 % respondents own Android phones whereas 15.8 % own iPhone, Blackberry and Windows having none as shown on Figure 4.4.

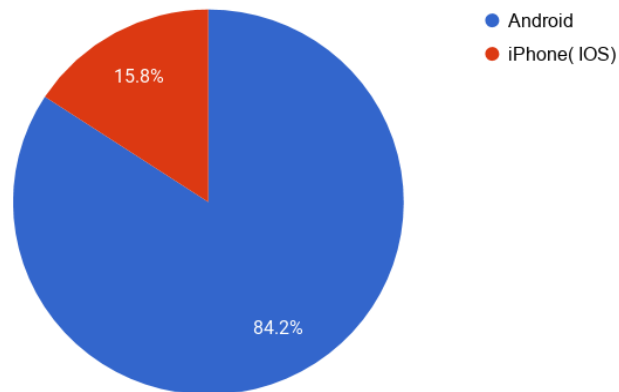


Figure 4.4 Operating System of Respondent's Mobile Phones

4.2.5 Characteristics that Respondents Use to Identify a Licit Cobalt ores Bag

Figure 4.5 illustrates the characteristics that respondents consider in identifying a licit Cobalt ores bag. They include artisanal mine approval number, Cobalt bag serial number, weight, smelting place, transportation method and buyer.

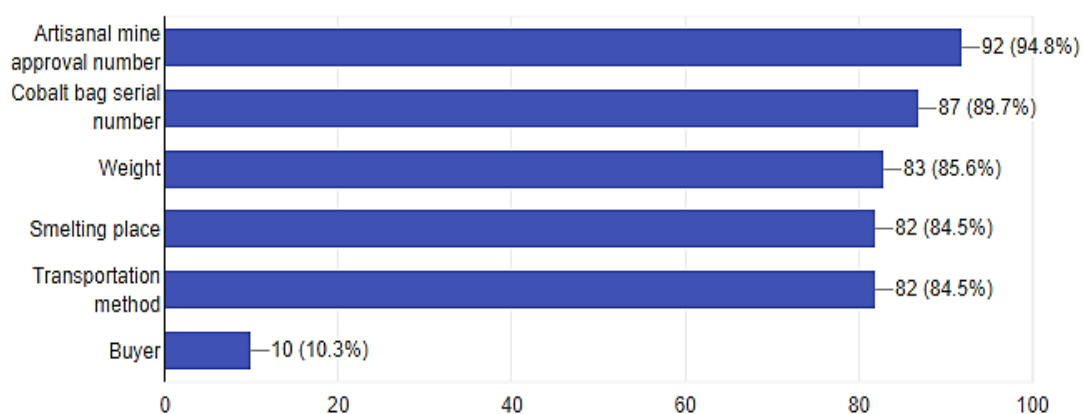


Figure 4.5 Characteristics that Respondents Consider in Cobalt ore Bag Identification

4.2.6 Importance Attached to the Characteristics Considered by Respondents in Identifying Licit Cobalt ores Bags

Figure 4.6 illustrates that artisanal approval number and Cobalt serial number are the most important when verifying a Cobalt ores bag status, they are followed by transportation method, smelting place, weight and buyer as considered by respondents.

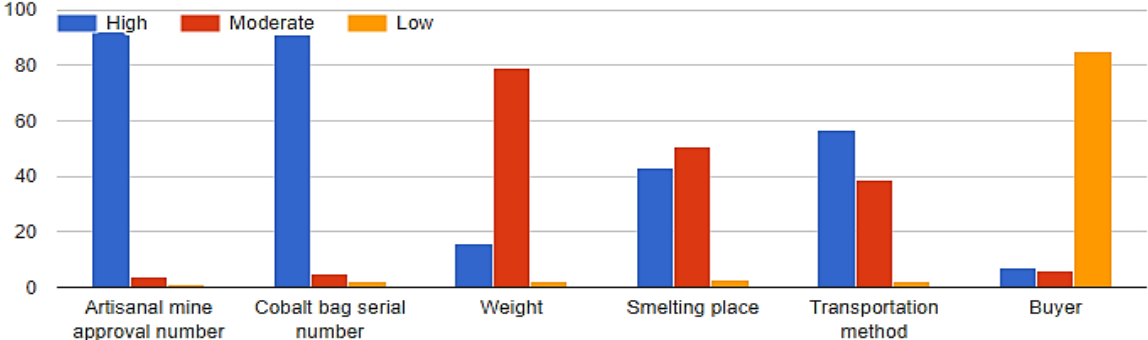


Figure 4.6 Importance Attached to the Characteristics in Checking Cobalt ores Bag

4.2.7 Capacity of Cobalt ores Bag

Figure 4.7 illustrates that depending on the artisanal mine 25.3 % use 45kg to bag Cobalt ores, 26.3 % of artisanal mines use 20kg, 29.5 % use 35kg, 12.6 % use 40kg and 6.3 % use 50kg.

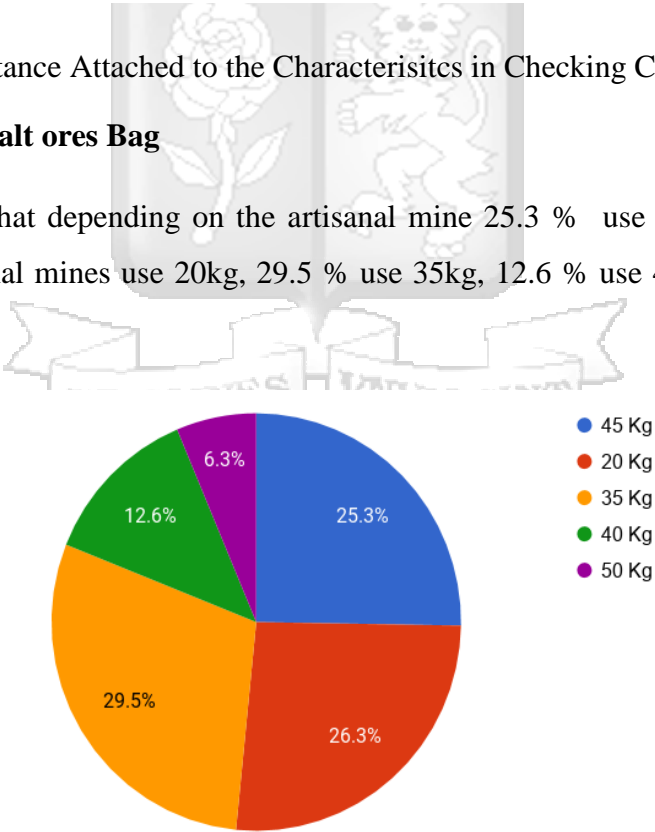


Figure 4.7 Capacity of Cobalt ores Bag

4.2.8 Particulars Respondents Check When Verifying a Cobalt ores Bag

Respondents check if a Cobalt ores bag comes from a vetted artisal mine by confirming the weight, confirming the extraction date, confirming the Cobalt ores serial number.

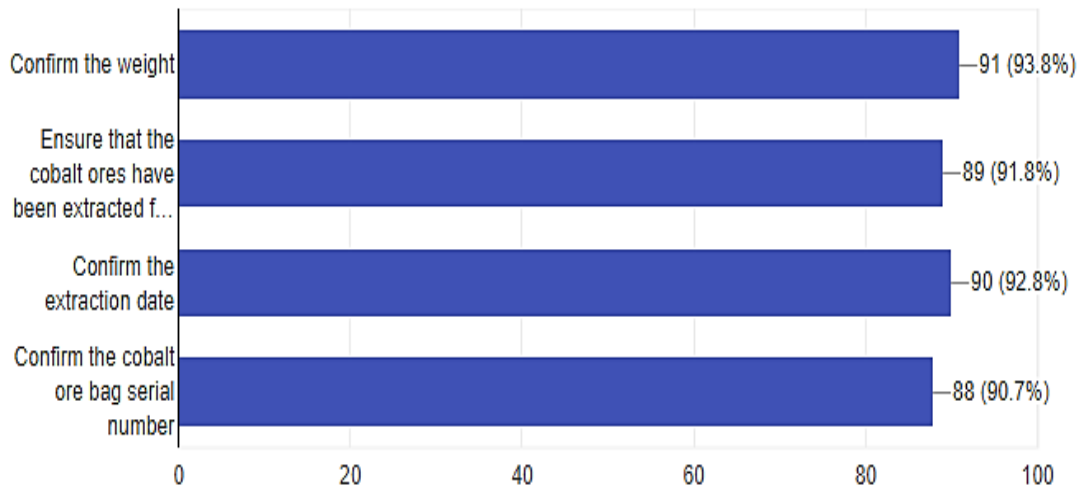


Figure 4.8 Particulars Respondents Consider When Verifying Cobalt ores Bag

4.2.9 Technologies Respondents are Accustomed To

Figure 4.9 illustrates that 29.5 % of respondents are accustomed to Barcodes and 61.1 % are accustomed to QR codes. Nevertheless, 9.5 % of respondents had no idea of these technologies.

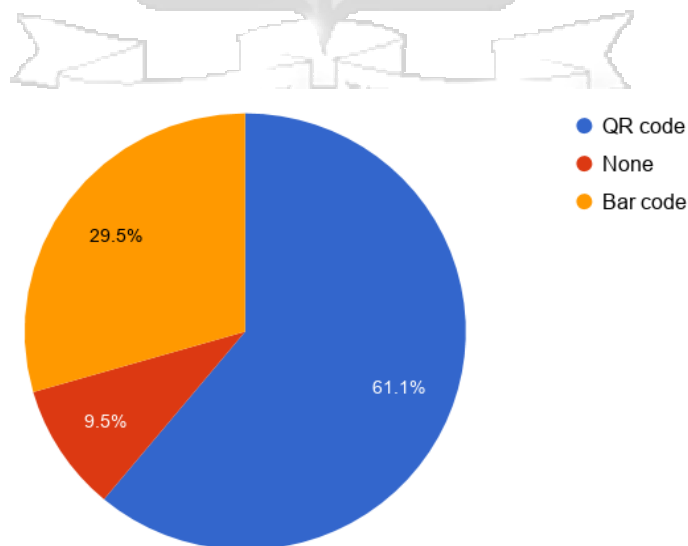


Figure 4.9 Technologies Respondents are Accustomed To

4.2.10 Respondent's Ability to Use a Mobile Phone

Figure 4.10 illustrates that Respondents are able to access the internet, download an application, take pictures and send or receive emails.

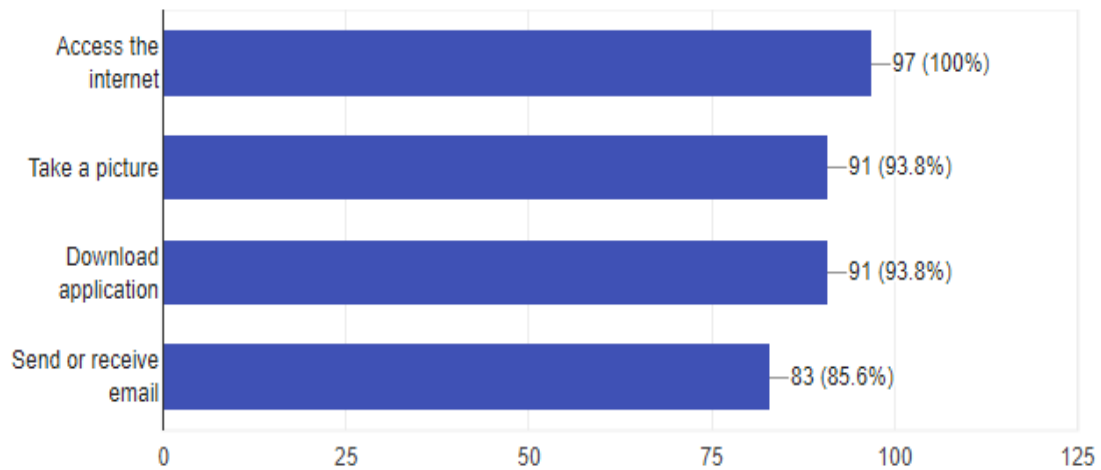


Figure 4.10 Respondents Ability to Use a Mobile Phone

4.2.11 Features Respondents Would Like to See on the Proposed Application

Figure 4.11 illustrates that 68.4 % of respondents would prefer features like QR code, 21.1 % would prefer feedback system and 7.4 % would prefer notifications on the new application. 3.2 % of respondents had no idea of these technologies.

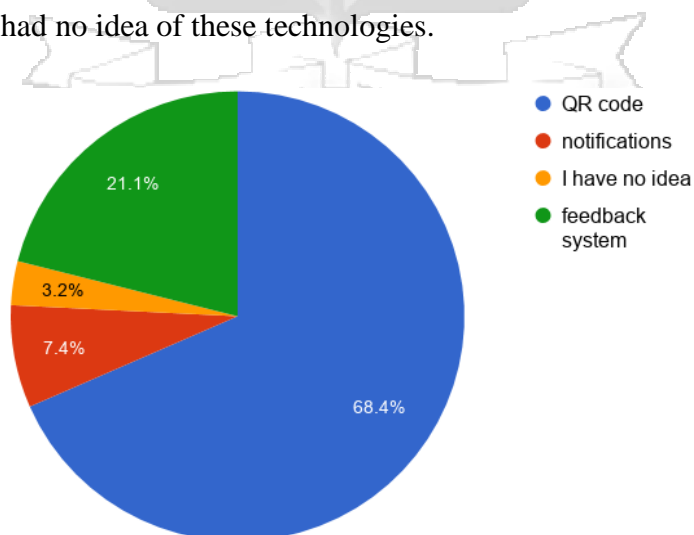


Figure 4.11 Features Respondents Would Prefer on the Proposed Application

4.3 Requirements Analysis

The requirements for the mobile application for tracking and verification of Cobalt ores can be split in functional and non-functional requirements.

4.3.1 Functional Requirements

This represents the functions and processes that the implemented application must perform successfully. They include: Verify Cobalt ores bag, the authorised users should be able to request for verification of a Cobalt ores bag, get the verification results, view the verification reports by retrieving a history of all the Cobalt ores bags they have scanned before, make a remark and report about the scanned Cobalt ores bag.

Create account, mine inspectors and mine officers should be able to set their first name, lastname, email address and password , they should then be able to login into the system using the correct email address and password. Manage Artisanal mines, mining officers should be able to add, delete an artisanal mine as well as view all the Cobalt ores bags extracted by the same. Manage Cobalt ores bags, mining officer should be able to add a Cobalt ores bag for the specific artisanal mine, generate a QR code for each Cobalt ores bag as well as view the scan details and the overall production report for all artisanal mines,finally he should be able to delete Cobalt ores bags. Logout, mining officers and mine inspectors should be able to logout of the personal account.

Manage users where the administrator should be able to edit users account status, view the overall Cobalt production report for each artisanal mine.

4.3.2 Non-Functional Requirements

These are requirements that do not affect the core functionality of the system but they make the system interactive and user friendly. They include:

Security – The backend web application has an administrator who controls the user account status. Only authorised users should be allowed to use the system functionalities.

Availability and Reliability – The system should be reliable and always available to perform tasks requested by the user.

Scalability – The system should allow additional functionalities for future improvements and upgrades.

Integrity – The system should ensure that stored data is not altered or corrupted.

4.4 System Architecture

This research proposed the system architecture based on the requirements collected. The researcher made use of the client-server architecture to develop the system. A client-server architecture operates as a distributed model that splits functions between servers and clients. Figure 4.12 illustrates the client-server architecture of the application for tacking and verification of Cobalt ores in artisanal mines.

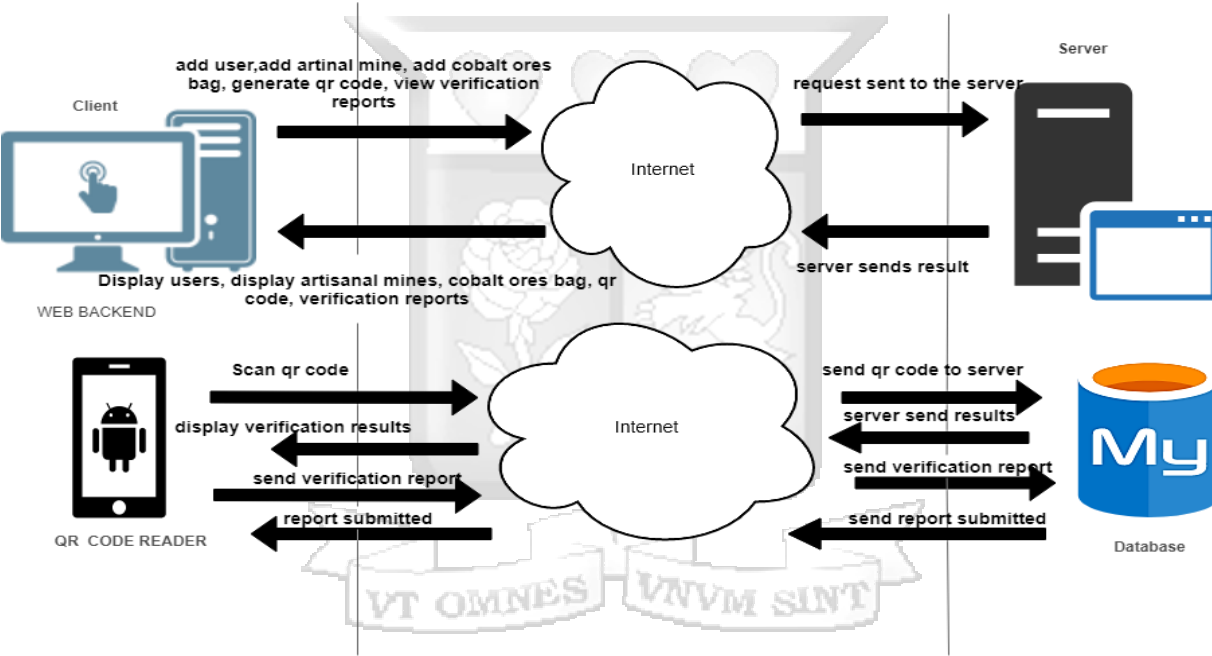


Figure 4.12 Client Server Architecture

The mining officer adds an artisanal mine and stores all its details in the artisanal mines table. He can then carry on and associate each artisanal mine with its own Cobalt ores bags, thereafter generate a QR code for each Cobalt ores bag. The researcher suggests that the mining officer prints the QR code on a Self Adhesive Sticker Paper A4 which is compatible with any Inkjet printer. The serial number of each Cobalt ores bag is used to generate the QR code which means the Cobalt ores bag can not be rebranded . On the client side, the Android application is made of a QR code scanner. The mine inspector captures the serial number of the Cobalt ores bag and launches the verification process.

The application verifies with the database if the Cobalt ores bag is stored in the database or not. The verification report consists of the date on which the verification has been done, the verified Cobalt ores bag and a remark from the mine inspector which gives more details about the conditions in which the Cobalt ores bag was found. Furthermore, if the application sent back a warning flag this means the Cobalt ores bag was not extracted from a vetted artisanal mine. In this case, the mining inspector can take appropriate measures as required by the mining code.

4.5 Use Case Diagram and Description

Figure 4.13 illustrates the use case diagram for the application. It gives different functionalities of the application and the interaction between actors and other sub-system.

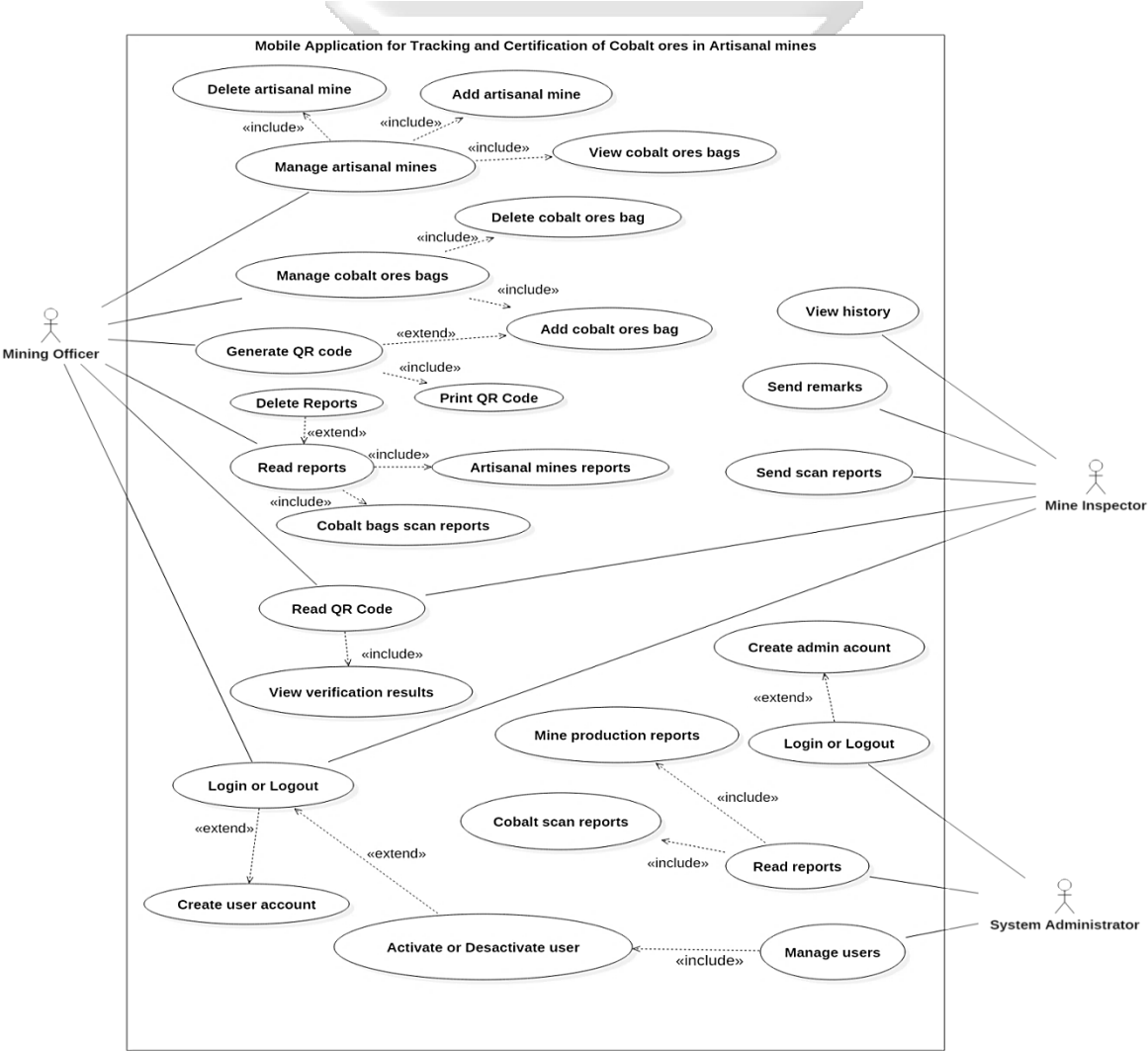


Figure 4.13 Use Case Diagram

The following tables describe different use cases in the system, their triggers and the information that is sent by different uses cases:

Table 4.1 Verify Cobalt ores Bags

Primary Actors:	Mine Inspector
Stakeholders:	Mining Officer
Precondition:	Want to verify a Cobalt ores bag. Presence of Cobalt ores bag.
Post condition:	Verify Cobalt ores bag, View verification results which reveal whether the Cobalt ores bag comes from a vetted mine or not.
Main success scenario	
Actor	System
<ol style="list-style-type: none"> 1. User views the menu 2. User selects scan QR code 3. User reads QR code on the Cobalt ores bag using the QR code scanner 4. The QR code scanner displays the Cobalt ores bag serial number. 5. User launches the verification process. 6. User selects Report menu 7. User gives a report of the Cobalt ores bags conditions 	<ol style="list-style-type: none"> 5.1 The system sends verification results to the user. 7.2 The report is submitted to the system.

Table 4.2 View Cobalt ores Bags Verification History

Use Case: View Cobalt ores bags Verificatio History	
Primary Actors:	Mine Inspector
StakeHolders:	Mining Officer
Precondition:	User has verified a Cobalt ores bag before. Cobalt ores bag was successfully verified.
Post condition:	User view the history report.
Main success scenario	
Actor	System
User clicks on history menu	Verification history accessible

Table 4.3 Create User Account

Use Case: Create User Account	
Primary Actor:	Mining Officer, Mine Inspector
Stakeholders:	
Precondition:	Need to Manage artisanal mines, Cobalt ores bags.
Post Condition	Activation request sent
Main success scenario	
Actor	System
Users submit registration details	User account created and Activated

Table 4.4 User Login

Use Case: User Login	
Primary Actors:	Mining Officer, Mine inspector
Stakeholders:	
Precondition:	Need to Manage Cobalt ores bags and artisanal mines. User account successfully created. User account is activated.
Post condition	Manage Artisanal mines, Cobalt ores bags.
Main success scenario	
Actor	System
User user submit login details	User succesfully logs in.

Table 4.5 Manage Artisanal Mines

Use Case:Manage Artisanal mines	
Primary Actors:	Mining Officer
Stakeholders:	
Precondition:	User account successfully created. Mining Officer account is activated. Mining Officer is logged into the system.
Post condition	Add new Artisanal mine.
Main success scenario	
Actor	System
1.Add Artisanal mines details. 2.View Cobalt ores bags.	2.1 Displays Cobalt ores bags list.

Table 4.6 Manage Cobalt ores Bags

Use Case:Manage Cobalt ores bags	
Primary Actors:	Mining Officer
Stakeholders:	
Precondition:	User account successfully created. Mining Officer account is activated. Mining Officer is logged into the system.
Post condition	Add new Cobalt ores bag
Main success scenario	
Actor	System
1.Add Cobalt ores bags details. 2. View Cobalt ores bag verification reports.	2.1 Displays Cobalt ores bags verification reports.

Table 4.7 Generate QR code

Use Case: Generate QR code	
Primary Actors:	Mining Officer
Stakeholders:	
Precondition:	User account successfully created. Mining Officer account activated. Mining Officer is logged into the system. Cobalt ores bag successfully added.
Post condition	Generate QR code
Main success scenario	
Actor	System
1.Add Cobalt ores bag details. 2. Generate Cobalt ores bags QR code	2.1 Displays Cobalt ores bag QR code.

Table 4.8 User Logout

Use Case: User Logout	
Primary Actors:	Mining Officer
Stakeholders:	
Precondition:	Mining Officer is logged into the sytem
Post condition	Logged out of the account
Main success scenario	
Actor	System
User clicks on logout option.	User successfully logs out

Table 4.9 Create Administrator Account

Use Case: Create Administrator Account	
Primary Actor:	System Administrator
Stakeholders:	
Precondition:	Need to Manage Mining Officers.
Post Condition	Activation request sent
Main success scenario	
Actor	System
Users submit registration details	Administrator account created

Table 4.10 Administrator Login

Use Case: Administrator Login	
Primary Actors:	System Administrator
Stakeholders:	
Precondition:	Need to activate or deactivate users account.
Post condition	User account activated or deactivated.
Main success scenario	
Actor	System
Administrator submit login details	Administrator succesfully logs in.

Table 4. 11 Manage Users

Use Case: Manage Users	
Primary Actors:	System Administrator
Stakeholders:	
Precondition:	Need to manage users account.
Post condition	Activate user, Deactivate user.
Main success scenario	
Actor	System
1. Activate user	1.1 User status set activated
2. Deactivate user	2.2 User status set deactivate

Table 4.12 Adminstrator Logout

Use Case: Adminstrator Logout	
Primary Actors:	System administrator
Stakeholders:	
Precondition:	System administrator is logged in.
Post condition	Logged out of the administrator account.
Main success scenario	
Actor	System
Administrator clicks on logout option.	Administrator successfully logs out.

4.6 Sequence Diagram

The sequence Diagram illustrates the interactions between the main entities of the system. Figure 4.14 shows how users interact with the system and how they send and receive feedback from the system.

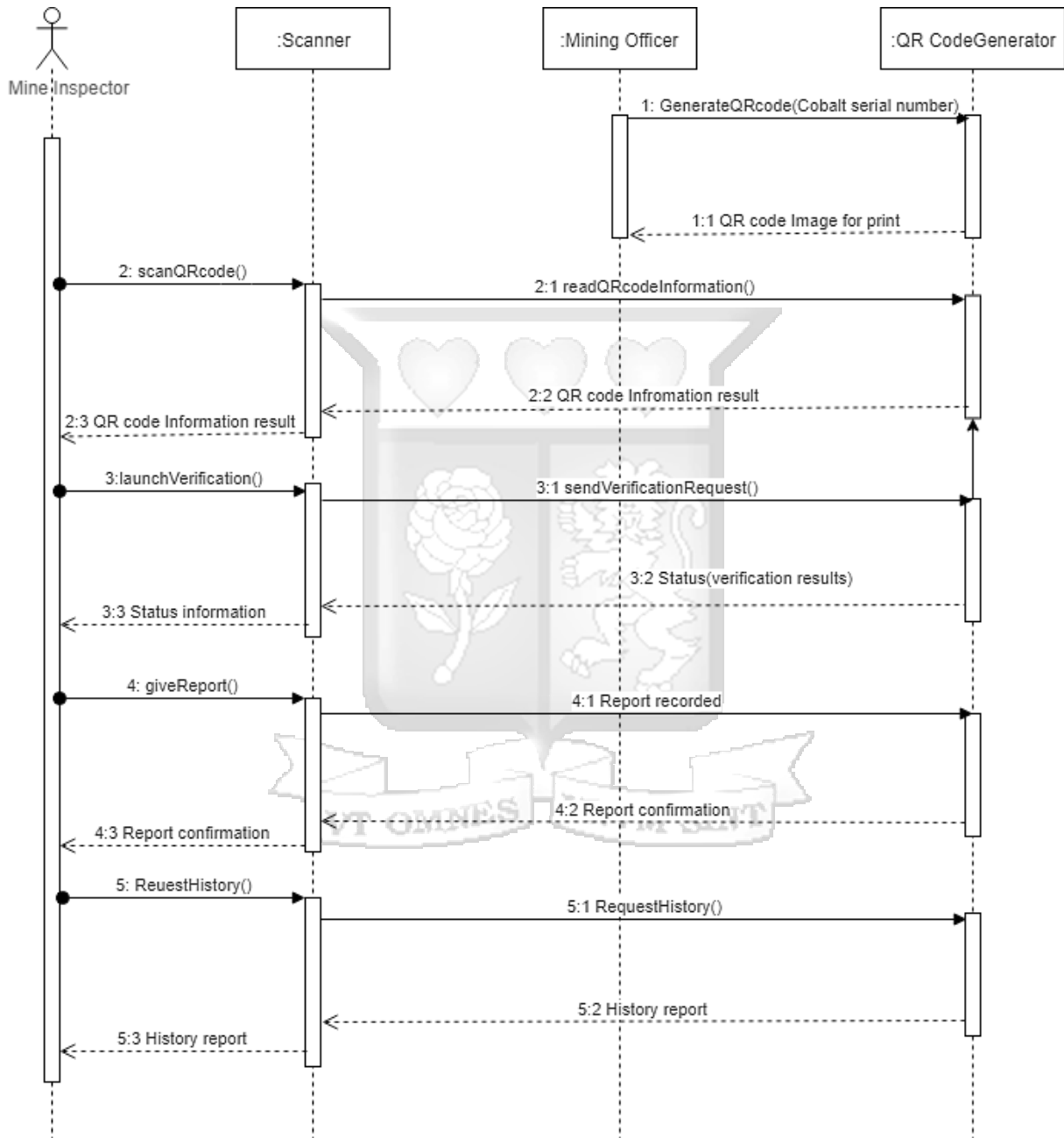


Figure 4.14 Sequence Diagram

4.7 Entity Relationship Diagram

An entity relationship diagram represents conceptually the database design. Entities, attributes and relationships are identified and represented in Figure 4.15.

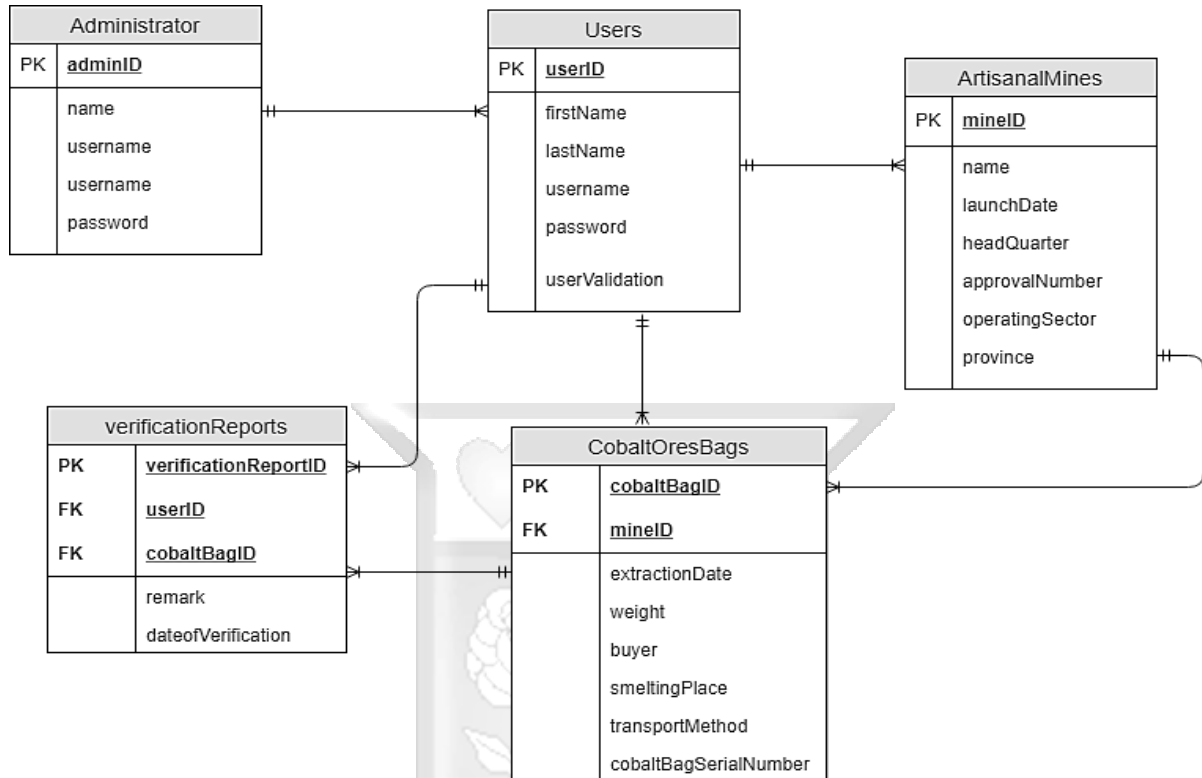


Figure 4.15 Entity Relationship Diagram

4.8 Database Schema

Users Table

The following table contains all users of the system, mining officers and mine inspectors.

Table 4.13 Users Table

Column Name	Data Type	Index
UserID	Integer(11)	Primary key
FirstName	Varchar(30)	
LastName	Varchar(30)	
Username	Varchar(30)	
Password	Varchar(30)	
userValidation	Enum(activate, deactivate)	

Artisanal Mines Table

This table contains all the details of artisanal mines recognised by mining officer as vetted mines.

Table 4.14 Artisanal Mines Table

Column Name	Data Type	Index
mineID	Integer(11)	Primary key
Name	Varchar(30)	
launchDate	Varchar(30)	
headQuarter	Varchar(30)	
approvalNumber	Varchar(30)	
operatingSector	Varchar(30)	
Province	Varchar(30)	

Cobalt ores Bags Table

This table contains all the details of Cobalt ores bags. Each Cobalt ores bag is associated with the artisanal mine from which the Cobalt ores have been extracted.

Table 4.15 Cobalt ores Bags Table

Column Name	Data Type	Index
cobaltbagID	Integer(11)	Primary key
mineID	Integer(11)	Foreign key
extractionDate	Date	
Weight	Varchar(30)	
Buyer	Varchar(30)	
SmeltingPlace	Varchar(30)	
transportMethod	Varchar(30)	
cobaltSerialNumber	Integer(11)	

Verification_Reports Table

Table 4.16 shows of all reports submitted by the mine inspector after he has successfully verified or certified the Cobalt ores bag. Each varication report is associated with a remark and the date on which the report has been sent.

Table 4.16 Verification_Reports Table

Column Name	Data Type	Index
verificationReportID	Integer(11)	Primary key
cobaltbagID	Integer(11)	Foreign key
userID	Integer(11)	Foreign key
Remark	Varchar(30)	
deteofVerification	Varchar(30)	

Adminstrator Table

Table 4.16 shows records of the system administrator.

Table 4.17 Adminstrator Table

Column Name	Data Type	Index
adminID	Integer(11)	Primary key
Name	Varchar(30)	
Username	Varchar(30)	
Password	Varchar(30)	

4.9 Design Class Diagram

Figure 4.16 is the design class diagram illustrating the relationships between classes, their corresponding methods and attributes.

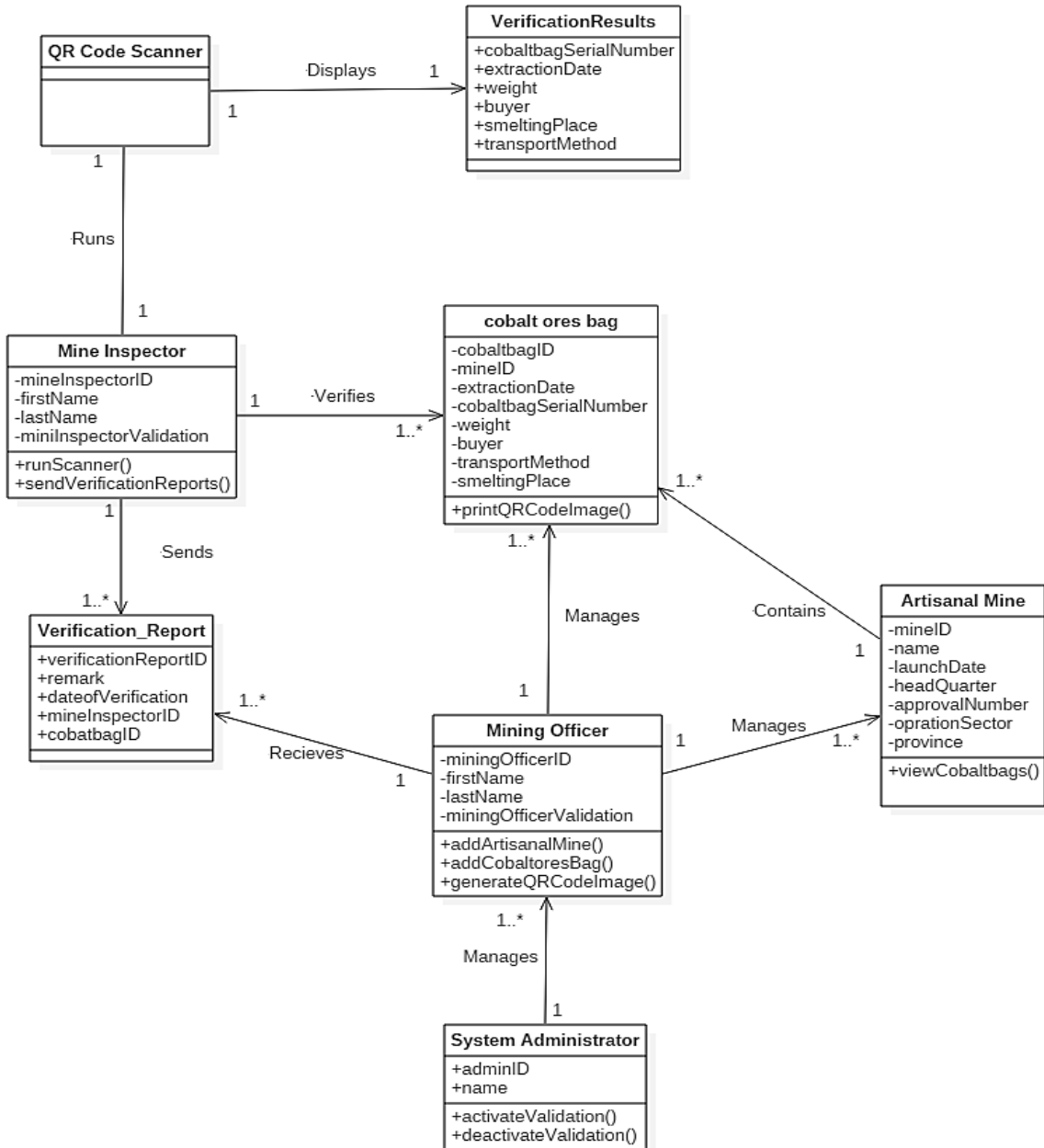


Figure 4.16 Design Class Diagram

4.10 User Interface Flow Diagram

The user interface flow diagrams are illustrated in this section. They include mobile application wireframes and web application wireframes. Figure 4.17 shows the mobile application login screen where the user is taken after the splashscreen is dismissed like in Figure C.4. If the user has successfully logged in, he is then taken to the Scan QR code activity where he scans the QR code and get the Cobalt ores bag serial number as shown respectively by Figure 4.18 and Figure 4.19, he can then launch the verification process and get the verification results as shown by Figure 4.20. The user proceeds to the report and remark activity to submit the Cobalt ores bag scan report as shown by Figure 4.21.

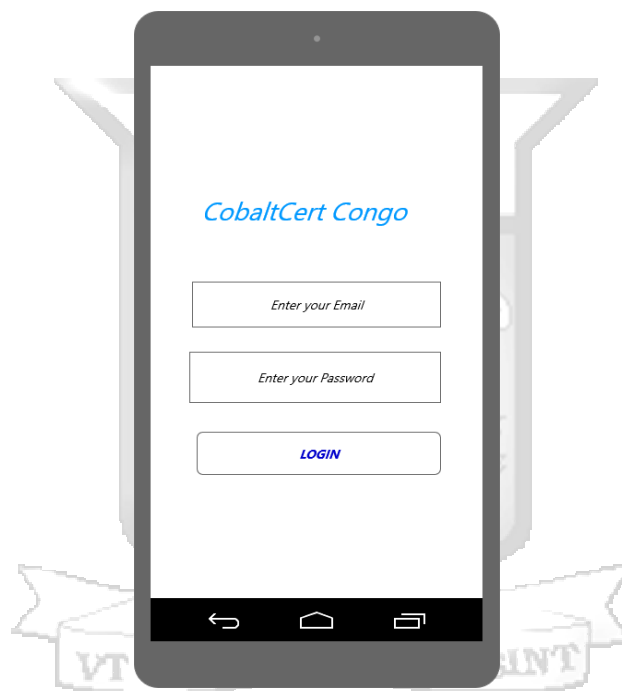


Figure 4.17 User Login Screen

After the user has successfully logged in, he is then taken to the Scan QR code activity where he Scans the QR code as shown by Figure 4.18.

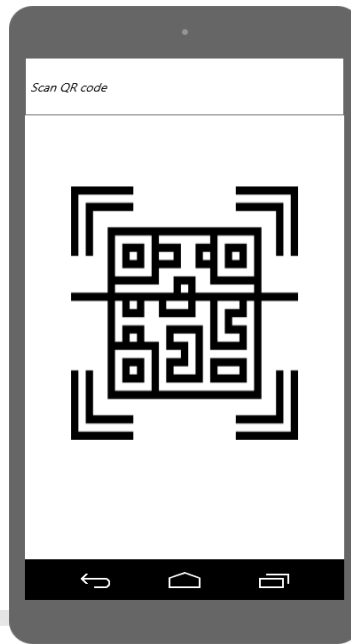


Figure 4.18 QR Code Scanner Wireframe

After scanning the QR code, the QR code scanner returns the Cobalt ores bag serial number. The user can then launch the verification process as shown by Figure 4.19.



Figure 4.19 QR Code Scan Result

After launching the verification process, the Cobalt ore bag serial number is then compared to the one stored in the database. The result is displayed to the user as shown by Figure 4.20.

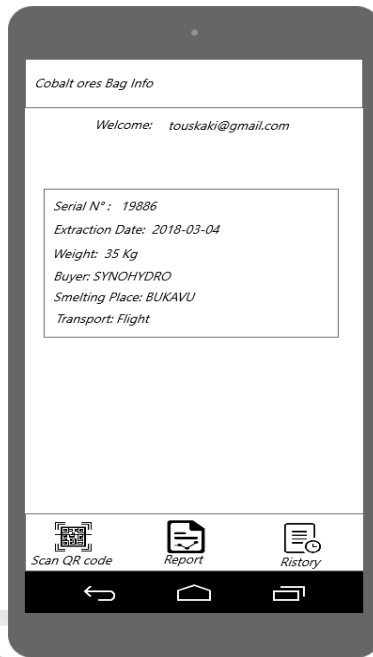


Figure 4.20 Verification Results Wireframe

After successfully verifying the Cobalt ores bag, the user proceeds to the report activity and make the Cobalt bag scan report which is submitted to the system as shown by Figure 4.21.

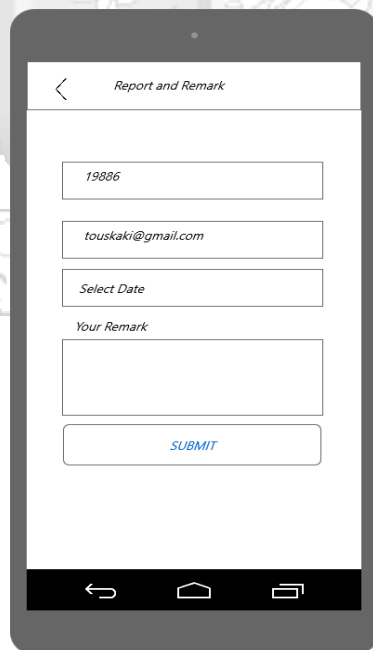


Figure 4.21 Verification Report and Remark

The user can keep track of all Cobalt ores bag that he has previously scan by checking the history page as show by Figure 4.22.

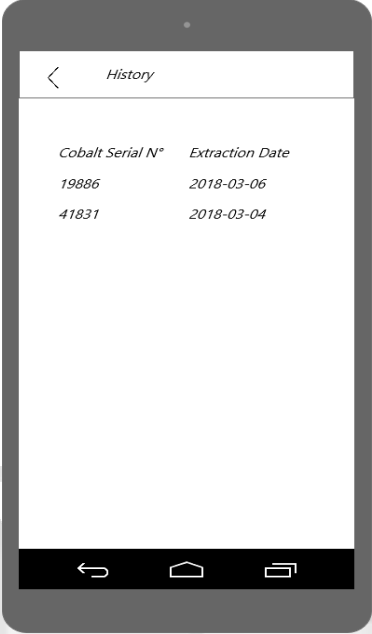


Figure 4.22 Verification History Wireframe

Web Application Wireframes

The web application has two modules, user module and administrator module. After creating an account as shown by Figure C.2, the user can then login into the system by providing his cradentials as shown by Figure 4.23.

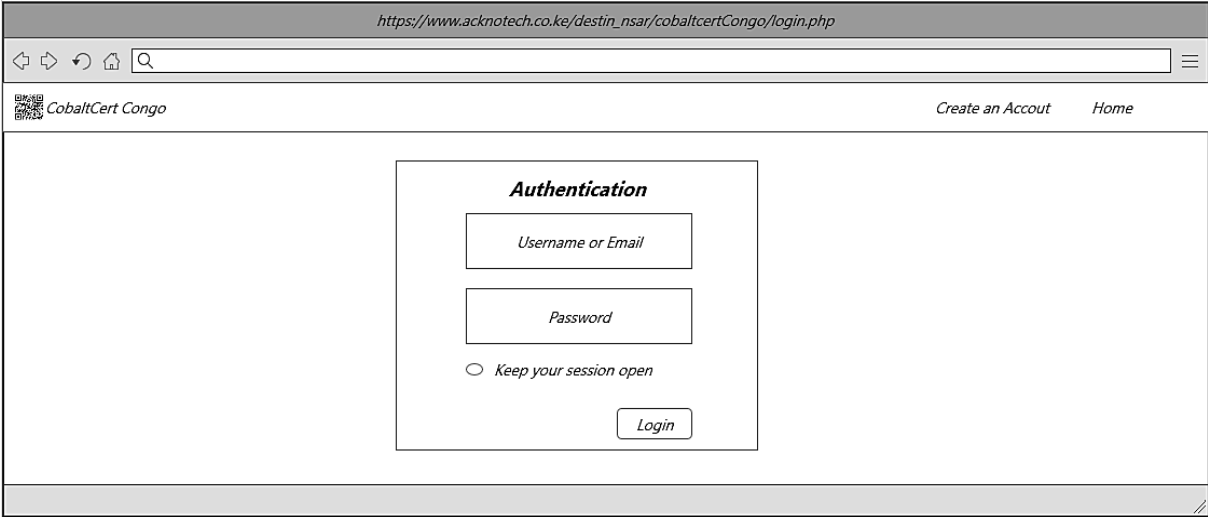


Figure 4.23 User Login Wireframe

After the user has successfully logged in into the system, he can then add or delete an artisanal mine and view the Cobalt ores bags associated to it as shown by Figure 4.24.

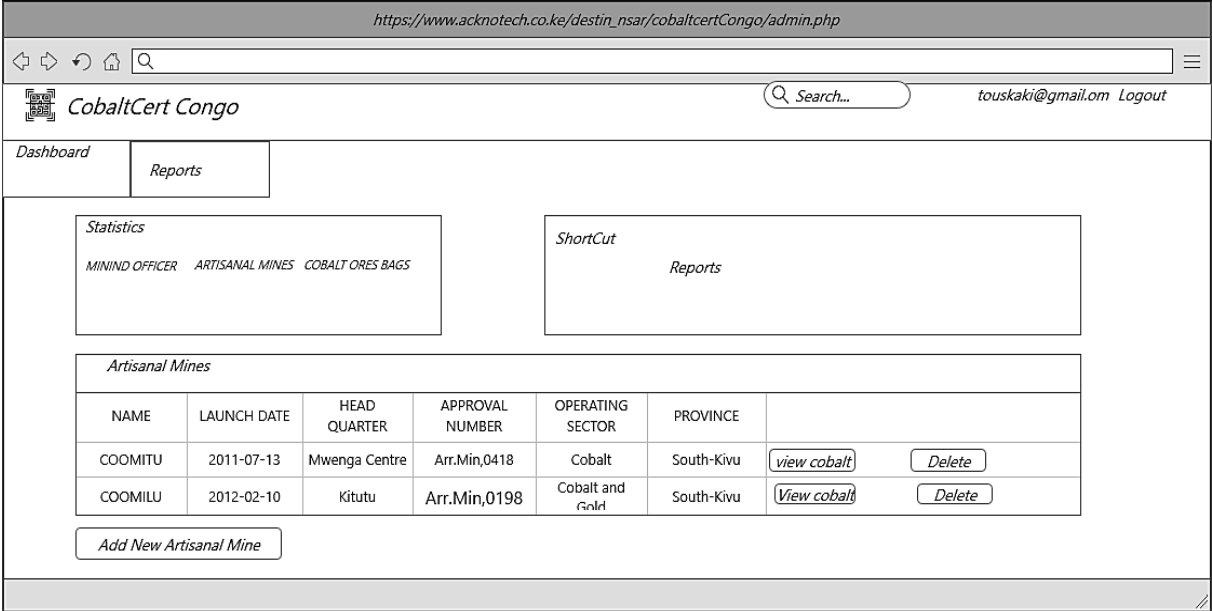


Figure 4.24 Add Artisanal mine Wireframe

The user can then add or delete a Cobalt ores bag mine and Generate the QR code code which holds the Cobalt bag serial number as shown by Figure 4.25.

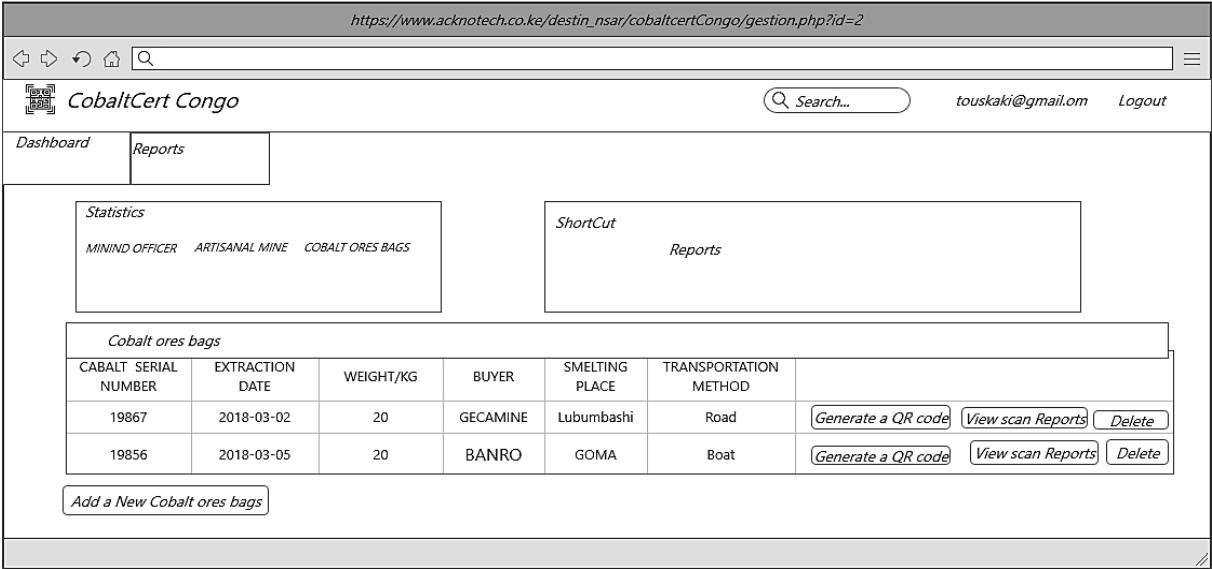


Figure 4.25 Add Cobalt ores Bag and QR Code Generation Wireframe

The user can view all the verification report as submitted the mine inspector as show by Figure 4.26.

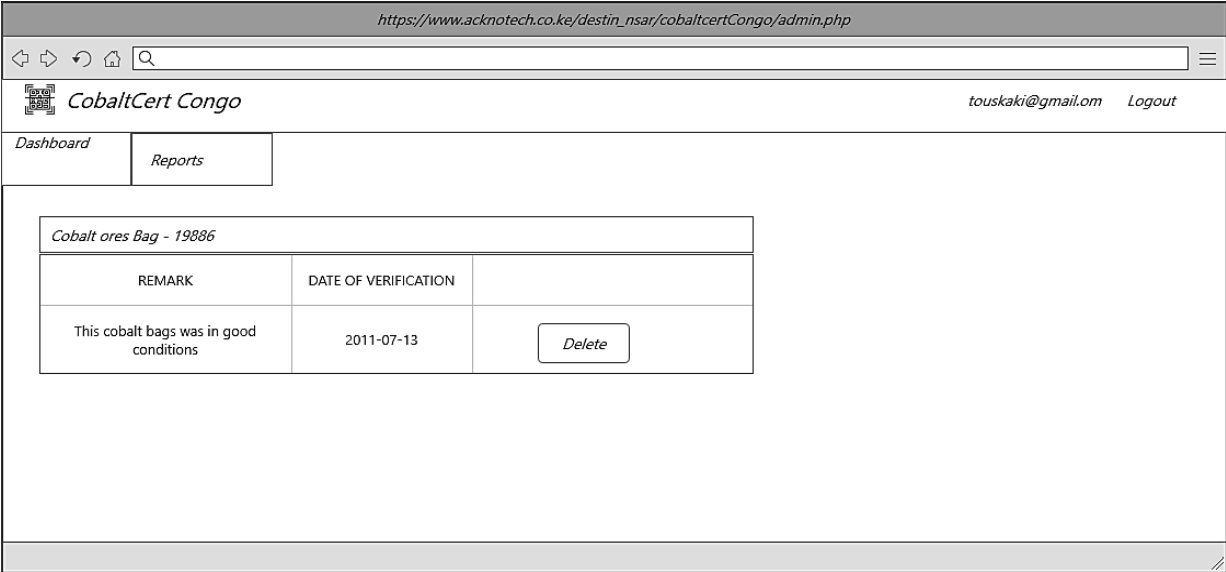


Figure 4.26 Verification Report Wireframe

The user can also view all the artisanal mines production report as shown by Figure 4.27.

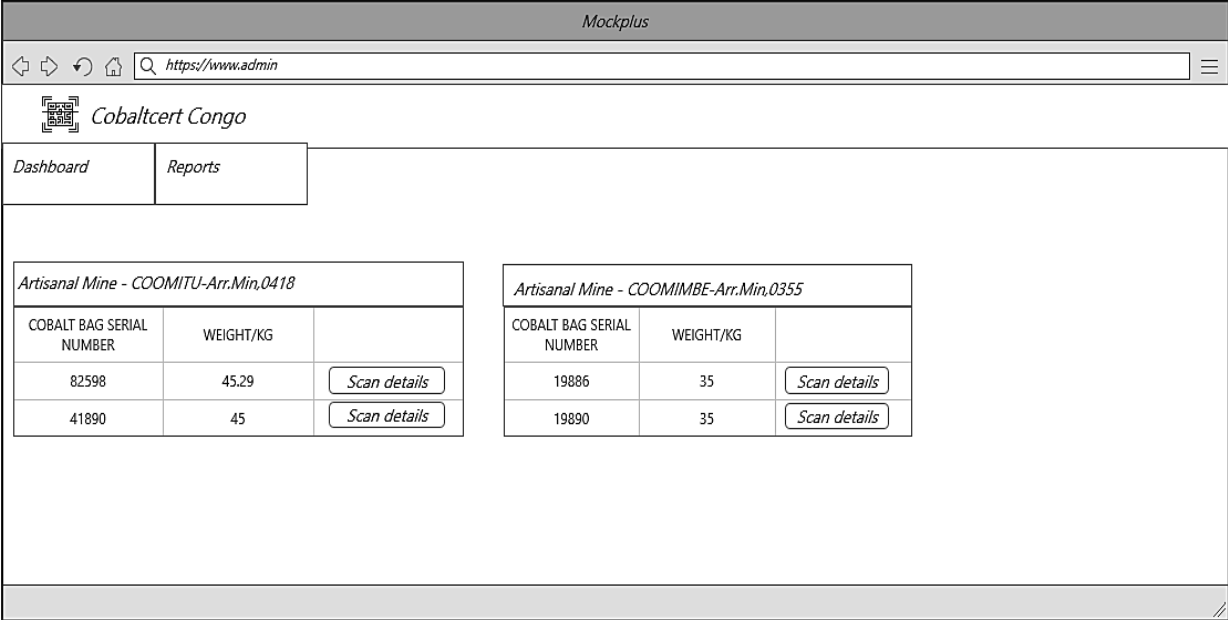
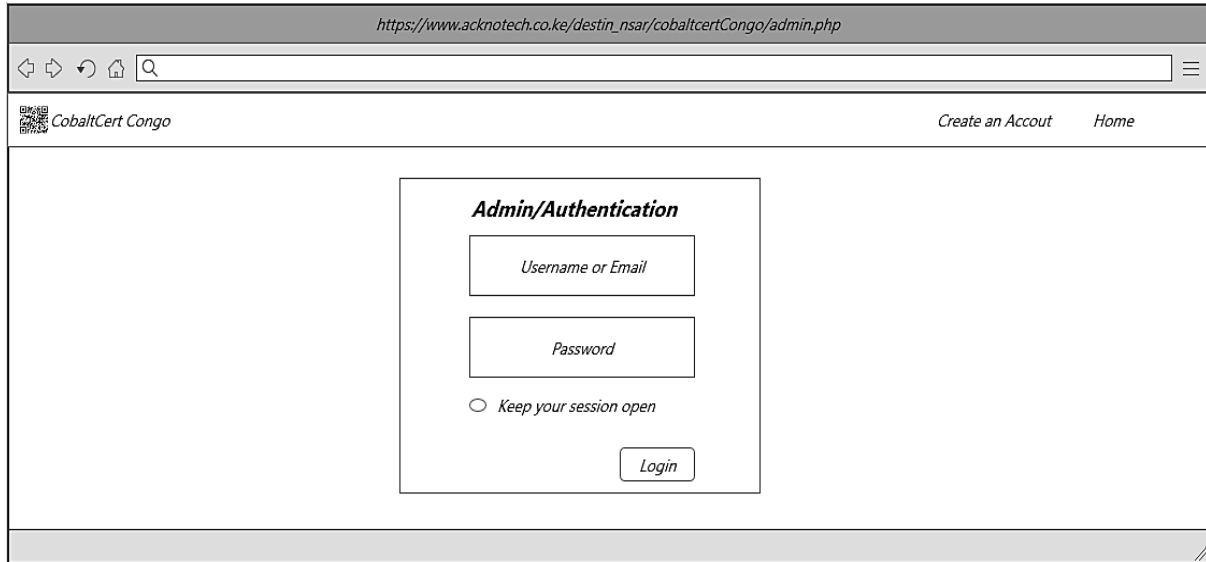


Figure 4.27 Mine Production Report Wireframe

Administrator Interfaces

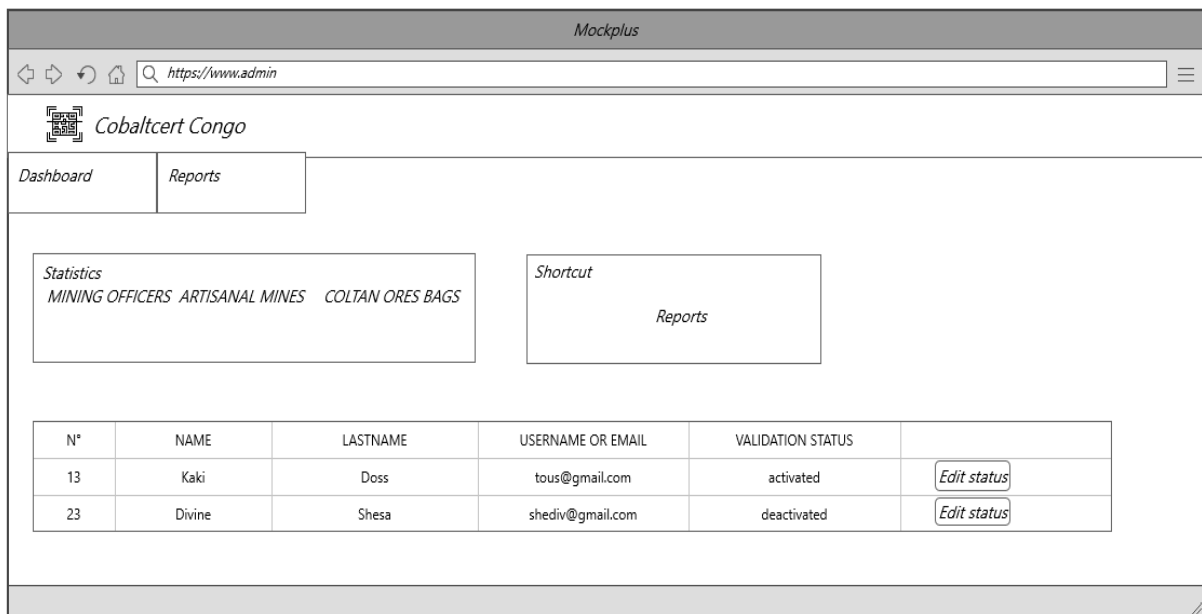
After creating an account as shown by Figure C.3, the administrator can then login into the system by providing his credentials as shown by Figure 4.28.



The wireframe shows a web browser window with the URL `https://www.acknotech.co.ke/destin_nsar/cobaltcertCongo/admin.php`. The page header includes the logo for 'CobaltCert Congo' and navigation links for 'Create an Account' and 'Home'. The main content area features a central box titled 'Admin/Authentication' containing a login form with fields for 'Username or Email' and 'Password', a checkbox for 'Keep your session open', and a 'Login' button.

Figure 4.28 Administrator Login Wireframe

The system administrator can then manage users account by activating or deactivating their account status depending on the user job position as shown by Figure 4.29.



The wireframe shows a web browser window with the URL `https://www.admin`. The page header includes the logo for 'Cobaltcert Congo' and navigation tabs for 'Dashboard' and 'Reports'. The main content area features a 'Statistics' section with links for 'MINING OFFICERS', 'ARTISANAL MINES', and 'COLTAN ORES BAGS', and a 'Shortcut' section with a link for 'Reports'. Below these sections is a table with columns for 'N°', 'NAME', 'LASTNAME', 'USERNAME OR EMAIL', 'VALIDATION STATUS', and 'Edit status'.

N°	NAME	LASTNAME	USERNAME OR EMAIL	VALIDATION STATUS	Edit status
13	Kaki	Doss	tous@gmail.com	activated	Edit status
23	Divine	Shesa	shediv@gmail.com	deactivated	Edit status

Figure 4.29 User Validation Status Wireframe

4.11 Summary

Data collected from the respondents helped in understanding the system requirements. The proposed architecture is a client-server architecture where the Android application and the web portal act as client and whereas the database and the server act as servers. Parameters to be used to verify whether the Cobalt ores bag comes from a vetted artisanal mine include, serial number, extraction date, artisanal mine, weight, buyer, smelting place and transportation method. The next chapter describes the prototype building and testing.



CHAPTER 5: SYSTEM IMPLEMENTATION, TESTING AND VALIDATION

5.1 Introduction

This chapter contains the implementation of the system, testing and validation. It explores different module of the system, how the implementation was done . Testing include functional testing and usability testing to check if the system attained the objectives of the proposed solution.

5.2 System Implementation

Agile software development methodology was used to design and develop the system as discussed in the chapter three. The system named Cobaltcert Congo has a front-end and a back-end. The front-end is an Android application developed using Java and xml; it is used to verify the Cobalt ores bags. The back-end is a web application which was built using Bootstrap modal and PHP. MySQL was used as the relational database management system.

The mining officer adds an artisanal mine in the system which is then recognised as a vetted mine. Each artisanal mine is associated with the Cobalt ores bag. The mining officer adds the Cobalt ores bags and can then generate a QR code for each one of them. The researcher suggests that the mining officer prints the QR code on a Self Adhesive Sticker Paper which is compatible with any Inkjet printer and attaches it to the bag, this way the Cobalt ores bag can not be rebranded.

The Android application is a client side which is made of QR code scanner. The mining inspector captures the serial number of the Cobalt ores bag and launch the verification process, the application verifies with the database whether the Cobalt ores bag is registered as extracted from a vetted mine. The feedback received by the application include the Cobalt ores bag details, which is also the main component that allows mine inspectors to verify a Cobalt ores bag.

5.2.1 Cobaltcert Congo Mobile Application

This application was designed to run on Android mobile phones which has a camera and connect to Internet.

User Login

Figure 5.1 represents the login activity of the Cobaltcert Congo mobile application which is launched after the splashscreen has been dismissed like in Figure D.8. The user must login with his credentials to be able to verify the a Cobalt ores bags.

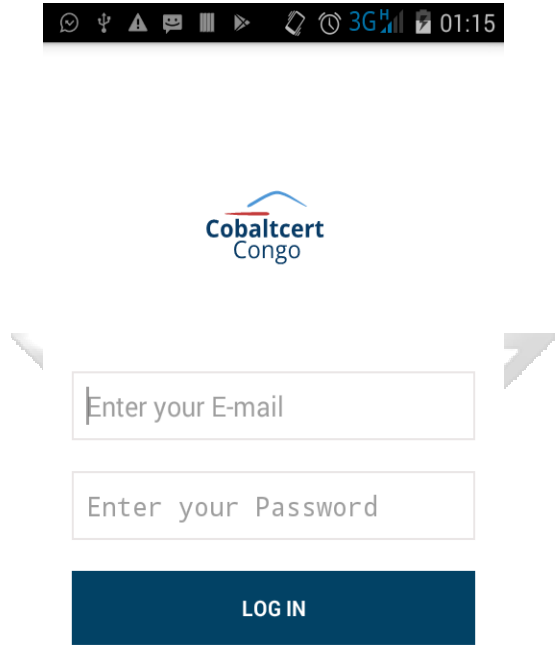


Figure 5.1 Android Application User Login Screen

QR code Scanner

To verify a Cobalt ores bag , the mine inspector focuses the phone camera on a QR code image which scans the image and returns the serial number of the Cobalt ores bag as shown by Figure 5.2.

Figure 5.2 shows the main activity of the Cobaltcert Congo mobile application.

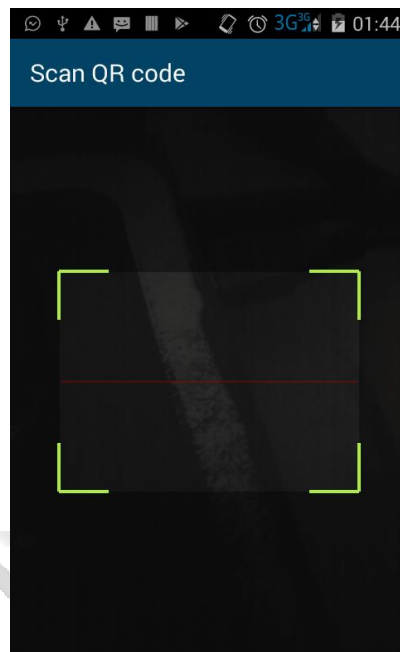


Figure 5.2 QR Code Scanner

QR code Scan Result

Figure 5.3 illustrates the scan result returned by the QR code scanner activity which prompts the user to start the verification process.

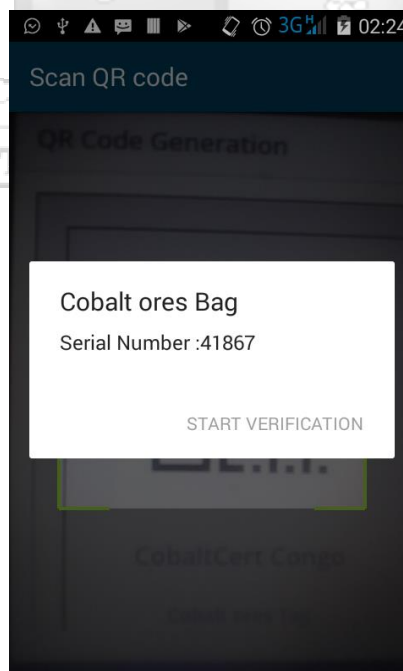


Figure 5.3 Scan Result

Verification Results

Figure 5.4 shows a sample of verification results which the mine inspector should get after launching the verification process.

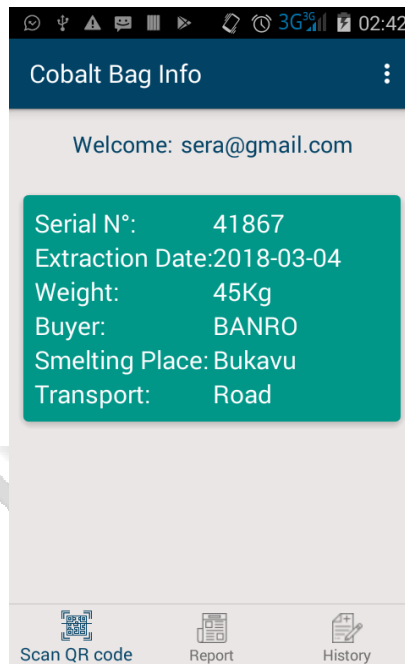


Figure 5.4 Verification Results

Verification History

figure 5.5 illustrates the record of all the scanned QR code images done by the mine inspector.

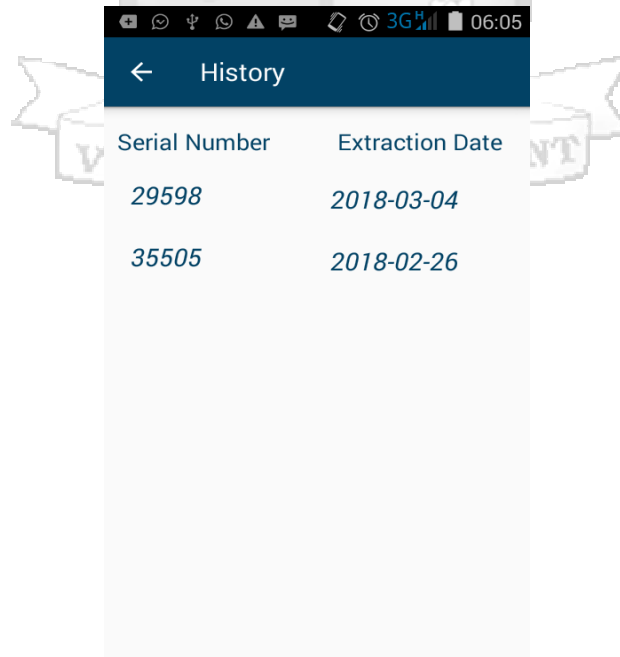
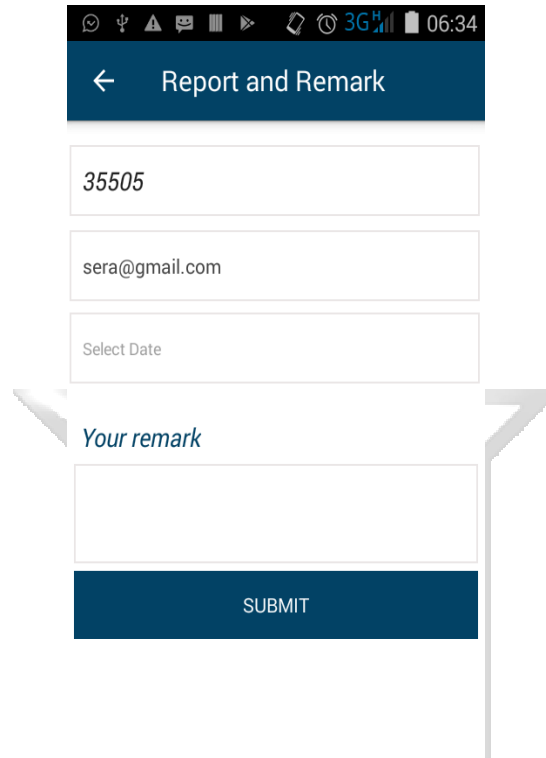


Figure 5.5 Verification History

Verification Report

Figure 5.6 illustrates the report activity where the mining inspector can submit a report after he successfully verified the Cobalt ores bag.



The screenshot shows a mobile application interface for submitting a report. At the top, there is a dark blue header with a white back arrow and the text "Report and Remark". Below the header, there are four input fields. The first field contains the number "35505". The second field contains the email address "sera@gmail.com". The third field is labeled "Select Date" and is currently empty. The fourth field is labeled "Your remark" and is also empty. At the bottom of the form is a dark blue button with the word "SUBMIT" in white capital letters. The background of the page is white with a faint watermark of a map of Congo and the text "VT OMNES VNVM SINT".

Figure 5.6 Verification Report Page

5.2.2 Cobaltcert Congo Web Application

Mining officer uses the web application to add artisanal mines and associate them with their Cobalt ores bags, thereafter he generates the QR code for each Cobalt ores bag. He can also view the verification reports for each Cobalt ores bag and the mine production report for each artisanal mine. The system administrator use the web application to activate or deactivate mining officers and mine inspectors account status depending on which position the users have swapped to as required by the Ministry of mines policy.

User Login

The mining officer enters his username or email address and password. If they match with what is stored in the database and the user login validation is activated, then the access is granted otherwise access is denied as shown by Figure 5.7.

Figure 5.7 shows the login page where users, mining officers enter their username and password to get access to Cobaltcert Congo web application.

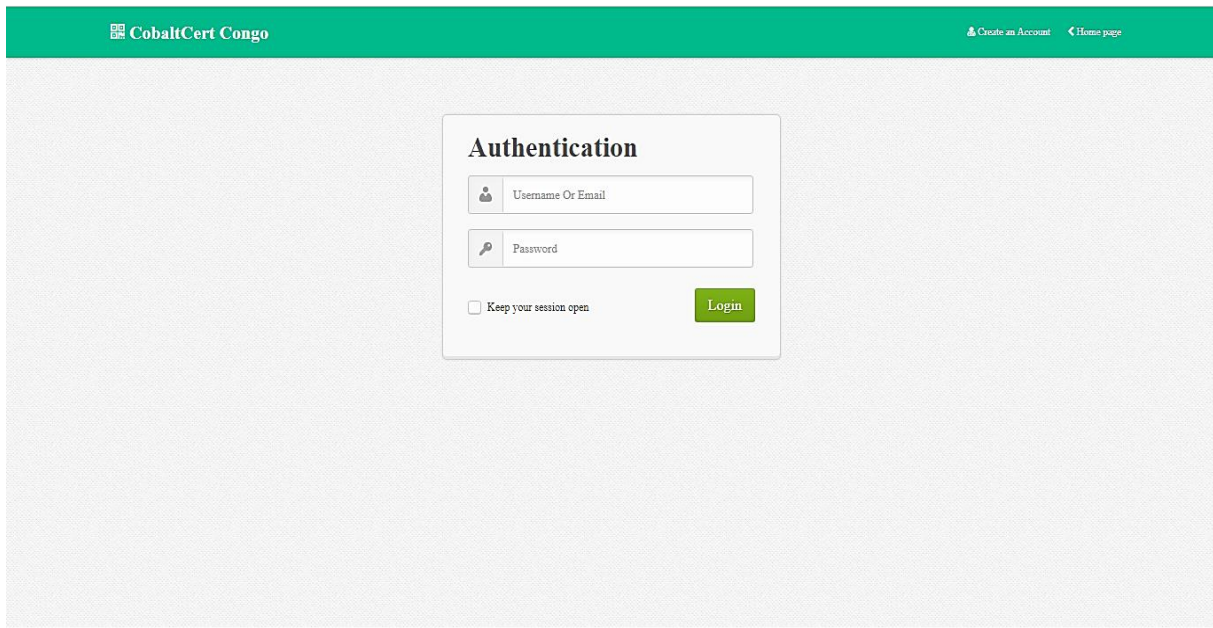


Figure 5.7 User Login Page

Add Artisanal mine

Figure 5.8 shows a the page where the mining officer adds the artisanal mine in the system. He can then view all the Cobalt ores bags associated with the artisanal mine or delete them.

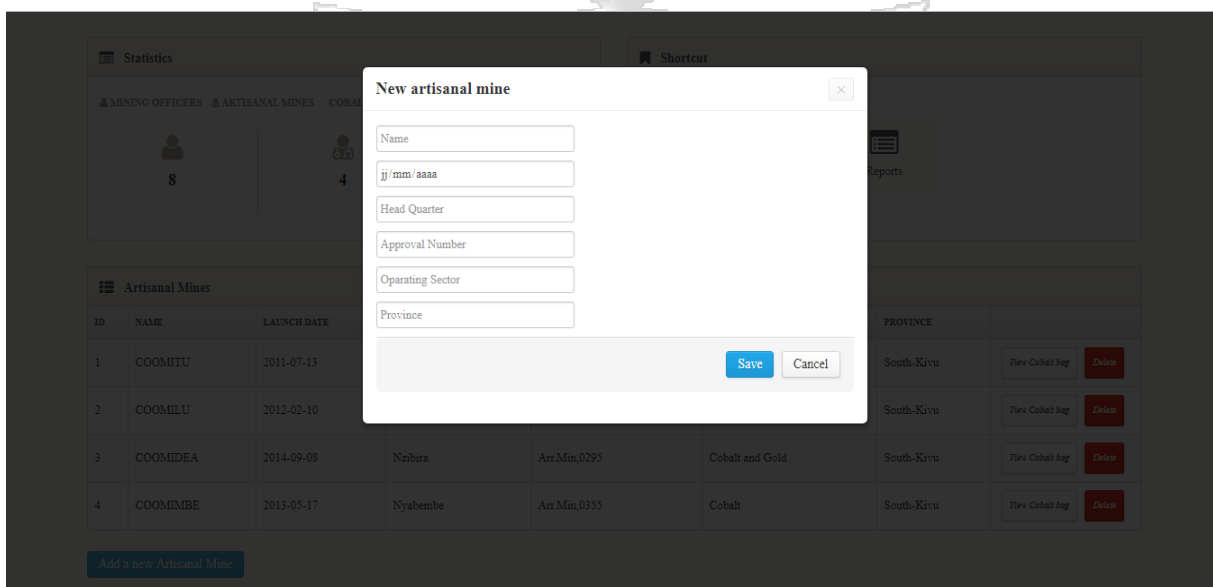


Figure 5.8 Add New Artisanal Mine

All Artisanal Mines

Figure 5.9 shows all artisanal mines that have been added into system by the mining officer.

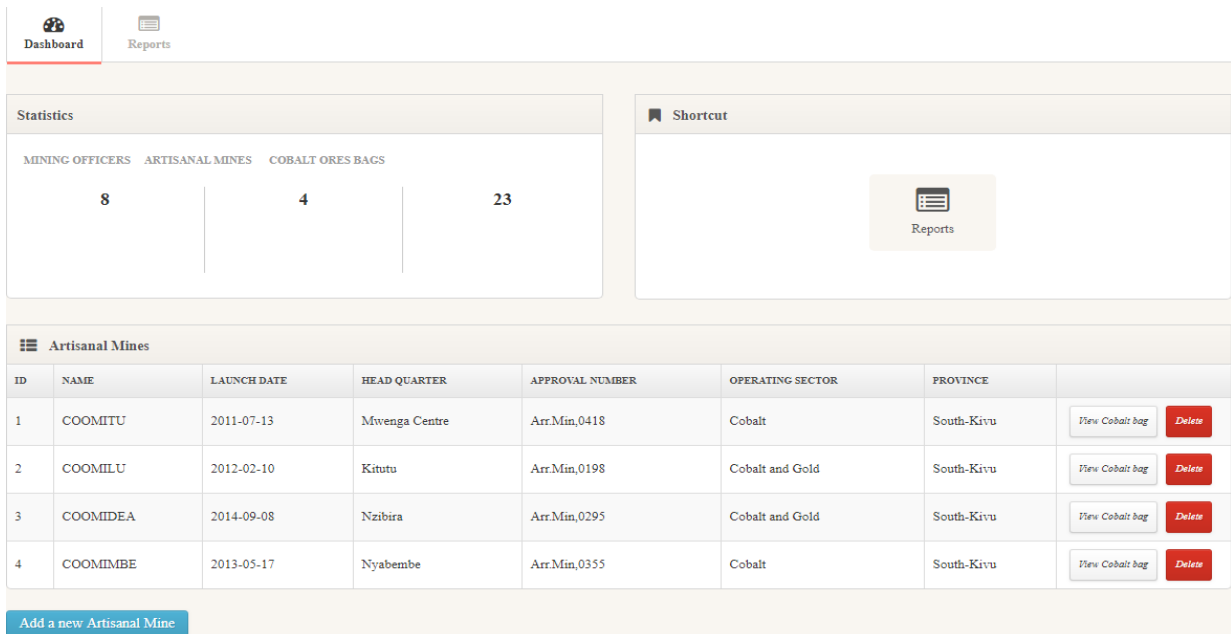


Figure 5.9 All Artisanal Mines

Add New Cobalt ores Bag

Figure 5.10 shows a the page where the mining officer adds the Cobalt ores bag in the system.

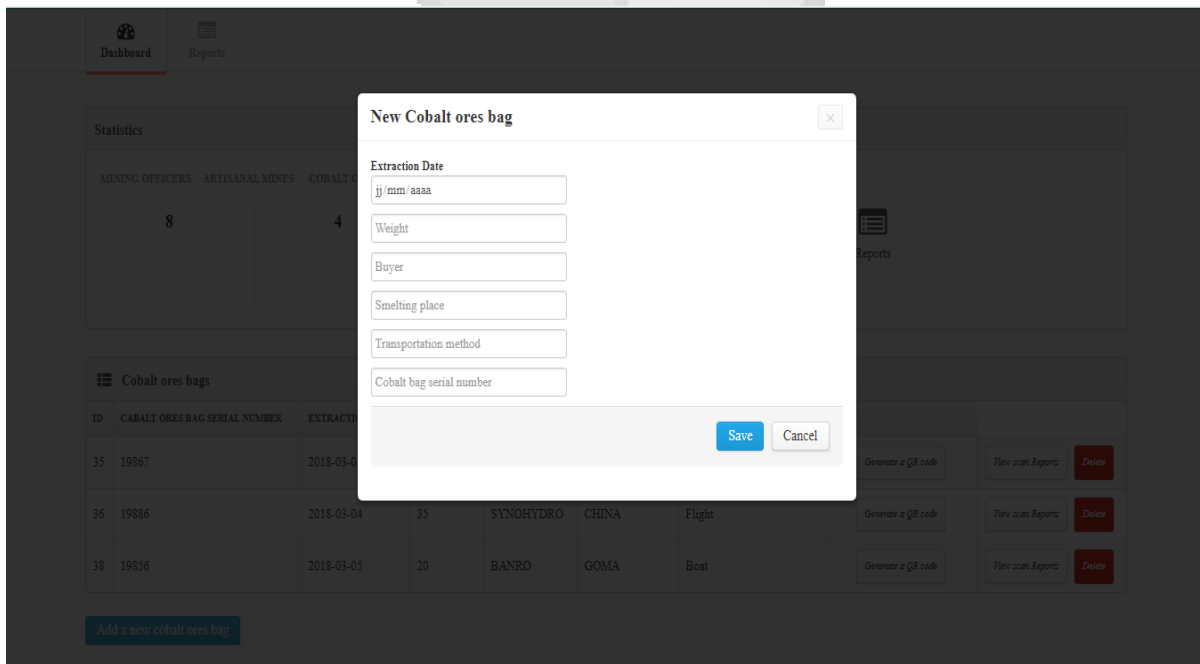


Figure 5.10 Add New Cobalt ores Bag

All Cobalt ores Bags

Figure 5.11 shows a list of all Cobalt ores bags that have been added into the system and associated to the artisanal mines by the mining officer.

ID	COBALT ORES BAG SERIAL NUMBER	EXTRACTION DATE	WEIGHT.KG	BUYER	SMELTING PLACE	TRANSPORTATION METHOD	
35	19867	2018-03-02	20	GECAMINE	Lubumbashi	Road	Generate a QR code View scan Reports Delete
36	19886	2018-03-04	35	SYNOHYDRO	CHINA	Flight	Generate a QR code View scan Reports Delete
38	19856	2018-03-05	20	BANRO	GOMA	Boat	Generate a QR code View scan Reports Delete

Figure 5.11 All Cobalt ores Bags

Generate QR code

Figure 5.12 shows the page where the mining officer generates a QR code for a Cobalt ores bag.

Cobalt Bag QR code

Print QR Code

Figure 5.12 QR Code Generation

Verification Report

Figure 5.13 shows the verification report of a Cobalt ores bag as submitted by a mine inspector.

Dashboard		Reports						
<div style="display: flex; justify-content: space-between; align-items: center;"> ☰ Cobalt ores Bag - 19886 </div> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 60%;">REMARK</th> <th style="width: 20%;">DATE</th> <th style="width: 20%;"></th> </tr> </thead> <tbody> <tr> <td>This cobalt bags was in good conditions</td> <td>2018-04-16</td> <td style="text-align: center;">Delete ✕</td> </tr> </tbody> </table>			REMARK	DATE		This cobalt bags was in good conditions	2018-04-16	Delete ✕
REMARK	DATE							
This cobalt bags was in good conditions	2018-04-16	Delete ✕						

Figure 5.13 Verification Report

Mine Production Report

Figure 5.14 shows mines production reports of the Cobalt ores bags as submitted by the mine inspector.

Dashboard		Reports												
<div style="display: flex; justify-content: space-between; align-items: center;"> ☰ Artisanal Mine - COOMITU-Arr.Min,0418 </div> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">QR CODE NUMBER</th> <th style="width: 30%;">WEIGHT KG</th> <th style="width: 40%;"></th> </tr> </thead> <tbody> <tr> <td>41890</td> <td>45</td> <td style="text-align: center;">Scan Details →</td> </tr> <tr> <td>41867</td> <td>45</td> <td style="text-align: center;">Scan Details →</td> </tr> <tr> <td>41831</td> <td>20</td> <td style="text-align: center;">Scan Details →</td> </tr> </tbody> </table>			QR CODE NUMBER	WEIGHT KG		41890	45	Scan Details →	41867	45	Scan Details →	41831	20	Scan Details →
QR CODE NUMBER	WEIGHT KG													
41890	45	Scan Details →												
41867	45	Scan Details →												
41831	20	Scan Details →												
<div style="display: flex; justify-content: space-between; align-items: center;"> ☰ Artisanal Mine - COOMILU-Arr.Min,0198 </div> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">QR CODE NUMBER</th> <th style="width: 30%;">WEIGHT KG</th> <th style="width: 40%;"></th> </tr> </thead> <tbody> <tr> <td>19867</td> <td>20</td> <td style="text-align: center;">Scan Details →</td> </tr> <tr> <td>19886</td> <td>35</td> <td style="text-align: center;">Scan Details →</td> </tr> <tr> <td>19856</td> <td>20</td> <td style="text-align: center;">Scan Details →</td> </tr> </tbody> </table>			QR CODE NUMBER	WEIGHT KG		19867	20	Scan Details →	19886	35	Scan Details →	19856	20	Scan Details →
QR CODE NUMBER	WEIGHT KG													
19867	20	Scan Details →												
19886	35	Scan Details →												
19856	20	Scan Details →												
<div style="display: flex; justify-content: space-between; align-items: center;"> ☰ Artisanal Mine - COOMIDEA-Arr.Min,0295 </div> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">QR CODE NUMBER</th> <th style="width: 30%;">WEIGHT KG</th> <th style="width: 40%;"></th> </tr> </thead> <tbody> <tr> <td>29578</td> <td>45</td> <td style="text-align: center;">Scan Details →</td> </tr> <tr> <td>29589</td> <td>45</td> <td style="text-align: center;">Scan Details →</td> </tr> </tbody> </table>			QR CODE NUMBER	WEIGHT KG		29578	45	Scan Details →	29589	45	Scan Details →			
QR CODE NUMBER	WEIGHT KG													
29578	45	Scan Details →												
29589	45	Scan Details →												
<div style="display: flex; justify-content: space-between; align-items: center;"> ☰ Artisanal Mine - COOMIMBE-Arr.Min,0355 </div> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">QR CODE NUMBER</th> <th style="width: 30%;">WEIGHT KG</th> <th style="width: 40%;"></th> </tr> </thead> <tbody> <tr> <td>35567</td> <td>20</td> <td style="text-align: center;">Scan Details →</td> </tr> <tr> <td>35578</td> <td>45</td> <td style="text-align: center;">Scan Details →</td> </tr> </tbody> </table>			QR CODE NUMBER	WEIGHT KG		35567	20	Scan Details →	35578	45	Scan Details →			
QR CODE NUMBER	WEIGHT KG													
35567	20	Scan Details →												
35578	45	Scan Details →												

Figure 5.14 Mines Production Report

System Administrator Login

Figure 5.15 shows the login page where the system administrator enters his username and password to get access to Cobaltcert Congo admin page.

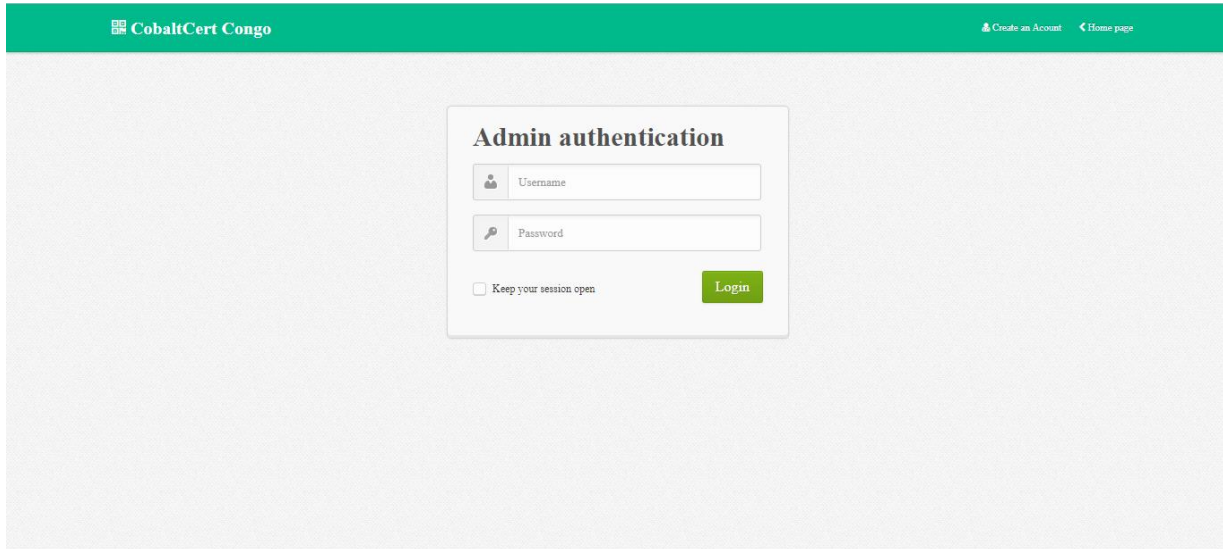
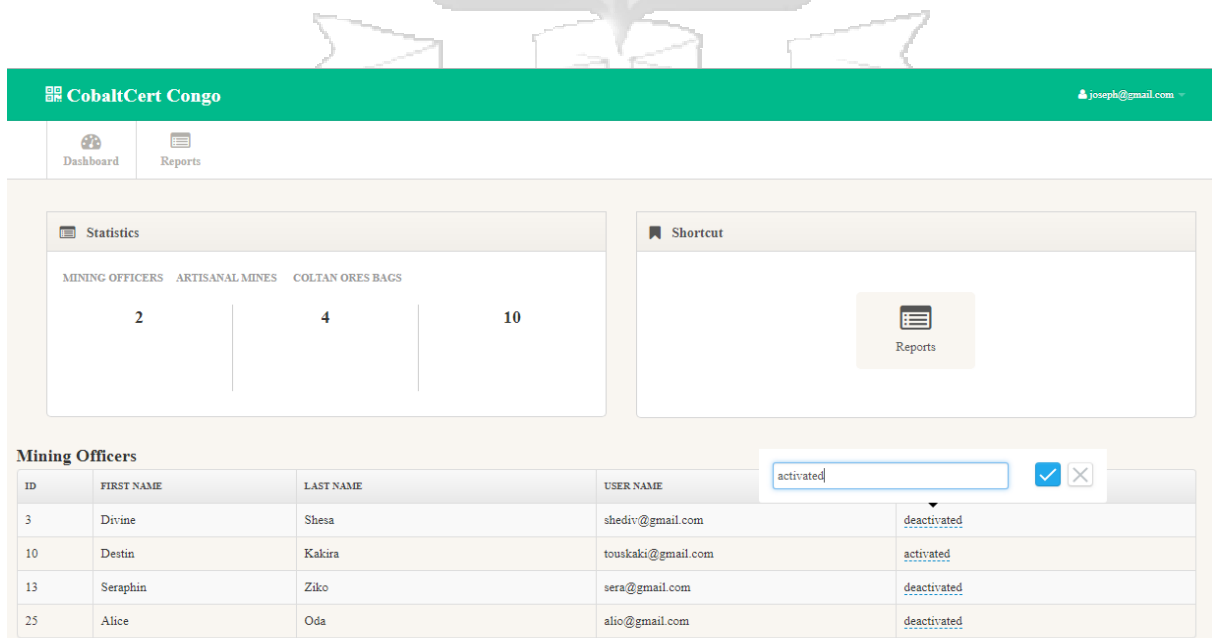


Figure 5.15 System Administrator Login

User Account Activation

Figure 5.16 shows the page where the system administrator manages users login status. He can activate the user account or deactivate it depending on whether the user has been assigned to another position.



ID	FIRST NAME	LAST NAME	USER NAME	STATUS
3	Divine	Shesa	shediv@gmail.com	deactivated
10	Destin	Kakira	touskaki@gmail.com	activated
13	Seraphin	Ziko	sera@gmail.com	deactivated
25	Alice	Oda	alio@gmail.com	deactivated

Figure 5.16 User Account Activation

Users Account Validation

Figure 5.17 shows a list of all users involved in the process of Tracking and Verification of Cobalt ores and their account status.

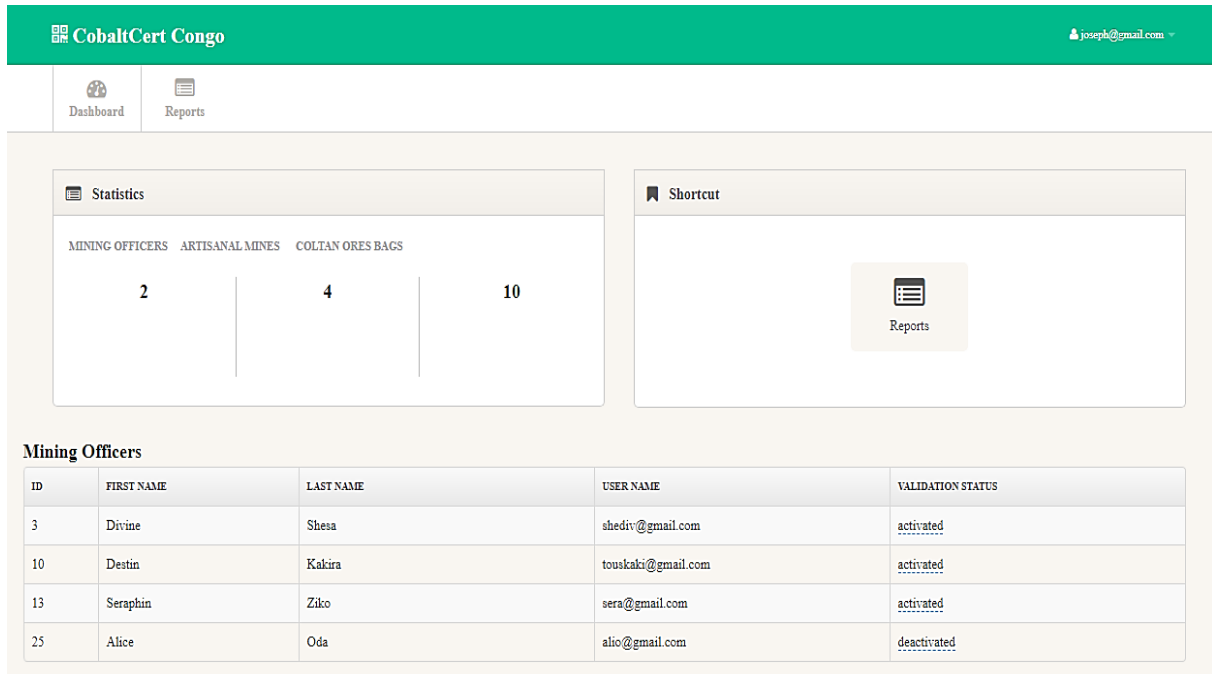


Figure 5.17 Users Account Validation

5.3 System Testing

This section describes the tests that were performed on both Android application and web application.

5.3.1 Compatibilty Testing

Compatibility test was used to ensure that the web application and the mobile application are compatible with the existing platforms. The web application was tested against the browsers commly used. Table 5.1 shows browser compatibility test results.

Table 5.1 Web Browser Compatibility Test

Browser Type	Compatibility
Firefox (Versions 8.0 and above)	Yes
Google Chrome (All versions)	Yes
Internet Explorer (Versions 4 and above)	Yes

Android Platform Compatibility Testing

The mobile application was tested against existing Android versions.

Table 5.2 Android Platform Compatibility Test

Android Platform	Compatibility
Android 10 (2.3.3)	No
Android 11 (3.0)	No
Android 11 (3.0)	No
Android 12 (3.1)	No
Android 13 (3.2)	No
Android 14 (3.3)	No
Android 15 (4.0.3)	No
Android 16 (4.1.2)	No
Android 19 (4.2)	No
Android 21 (5.0)	Yes
Android 22 (5.0)	Yes
Android 23 (6 .0)	Yes
Android 24 (7.0)	Yes
Android 25 (7.1.2)	Yes

5.3.2 Usability Testing Results

The usability and validation questionnaire was assembled using google forms. It was distributed to 15 respondents via email and data were analysed using google analytics.

Figure 5.18 shows that all respondents were able to generate a QR code

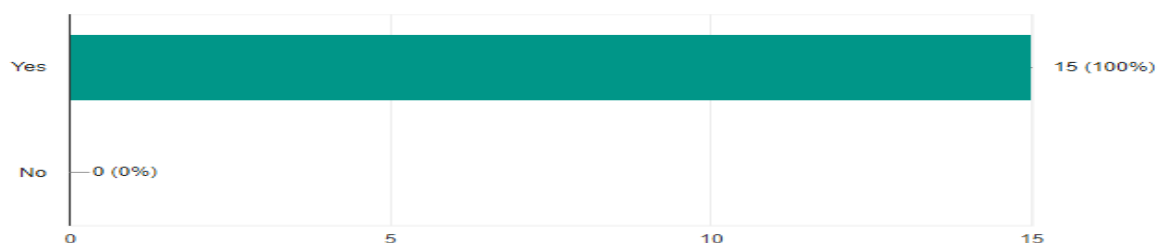


Figure 5.18 Respondents Ability to Generate a QR Code

All respondents were able to scan the QR code as illustrated figure 5.19

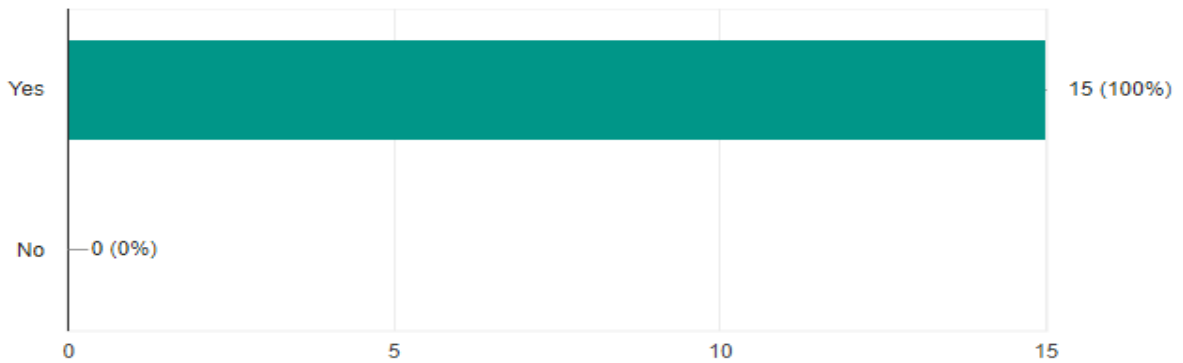


Figure 5.19 Respondents Ability to Scan a QR Code

Figure 5.20 illustrates some of the features that users thought were interesting.

QR code
Report
Reports and QR code
QR code generator
QR code scanner
Ability to view QR code scan report
add artisanal mines and cobalt ores bags
Send a report and remark
sending Scan report and remark
The ability to associate an artisanal mine to the cobalt ores bags extracted
View all the scan report
Generate QR code and view all the report submitted by the inspector

Figure 5.20 Features That Interested Users The Most

Figure 5.21 shows different comments and suggestions given by the respondents.

great app
This application is every excellent
The application is good but it should be implemented on other platform like IOS
The application is really helpful
This application has changed for good my work as mine inspector
Excellent app
Good application
The application is very goog but you should think about expanding it to other platform
it is just perfect
I did not get the chance to use the android application because I have a iPhone
Good job
This is a innovative application

Figure 5.21 Recommendations and Comments about the Application

5.4 Validation

The validation was conducted so as to check if the system implemented addressed the challenges in the process of tracking and verification of Cobalt ores in artisanal mines.

5.4.1 Validation Results

All the respondents affirmed that the functionalities provided by application helped solve the problems faced during tracking and verification Cobalt ores bags.

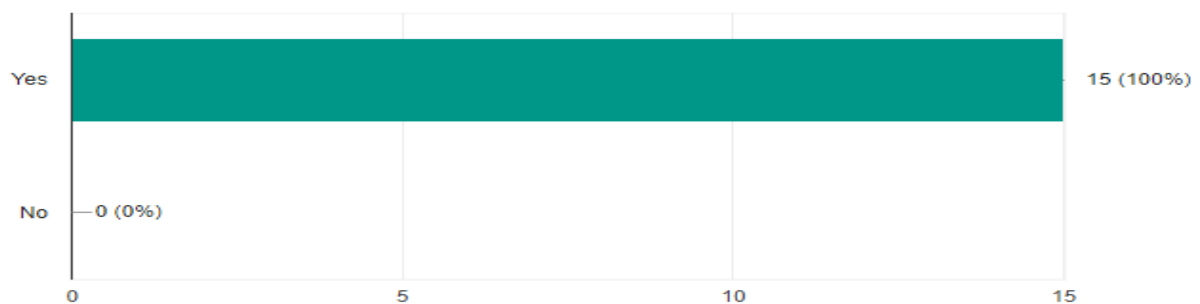


Figure 5.22 Capability of the Application to Solve Problems When Tracking and Verifying Cobalt ores Bags

All the respondents were satisfied with the proposed solution.

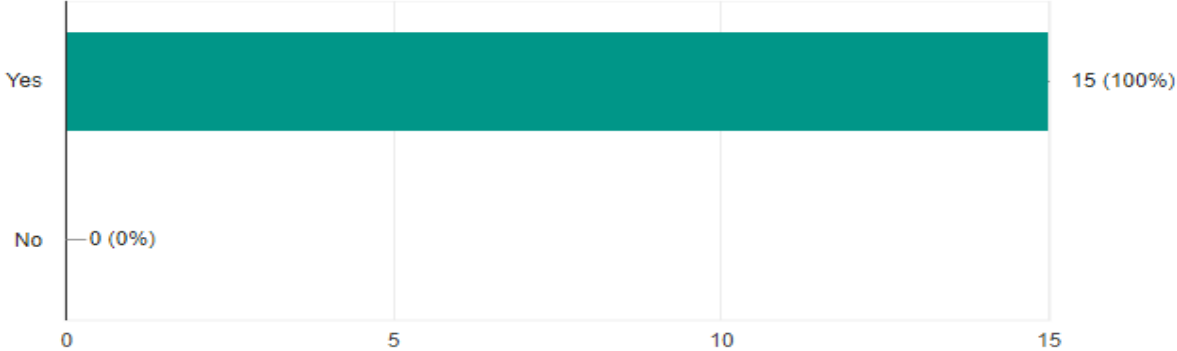


Figure 5.23 Satisfaction With the Implemented Solution

Figure 5.24 below illustrates how users rated their interaction with the mobile application. The majority of them found the navigability and the readiness of the system to be respectively very good, excellent and good. Users also found the system to be easy to learn and use, easy to find the core functionality, useful and satisfying.



Figure 5.24 System Performance Rating

All respondents were able to get the verification results after scanning the Cobalt ores bag.

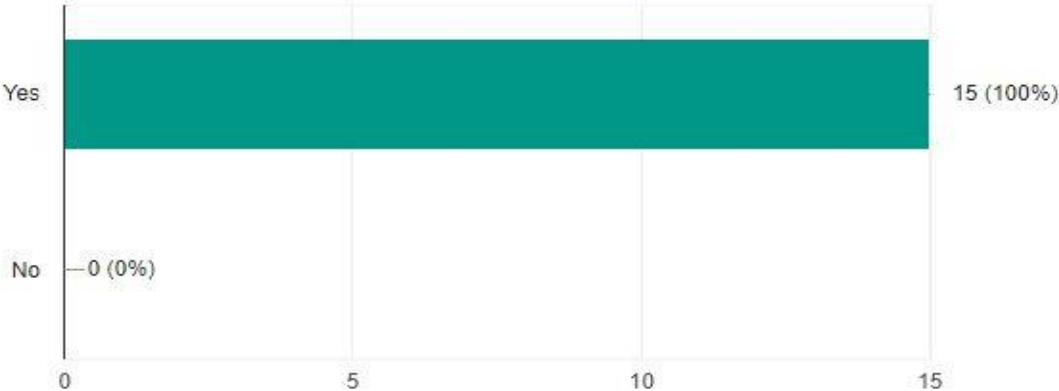
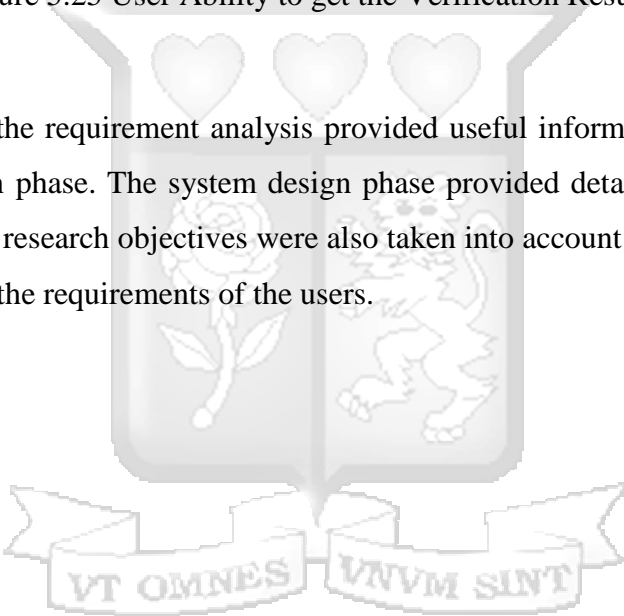


Figure 5.25 User Ability to get the Verification Results

5.5 Summary

Data collected during the requirement analysis provided useful information that was used in system implementation phase. The system design phase provided details on how the system was implemented. The research objectives were also taken into account so as to make sure the developed system met the requirements of the users.



CHAPTER 6: DISCUSSIONS

6.1 Introduction

This chapter discusses the research findings and achievements. It seeks to see if the research objectives were achieved and reviews the solution that was adopted.

6.2 Findings and Achievements

The research findings were used to develop a proper solution and identify the most suitable technology. The literature review showed that methods and technologies used to support tracking and verification of Cobalt ores in artisanal mine involve the Regional Certification Mechanism, Mine site Inspection and Certification, ICGLR Chain of Custody Tracking Standards, Regional mineral Tracking database Unit and Barcode technology. On one hand Mine site Inspection and certification could not guarantee the traceability of the Cobalt ores bags since it is always conducted once a year. On the other hand Regional Mineral Tracking Database unit which is managed by ICGLR uses data from member State chain of custody systems but DRC does not yet implement its own chain of custody system, therefore Regional Mineral Tracking Database unit can not be used to track and verify Cobalt ores in artisanal mines. Barcodes can be easily duplicated therefore they are unreliable.

The questionnaire were distributed to 95 respondents in South-Kivu, 55.8 % of them were mining officers and 44.2 % were mine inspectors. As required by the Ministry mines legislation, each employee has to swap his working position regularly. 43.3 % of respondents change their position from mining officer to mine inspector and vice versa every three months, 30.5 % change every six months and 24.2 % after one year.

Characteristics that respondents consider in identifying a licit Cobalt ores bag include artisanal mine approval number, Cobalt ores bag's serial number, weight, smelting place, transportation method and the buyer. The majority of respondents considered artisanal mine approval number to be very crucial when identifying a licit Cobalt ores bag, followed by the serial number of the Cobalt ore bag, the weight, then smelting place and transportation method and finally the buyer. 84.5% respondents own Android phones while 15.5% own iPhone. Respondents are accustomed to barcodes and QR code technologies. Respondents are capable of accessing the internet, downloading an application, taking a picture and sending or receiving emails.

Respondents wanted features like QR code scanner, feedback system and notifications to be included on the new application.

Tracking and verification of Cobalt ores was always being done manually in the Democratic Republic of Congo, there was a need to for a system that could perform this task automatically and achieve the same. To fill the gaps of the previous technologies and approaches used to track and verify Cobalt ores bags, QR codes technology was adopted to come up with a mobile application and a web backend system for online tracking and verification of Cobalt ores in artisanal mines. The mobile application was developed to be used by mine inspectors and to run on a mobile phone with an Android operating system which is data enabled and has a camera.

6.3 Review of Research Objectives in Relation to the Mobile Application

The first objective was to analyse the Characteristics of a licit Cobalt ores bag in artisanal mining sector. Findings from questionnaire demonstrate that respondents check the artisanal mine approval number, Cobalt ores bag serial number, weight, smelting place, transportation method and in some case the buyer. It is clear that these findings are in balance with the literature review as discussed in section 2.2.

The second objective was to analyse technologies currently used to support tracking and verification of Cobalt ores in artisanal mining sector. Results from findings indicate that respondents are familiar with Barcodes and QR codes technologies. These technologies are in line with the literature review as discussed respectively in section 2.4 and 2.5.

The third objective was to investigate how tracking and verification of Cobalt ores is currently done in artisanal mining sector. Results from findings indicate that respondents track and verify Cobalt ores bags manually as discussed in section 2.3, it is obvious that the literature review is in balance with findings from the study.

The fourth objective was to design, develop and test a mobile application for tracking and verification of Cobalt ores in artisanal mining sector. Findings demonstrated that users wanted to see features like QR code scanner, feedback system and notifications on the proposed application.

The developed application was in balance to the technology discussed in the literature review on section 2.5. The usability testing was used to test the developed application, as shown in Appendix B, section A.

The fifth objective was to validate the efficacy of the mobile application for tracking and verification of Cobalt ore in artisanal mining sector. Validation questionnaire was used to validate the developed application, as shown in Appendix B, section B. All the respondents did not face any problems generating, scanning the QR code and getting Cobalt ores bags details therefore the application proves to be genuine.

6.4 Advantages of the Application in Contrast with the Current System

In contrast with other approaches and technologies used by mine inspectors to track and verify the Cobalt ores in artisanal mines, this application proposes a web back-end application which is used to manipulate data and represent it.

The application provides a real-time access to the information about artisanal mines and the Cobalt ores bags associated to them. The information can be accessed anywhere, at any time.

6.5 Limitations of the Application

The mobile application was designed to be used only by mining officers and mine inspectors involved in the process of tracking and verification of Cobalt ores bag. Only users whose smartphones run on Android operating system can use the application. Internet connectivity is also required to use the application.

CHAPTER 7: CONCLUSIONS, RECOMMENDATIONS AND FUTURE WORK

7.1 Introduction

This chapter is a discussion of conclusions, recommendations and future work.

7.2 Conclusions

This study found out that the characteristics that mining officers and mine inspectors consider to determine whether the Cobalt ores bag is licit or authentic and come from a vetted artisanal mine include, artisanal mine approval number, Cobalt ores bag serial number, weight, smelting place, transportation method and buyer. An analysis of methods and technologies currently used to track and verify Cobalt ores established that those technologies involve barcodes and QR code.

The research highlights different methods and technologies used to track and verify Cobalt ores bags in artisanal mines. A mobile application with a back-end for tracking and verification of Cobalt ores was developed using one of the technologies discussed. Agile methodology was used to develop the system. In Agile methodology tasks are divided in small time frames. It is communication oriented, flexible and speedy. A questionnaire was distributed to 15 respondents for testing and validation.

7.3 Recommendations

To the Democratic Republic of Congo government, tracking and verification of Cobalt ores bags in artisanal mines decreases drastically branding and suggeling of Cobalt ores bags, therefore, my recommendation is to the Ministry of mines to adopt the system by generating unique QR codes for each Cobalt ores bag after associating it to the vetted artisanl mine through mining officers. The Cobalt ores bag details are saved in the central database from whose data mine inspectors can verify Cobalt ores bag before exporting it out of the country.

7.4 Future Work

This research focused only on tracking and verification of Cobalt ore extracted from artisanal mines. The researcher found out that the proposed solution could be expanded to other mining sector such as gold and diamond. In order to allow other mine inspectors who do not own Android phones, the application will be developed on other platform like iOS and windows.

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APPENDICES

Appendix A: Questionnaire

Dear Respondents,

I am a Masters student in the Faculty of Information Technology, Strathmore University conducting research entitled A MOBILE APPLICATION FOR TRACKING AND VERIFICATION OF COBALT ORES IN ARTISANAL MINES: A CASE STUDY OF DEMOCRATIC REPUBLIC OF CONGO. You have been selected to be part of this study. Your participation in filling out this questionnaire will be highly appreciated. Any data captured will not be treated with confidentiality and used for academic purpose only.

Kind Regards,

Destin Nsarhaza Kakira

*Required

Section A: Respondent detail

A1. Which category below fits to your work position*?

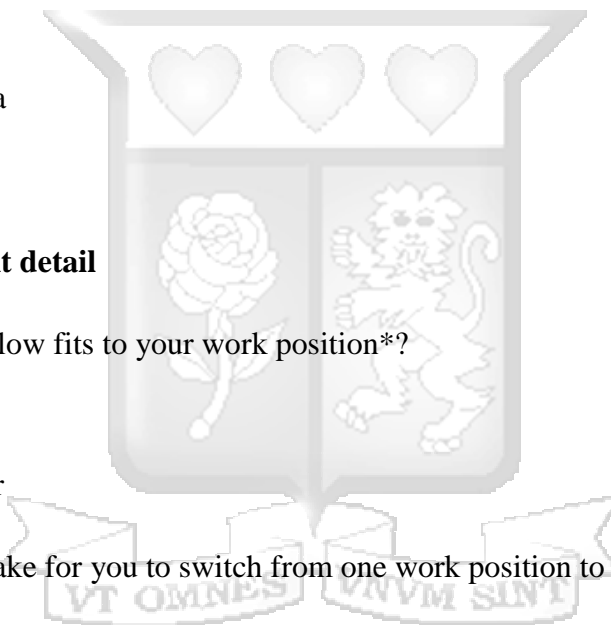
- Mining officer
- Mine inspector

A2. How long does it take for you to switch from one work position to another*?

- 3Months
- 6Months
- 1 Year

A3. Do you own a mobile device*?

- Yes
- No



A3. What operating system does your mobile use*?

- Android
- Windows
- iPhone(IOS)
- Blackberry
- Others

Section B: Characteristics of a licit cobalt ores bag.

B1. Please tick (X) ALL characteristics that you consider in identifying licit cobalt ores by (Choose ALL that apply)*

- Artisanal mine approval number
- Cobalt bag serial number
- Date of extraction
- Weight
- Smelting place
- Transportation destination
- Buyer

B2. Rank the importance attached to the characteristics when verifying the legality of Cobalt ore using the scale (High, Moderate, and Low)*

	High	Moderate	Low
Artisanal mine approval number	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cobalt ores serial number	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Date of extraction	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Weight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smelting place	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Transport Method	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Buyer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

B3. Please choose ONE option to indicate the official capacity of a licit Cobalt ores bag.

- 20kg
- 35 kg
- 40kg
- 45kg
- 50kg

Section C: Current methods of tracking and verification of Cobalt ores in artisanal mine in Democratic Republic of Congo.

C1. What do you check for when verifying a Cobalt ores bag? (Choose ALL that apply)*

- Confirm the weight
- Ensure that the cobalt ore have been extracted from a vetted artisanal mine
- Confirm the extraction date
- Confirm the cobalt ore bag serial number

Section D: Technologies available to support tracking and verification of Cobalt ores in artisanal mines.

D1. Are you aware with these technologies? (Choose ALL that apply)*

- Bar codes
- QR codes
- None

Section E: Application for tracking and verification of Cobalt ores in artisanal mines

E1. Are you able to do the following using a mobile phone? (Choose ALL that apply)*

- Access the internet
- Take a picture
- Download application
- Send or receive email

E2. What features would you like to see on the application for tracking and verification of Cobalt ores in artisanal mines (Choose ALL that apply)*

- Notifications
- Feedback system
- QR code
- None



Thank you for your time.

Appendix B: Usability Testing and Validation Questionnaire

Cobaltcert Congo Tracing and Verification System

*Required

Section A: Usability Testing

A1. Were you able to generate a QR code? (Choose ONE)* ?

- Yes
- No

A2. Were you able to scan a QR code? (Choose ONE)*

- Yes
- No

A3. Were you able to get verification results? (Choose ONE)*Yes

- Yes
- No

A5. How would you rate the whole application? (Choose only ONE per row)*

	Poor	Fair	Very Good	Good	Excellent
Navigability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy to learn and use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Easy to find the core functionality	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Responsiveness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Smelting place	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Useful and satisfying	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A6. What feature interested you the most? *

.....
.....

A7. Any comments, recommendations about this application? *

.....
.....
.....

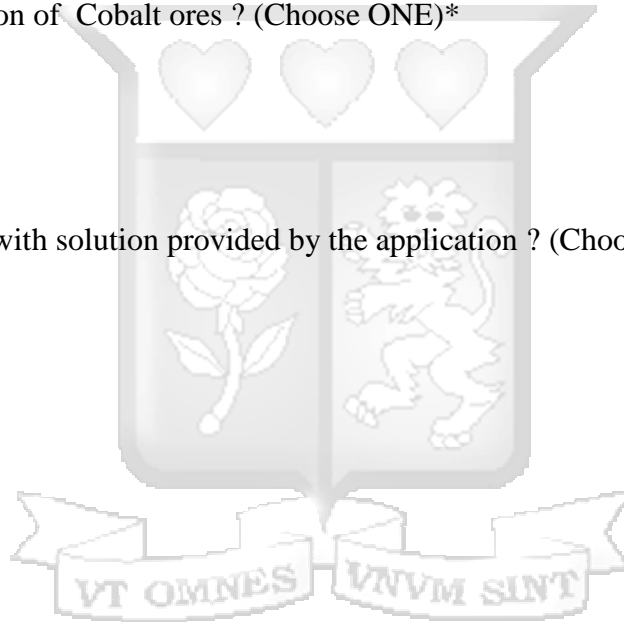
Section B: Validation

B1. Do the functionalities provided by the application solve the problems faced during tracking and verification of Cobalt ores ? (Choose ONE)*

- Yes
- No

B2. Are you satisfied with solution provided by the application ? (Choose ONE)*

- Yes
- No



Thank you for your time.

Appendix C: Wireframes

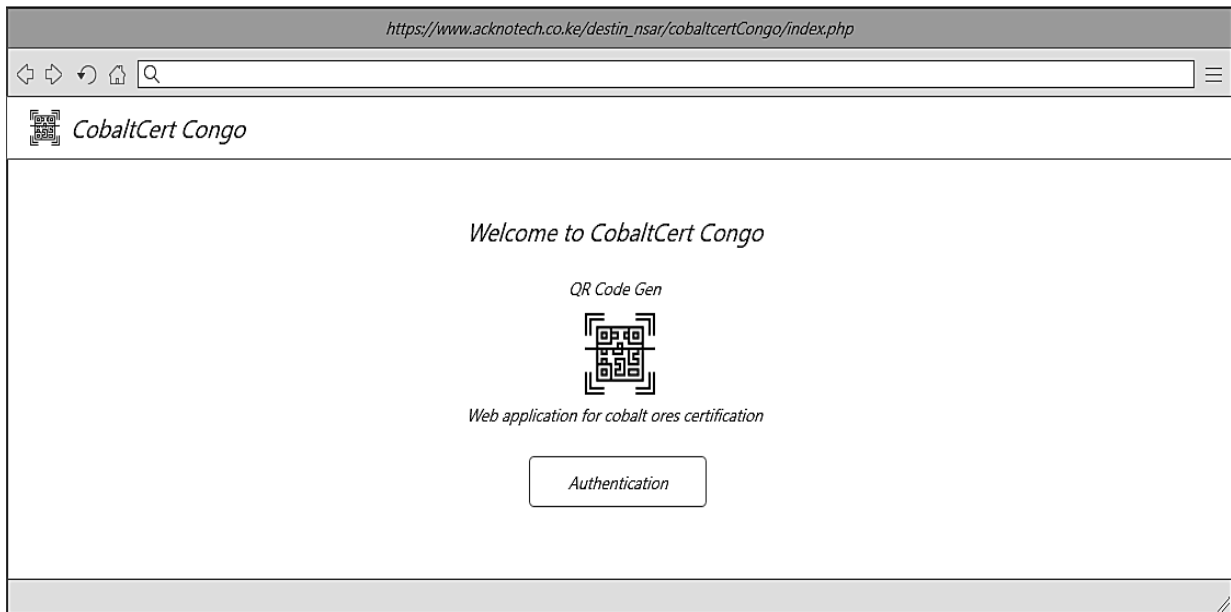


Figure C.1 Web Application Home Page Wireframe

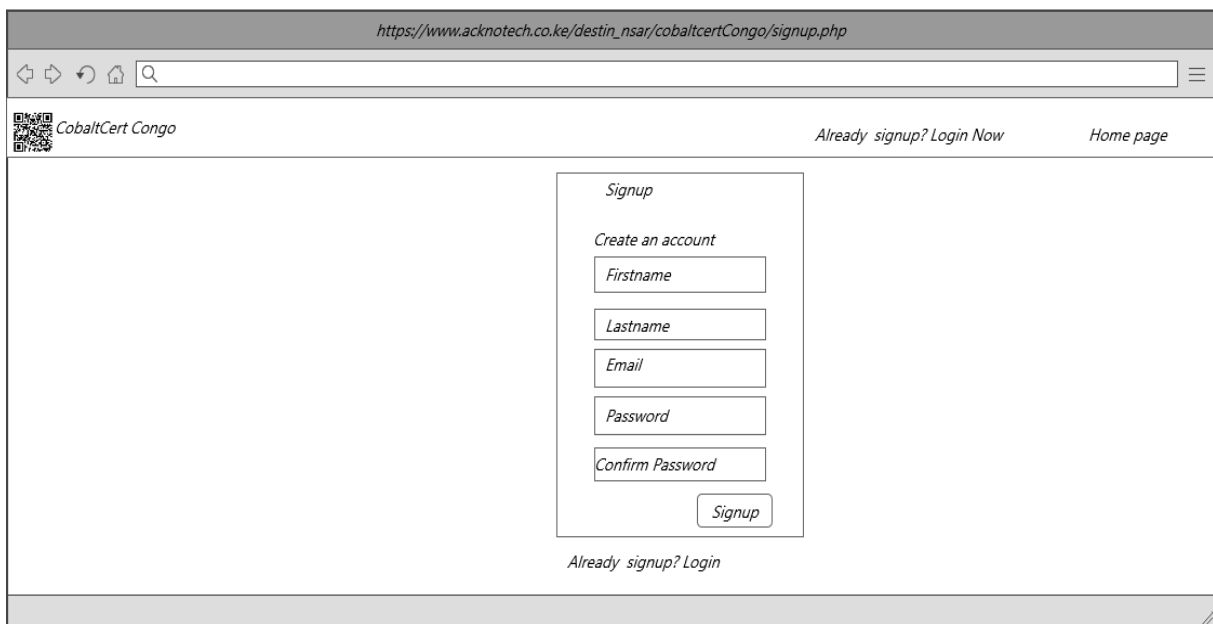


Figure C.2 Web Application User Signup Wireframe



Figure C.3 Web Application Administrator Signup Wireframe

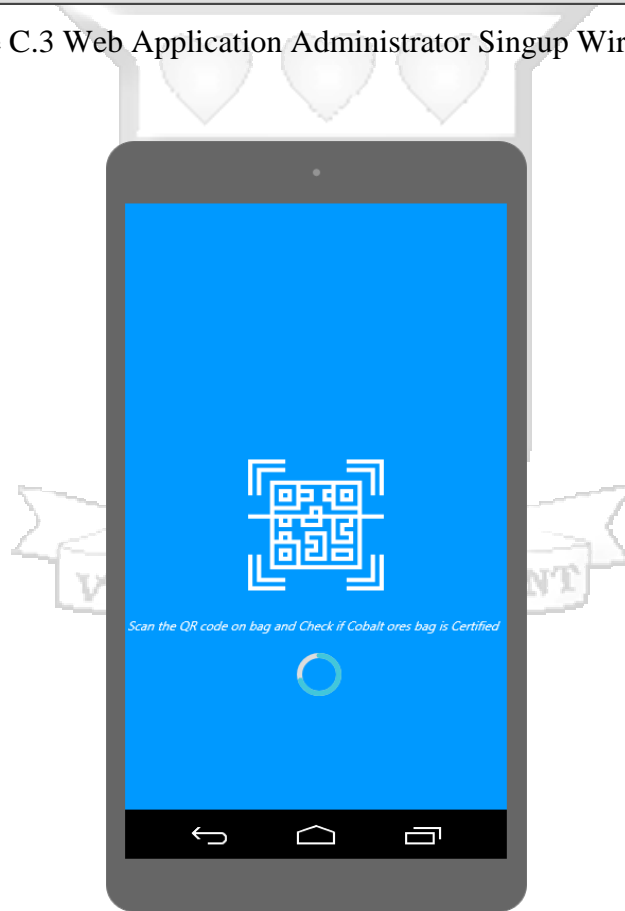


Figure C.4 Android Application Splash screen Wireframe

Appendix D : Screenshots

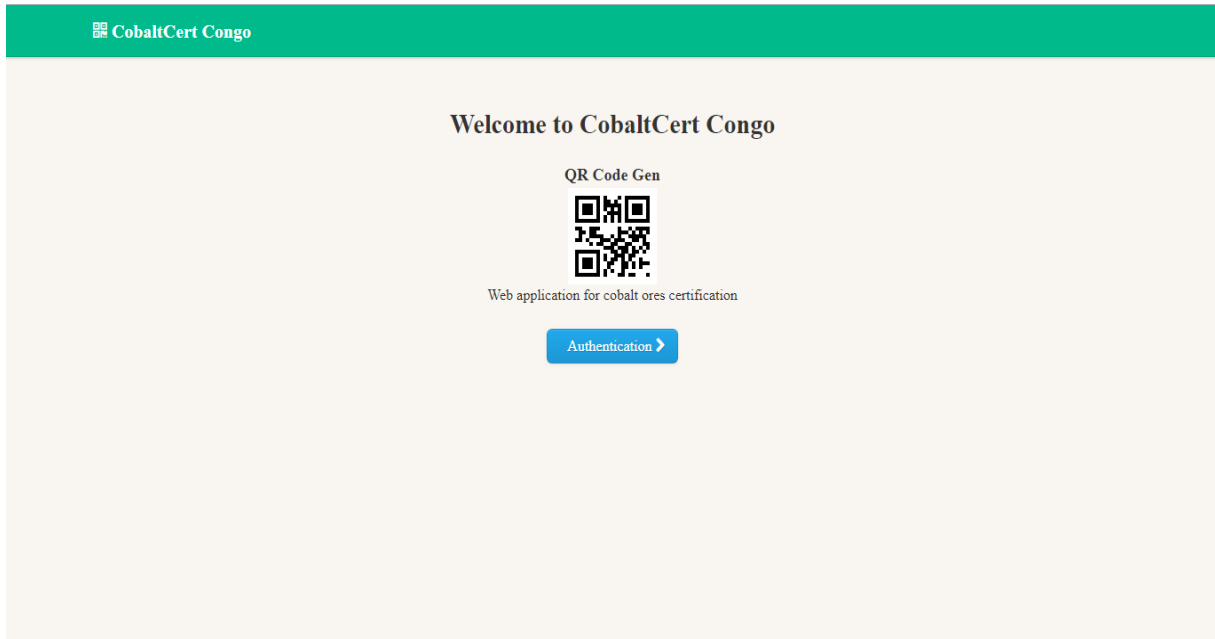


Figure D.5 User Web Application Home Page Screenshot

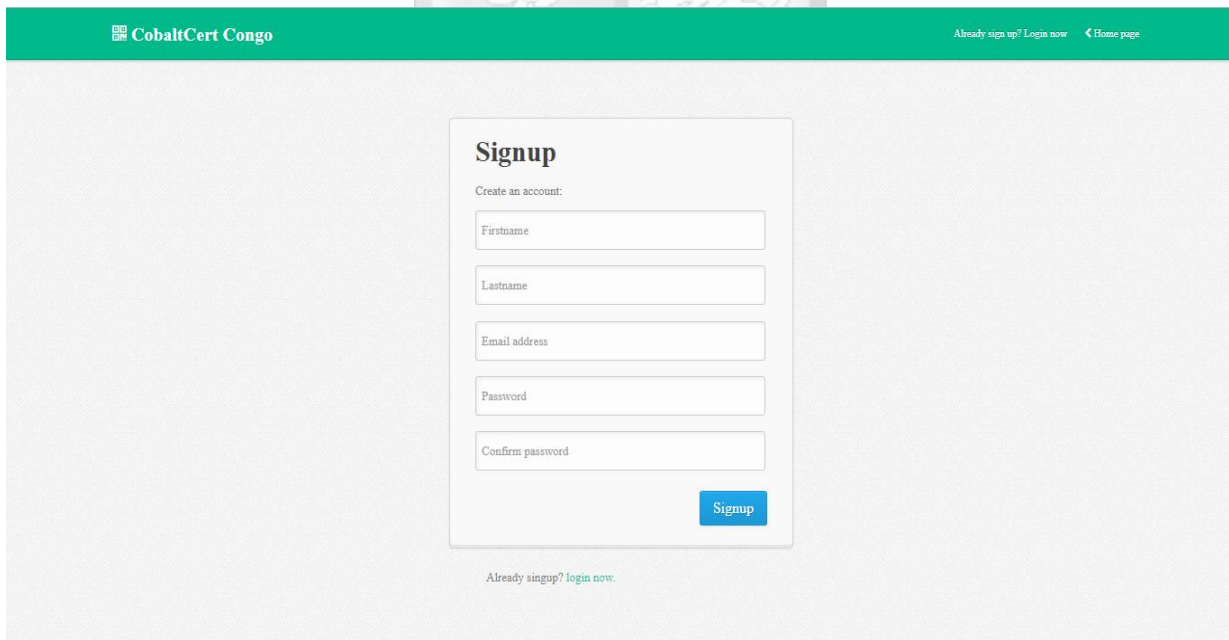


Figure D.6 User Signup Screenshot

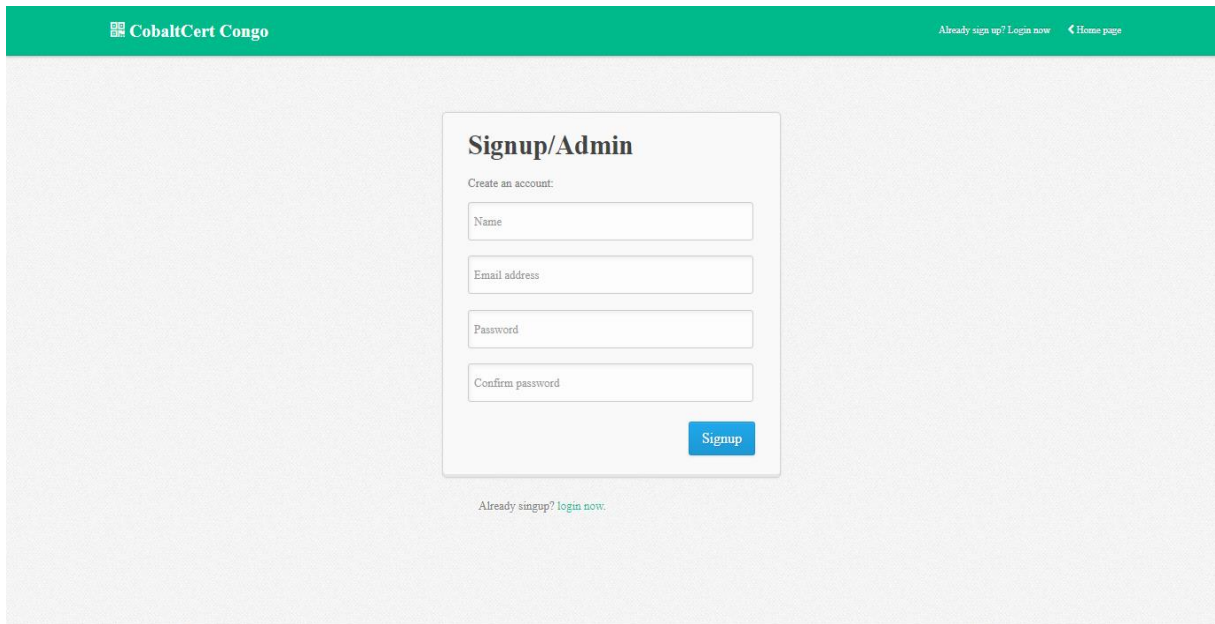


Figure D.7 Administrator Signup Screenshot

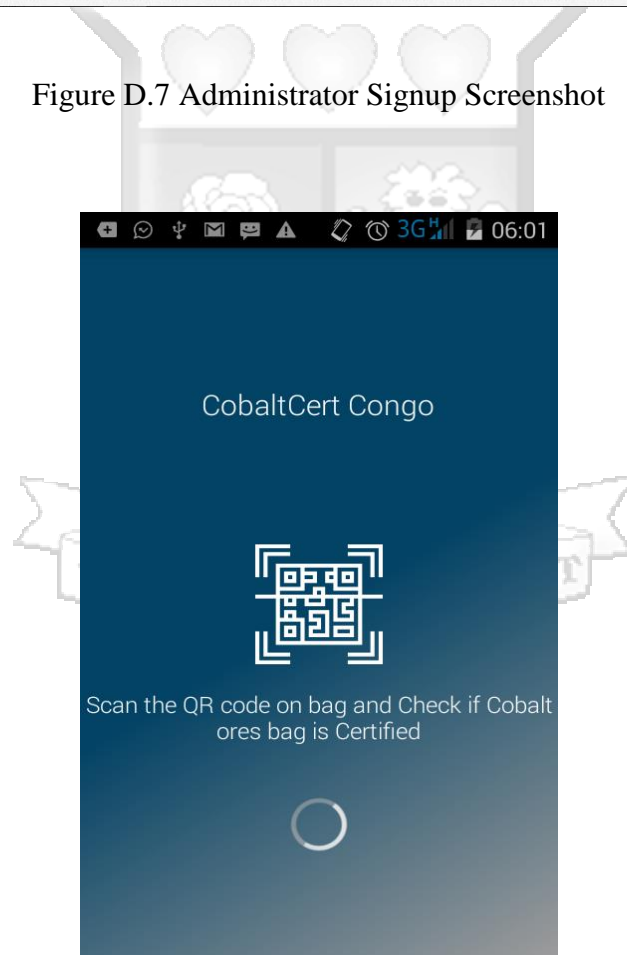


Figure D.8 Android Application Splash Screenshot

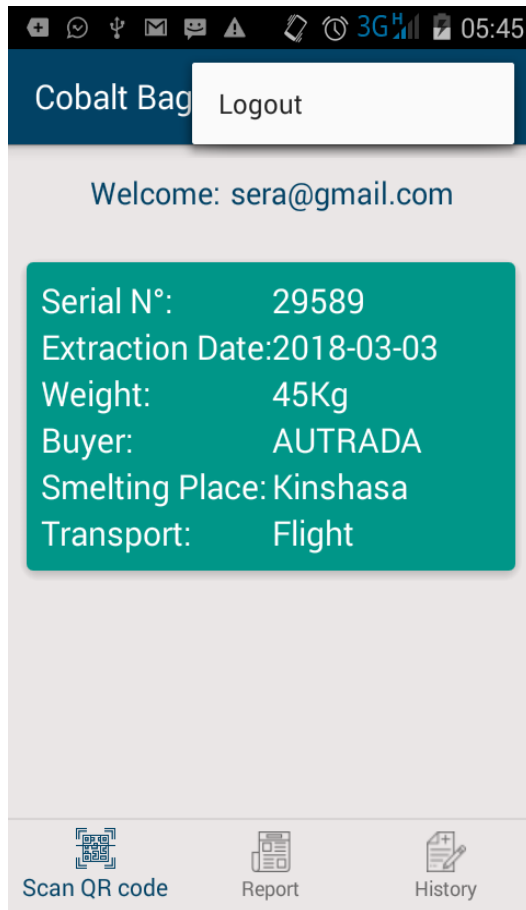
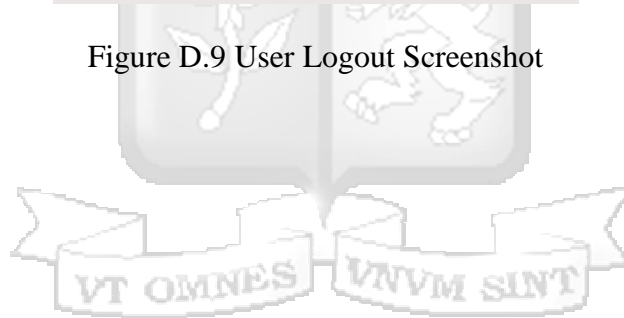


Figure D.9 User Logout Screenshot



Appendix E: Turnitin Report

The screenshot displays the Turnitin interface. The main document area shows the title: "A MOBILE APPLICATION FOR TRACKING AND VERIFICATION OF COBALT ORES IN ARTISANAL MINES: A CASE STUDY OF DEMOCRATIC REPUBLIC OF CONGO" and the author's name: "Destin Nsarhaza Kakira". The match overview sidebar on the right shows a total match percentage of 17% and a list of seven sources with their respective match percentages.

Rank	Source	Match Percentage
1	www.oecd.org Internet Source	4%
2	Submitted to Strathmor... Student Paper	3%
3	www.earthmagazine.org Internet Source	1%
4	www.mobile-libraries.bl... Internet Source	1%
5	qrbcn.com Internet Source	1%
6	thebestofafrica.org Internet Source	1%
7	Submitted to University... Student Paper	<1%

Figure E.10 Turnitin Report

