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Water Utility Mobile Application for Meter Reading: Android Based

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Abstract - **Water utility companies have a billing process which involves reading the meter and knowing the consumption of its customers. The major challenge faced by water utilities in Zambia is inaccurate customer billing. Affecting hugely this inaccurate customer billing is the manual meter reading process. For most water utilities in Zambia meter reading is a very complex task and the current method for meter reading uses manual work of reading the meter and updating details of the customers. The readings are maintained in a record book and due to manual processing of data there are possibilities of generating an incorrect bill. This process cause extra work load on the person who is capturing meter readings. The manual meter reading process is tedious and has a lot of challenges e.g. transfer errors when entering readings into the computer from the book, poor handwriting, manipulation of figures, lack of analysis of readings, low productivity and meter readers not visiting the property. The other problem with manual meter reading is that both the customer and the water utility company have challenges in monitoring and analyzing of consumption trends for customers and it is very difficult to monitor meter readers in the field. Although technologically advanced solutions exist, most water utilities in Zambia have no budget for them. The proposed model comprised of the android mobile application for capturing readings in the field and the web application for analysing readings and monitoring of field workers in real time. A usability test was undertaken consisting of 36 respondents which comprised of 75% meter readers and 25% customers. The results obtained from the mobile application, showed that the capturing, uploading, monitoring and analysis of readings were very good for the users and customers who participated in the study. Three user experience areas were used to undertake the survey namely, perceived ease-of-use, perceived flexibility and perceived information accuracy. Using the android and web application customers are also able to take their own readings and view graphical usage at any time anywhere.**

Keywords: Algorithms, Android, Android Application, Mobile Application, Web Application.

I. INTRODUCTION

Most water utility service providers in Zambia use manual process for taking meter readings. The readings are maintained in a record book or meter card and customers have to wait for the meter reader to read and update the meter card for them to know their consumption monthly. This results into customers and the water utility not being able to monitor consumptions regularly. In [9] they stated that manual meter reading process is time consuming, prone to readings manipulation and errors which result into customers complaining of inaccurate billing. This hugely affects water utility company non-revenue water, billing and collection efficiency. The manual meter reading process cause extra work load on person who is capturing meter readings

To solve the manual meter reading problem an android application and a web application was developed.The android based meter reading application is used by both the meter reader and customers to take readings while the web application is used for analysis of readings collected by both water utility company and its customers. The web application is also used for generation of reports on consumption graphical usage.

At the start of the meter reading cycle, a meter reader goes in the field visiting different customer properties and when taking readings at a property, a meter reader logs onto the application, search for the property by name, meter number, house number or account number, then enters the current reading from the meter, and finally when saving the application opens the camera and forces the meter reader to capture the image of the meter otherwise the readings are not saved if the picture is not taken, and automatically picks the GPS coordinates for the property. Then the meter reader send captured readings to server for further analysis. The meter reader can work either online or offline and has a choice either to send reading instantly or save on phone and send later. Thus this process reduces manual work and incorrect billing.

The time consuming process is turned into completely accurate and efficient process with more time on analysis. Customers are also able to take their own readings and analyze their consumption graphical usage at any time of the month using both the android application and the web application. This is a cheap and cost effective solution for manual meter reading process for water utility providers in Zambia. The application also works as a productivity monitoring tool and database cleanup tool. Economically, this study has produced a product that has the potential of improving efficiency and service delivery in the water sector. Both the water utility and their customers are able to make savings in their budgets by monitoring and analyzing their consumption usage. The mobile application will help management make informed decisions based on the information provided by the application.

Mobile Phone

In [3], they discussed the importance of the cell phone in everyday life that it decreases the chances of being forgotten. Everyday interaction with the phone makes the interface more familiar to the user. A cell phone is also less intrusive than dedicated devices. The familiar interface, non-intrusiveness, and affordability leads to less rejection from users.

II. TECHNOLOGIES

Android OS

Android operating system is one of the most widely used mobile Operating System these days and is based on the Linux kernel developed by Google. Android operating system is primarily designed for smartphones and tablets. Since Android is an open source it has become the fastest growing mobile operating system. Due to its open nature it has become favourite for many consumers and developers. Moreover software developers can easily modify and add enhanced feature in it to meet the latest requirements of the mobile technology. Android users download more than 1.5 billion applications and games from Google Play each month. Due to Its Powerful development framework users as well as software developers are able to create their own applications for wide range of devices. Some of the key features of Android operating system are: Application Frame work, Dalvik virtual machine, integrated browser, Optimized Graphics, SQLite, Media Support, GSM Technology, Bluetooth, Edge, 3G, Wi-Fi, Camera and GPS etc. To help the developers for better software development Android provides Android Software development kit (SDK). It provides Java programming Language for application development. The Android software development kit includes a debugger, libraries, a handset emulator based on QEMU (Quick Emulator), documentation, sample code, and tutorials[4]. The flexibility of the Android platform along with the phone's hardware capability allows systems to be extended in numerous ways[3].Android Operating system should ensure the security of users, user's data, applications, the device, and the network. To achieve the security of these components Android provides these key security features: 1) Security at the Operating System level through the Linux kernel. 2) Application sandbox for all applications 3) Secure interprocess communication. 4) Application signing. 5) Application-defined and user-granted permissions.

Java

It is general purpose, object -oriented programming language developed by sun micro system of USA in 1991 which was originally called as 'Oka' by James Ghosling. The important feature of the language is that it is a platform neutral language. Java is the first programming language which is not tied to any particular hardware or any OS. Programs developed in java can be executed anywhere on any system[8].

GPS and Google Maps

According to [5], they developed a location-based services supported Dr.What-Info system, i.e. a master multi-agent system on what the information is, using Google maps and an image recognition technology as a tourism information provider and as a route planner for tourists. In [6], they demonstrated an online mapping application that was successfully developed using Google Maps API v3, Google Geocoding, Microsoft SQL Server Express database, and Spry Framework for Ajax. The case study presented in this article provides the advanced functionality to display the locations and state-based summary counts of USDA's thousands of peoples' gardens on the Internet with customized icons and map legend. In a related study in [7], they observed an increasing interest in developing online map services using Google Maps Application Programming Interface (API), Yahoo! Maps API, Microsoft Bing Maps API, Nokia Ovi Maps API, and ESRI ArcGIS API. However, such online map services are mainly "mashups" in nature, meaning that they utilize Maps API as a platform and combine other spatial data from multiple sources to create new services. This paper[8] explains Multimedia mapping providing a unique approach to integrating geospatial information in digital map format and multimedia information (e.g., text, photographs, sound, and video). Multimedia mapping on the Internet is the direct result of advancement of Web mapping techniques, Internet technology, and Web standards (e.g., HTML, XML, Ajax). However, like traditional Internet GIS applications, multimedia mapping on the Internet is suffered from slow response time, limitation of data sizes, and the slow client/server communications.

III. LITERATURE REVIEW

The major challenge faced by water utilities in Zambia is inaccurate customer billing. Affecting hugely this inaccurate customer billing is the manual meter reading process. This section brings out some of the earlier used approaches to solve the problem at hand.

This study [9] explained that bill generation and meter reading is a very complex process in today scenario. The existing method of billing process uses manual work of taking reading of the meter, updating details of meter and sending bill to the customer. Up to now most methods implemented do not allow user to track their consumption each second.

In [10] they developed a system based on internet of things platform which was used for keeping track of consumption. It enables users to get the reading using an android phone and a client is able to view the graphical usage for a particular duration.

According to [2] it was explained that these days most of utility service provider companies use manual process for taking meter readings. Those readings are maintained on the meter card. This manual process is prone to errors and results into generation of incorrect bills. They developed an application which was used in utility meters for collecting data which is needed for billing purposes.There were savings in the budget for tracking monthly consumption of water. The application was built essentially to track the water usage and accessing the consumption data which resulted in better management of water.

In [11], they stated that the maximum part of the billing process is manual meter reading process which involve writing meter readings in the book and entering the same readings from the book onto the computer for bill generation.
This whole process results into billing errors and creates a lot of burden on the meter readers.In addition, customers have no platform to register any complaints. In this paper they suggested an Android application which was carried by meter

reader and a web application for customer to interact with the utility company. Using the Android application meter reader captured the image and uploaded to the server. The server performed the pre-processing on image and OCR extracted Meter reading and Customer number. Using these extracted details bill was generated, updating the database and PDF of the bill was send via mail to the customer.Thus this automated process reduced workload on the employees and incorrectness in the bill generation was avoided. However, the manual meter reading process was turned into efficient and automated process.

Since the mobile devices have been equipped with strong hardware and android operating system, many complex applications for daily activity and entertainment have been transferred successfully from computers to them. It is easier to perfom optical character recognition(OCR) for extracting data from images such as meter readings[12].

This paper [13] introduced a system based on image processing to obtain efficient and accurate reading of the digital meter. In this system the back camera of the mobile phone is used to capture the image of the meter. The system then applies a sequence of image processing functions to automatically extract and recognize the digits of the meter reading image. This image goes through three main stages: pre-processing which ends up with cropping the numeric reading area, segmentation of individual digits using horizontal and vertical scanning of the cropped numeric area, and recognition of the reading by comparing each segmented digit with the digits templates. The proposed system is implemented using Android Studio software with openCV library.It has been tested on 21 images of meters captured by Smartphone camera in Saudi Arabia, and results shows a recognition with the accuracy rate of 96,49% (per number digit) and 85.71% accuracy rate for the meter readings.

In [14], they proposed a system that is composed of a camera with a timer to instruct the camera to capture the photo of the meter reading at regular intervals of time. The system has a part for image pre-processing to convert the image to binary image, and then adjust it by changing brightness and contrast, finally crop the numeric area. To detect the digits of the meter reading and segment them, Support Vector Machine learning algorithm is applied to the pre-processed image. Then to each of the segmented image, Support Vector Machine is applied again to recognize digits from 0 to 9. Finally, the output is sent to the Server along with other details such as Consumer name, consumer number, date/time etc. If the server didn't receive the meter reading within specified time, then server assumes camera failure and sends out service people to change the faulty camera.

In [15],they introduced an automatic meter reading concept (AMR) which collected the readings automatically and then the system transfers them to the central database for billing. With this automation speed, accurateness and effectiveness increased. Here transistor logic (TTL) serial camera is used to capture the image and wirelessly transfer this to server or personal computer (pc) where it undergoes processing to extract digits and with reference to previous month data base new bill is generated with tariff consideration.

IV. EXISTING SYSTEM

The current procedure is that meter reader records meter readings in the record book or meter card. Then he/she has to go back to the office and start entering the readings from the book into the computer thus causing extra workload on the person taking readings. Though advanced solutions exist, most water utilities in Zambia have no budget for that. According to the customer's perspective, there is no way for them to monitor their consumption usage or take their own readings. Also the water utility companies face difficulties in monitoring staff productivity and analysing consumption trends for customers.

Problems with the existing system

i. Manipulation of figures
ii. Time consuming
iii. Transfer errors when entering readings onto the computer
iv. Meter readers not visiting the property
v. Meter cards or books getting soaked
vi. Lack of monitoring and analysis of readings

V. PROPOSED SYSTEM

The proposed system is to develop an android application and a web application. Android application will be used by the meter reader to get the meter reading in the field and will also be used by customers to take their own readings and view their consumption graphical usage. The web application will be used for further analysis of the readings by both the customer and the meter reader. This solution is more beneficial to meter readers, water utility company and the customers.

The process is simplified in that at the start of the day a meter reader goes with the phone in the field. Meter reader simply logs onto the application, search for the property by Name, Meter number or Account Number, then enters the current reading, and finally when saving, the application captures image of meter, and automatically picks the GPS coordinates for the property. The meter reader has a choice either to send reading instantly or save on phone and send later. Thus this process reduces manual work, transfer errors, frequenting the office, manipulation of figures and makes work very easy for the meter readers. All the properties are visited and photo taken for each property and meter which acts as proof of visiting the property. Customers are also able to take their own readings and monitor their graphical usage at any time anywhere. Using the web application productivity for the employees can be monitored in real time.

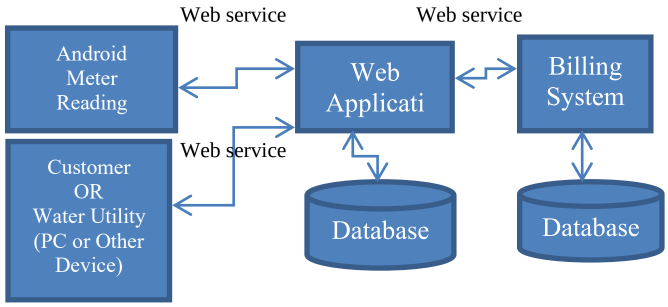

Fig 1: System Architecture

VI. RESEARCH METHODOLOGY

The methodology adopted for this research is design science on the basis that it is particularly suited to the task of solving the manual meter reading problems more efficiently or more effectively. The process model employed is the Design Science Research Process (DSRP). According to [16] this process has been widely utilised within information systems research. The main testing of the model (the DSRP Evaluation stage) involves independent verification and validation.

This section presents the methodology used in this research. The methods and processes used in this research are discussed in relation to how they address the research objectives. Design science [16]–[18] has been selected as the methodology used for this research. The selection of Design Science rather than alternatives such as Requirements Engineering [19] was made on the basis that it is particularly suited to the task of creating an artefact. In [20], they pointed out that design sciences' focus on designing solutions which is an 'ideal approach' in creating a mobile application for meter readings for water utility companies in Zambia.

The design science paradigm is concerned with the creation, and subsequent evaluation, of IT artefacts within an organisational context to solve specific problems [17], [18]. These artefacts include constructs, models, methods and instantiations (real-life products such as prototype systems) [18]. In [18], they differentiated between routine design and design science research by stating that routine design applies existing knowledge, such as current best practices, to organisational problems whereas design science research addresses either unsolved problems in new ways or solved problems more efficiently or more effectively.

The artefact associated with this research is a mobile application for meter readings for water utility companies in Zambia that addresses the manual meter reading problem more efficiently and effective. The organisational context is that of water utility companies in Zambia.

Process model for the research

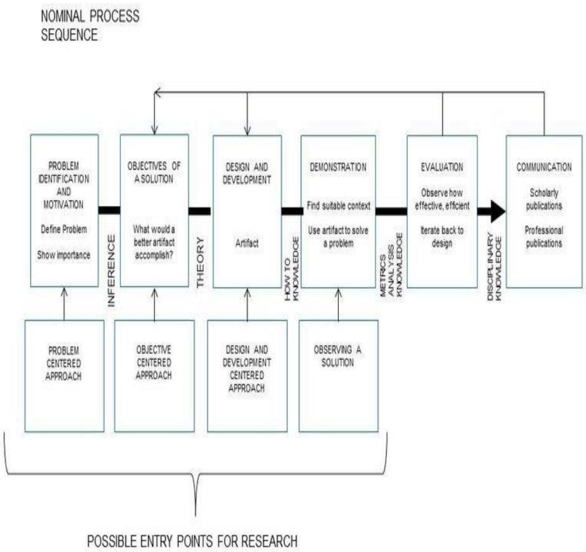

Fig 2 Design Science Research Process (DSRP) model after[16] .

Brief descriptions of the activities in the DSRP are outlined below:

Activity 1
The first of the activities, 'Problem Identification and Motivation', involves establishing the problem to be addressed and justifying the research based on the perceived benefits of the resulting artefact.
Activity 2
This involves creation of the 'Objectives of a Solution' and requires the researcher to define the objectives which will be based on the problem to be solved.
Activity 3
The activity 'Design and Development' involves the creation of the artefact.
Activity 4
For the 'Demonstration' activity the artefact is used in some appropriate environment to solve the stated problem.
Activity 5
In the 'Evaluation' activity the performance of the artefact is reviewed with reference to the stated objective(s) from activity 2. It may be the case that at this stage the researcher considers that the artefact requires further design and development and therefore resorts to activity 3 as part of an iterative process.
Activity 6
The final activity is 'Communication' in which the researcher puts forward their research to add to the body of knowledge in their field.

Applying the methodology to the research problem

This research has its focus on the problem of manual meter reading process for water utility companies in Zambia. The research is therefore based on a 'problem centered approach' and as such the entry point in the DSRP is at the first activity. The following sections describe how the chosen methodology will be followed in the course of this research. In addition, as the DSRP does not include the low-level detail of how to carry out the activities within the individual stages.

Problem Identification and Motivation

For the problem identification of this study refer to introduction paragraph one.

Objectives

For the objectives of this study refer to introduction paragraph two.

Design and Development

The Design and Development stage of the Pfeffers et al DSRP method has been adopted for this research. Below are the research questions.

1. How can meter readings for a water utility company be captured using a mobile device and sent to the server for further analysis by both the water utility company meter readers and its Customers?
2. How can a water utility company and its customers generate reports on consumption trends and consumption by graphical usage using a web application?

3. How can a water utility company and its customers analyze and monitor customer meter readings using a web application and an android application?
4. How can we assess and evaluate a mobile and a web application?

Model Design

There are a number of different methods from which to choose depending on the problem being investigated. Model design will usually involve some data collection to inform the parameters for the model**.** This Research covered the case of the Zambian water utility manual meter reading process. This research was designed to find a solution that was able to ease the manual meter reading process. Our Data sets included information on the following:

Customer details, date of picking reading, captured photo of the meter, current reading, and GPS coordinates of the property, total no of properties of a meter reader, towns, reading history of customers and consumption.

The next step is building an artefact. A number of software programs are now available to support specific design science methods but if no suitable software package is available then the researcher writes the program.

Model Creation

The model built comprises of the following components:

1. Algorithm for Initialising Readings
2. Algorithm for capturing image and meter reading
3. Algorithm for Uploading Readings and Images
4. Algorithm for Analysing readings

Demonstration

The DSRP followed in this research requires that the Demonstration activity involves the artefact to be used in some appropriate environment to solve the stated problem. The Demonstration activity was undertaken in order to identify any obvious errors/omissions.

Model Verification

Verification involved running and testing whether or not the artifact was working as it should. In this research, the model verification involved running several iterations of tests until the algorithms were able to produce usable results such as are represented in figure 3 to figure 13.

The Screen shot below show the sample output analysis generated using the algorithm for analyzing meter readings.

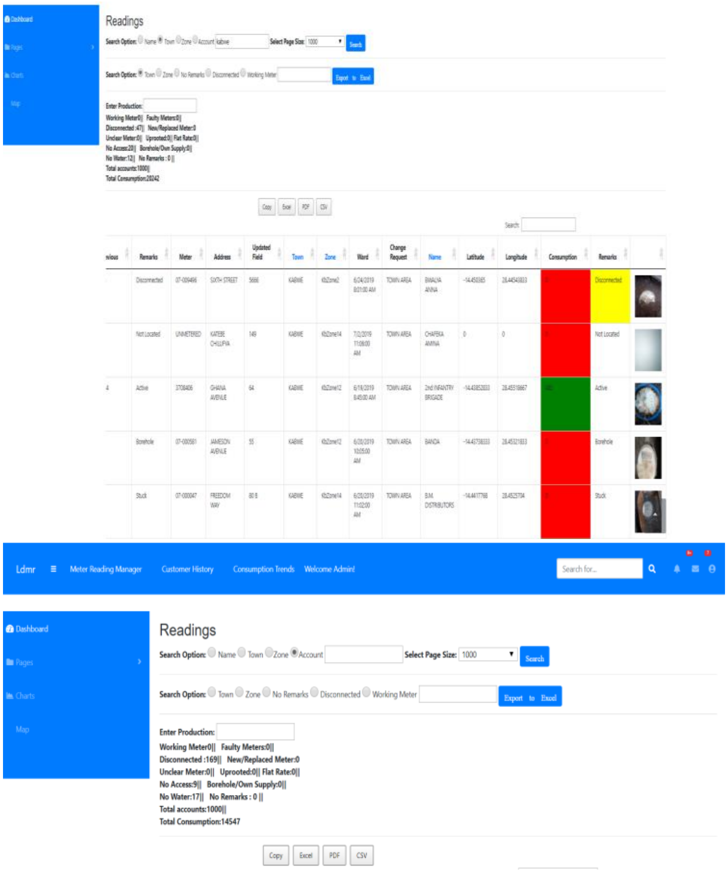

Fig 3 Sample generated meter reading analysed data.

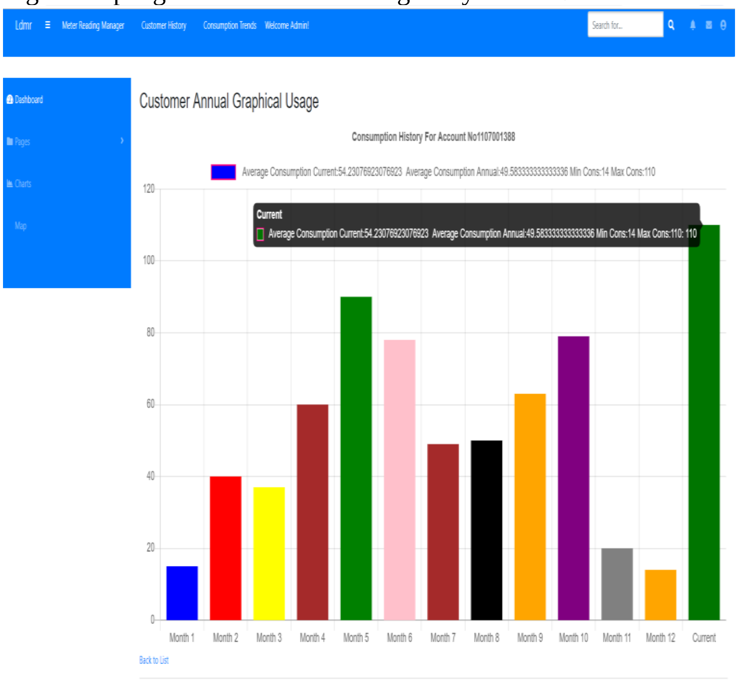

Fig 4 Sample generated graph for customer annual graphical usage.

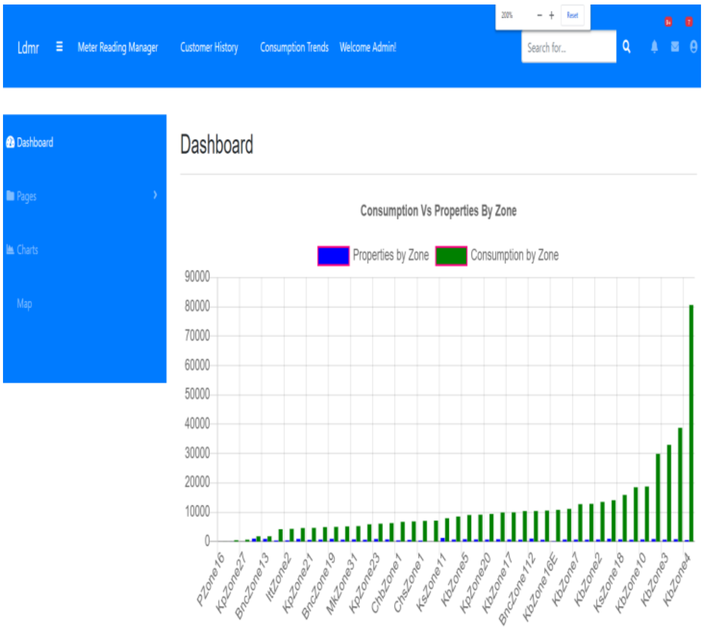

Fig 5 Sample generated graph for zonal consumptions.

Fig 6 Sample generated graph for meter readers productivity and consumption.

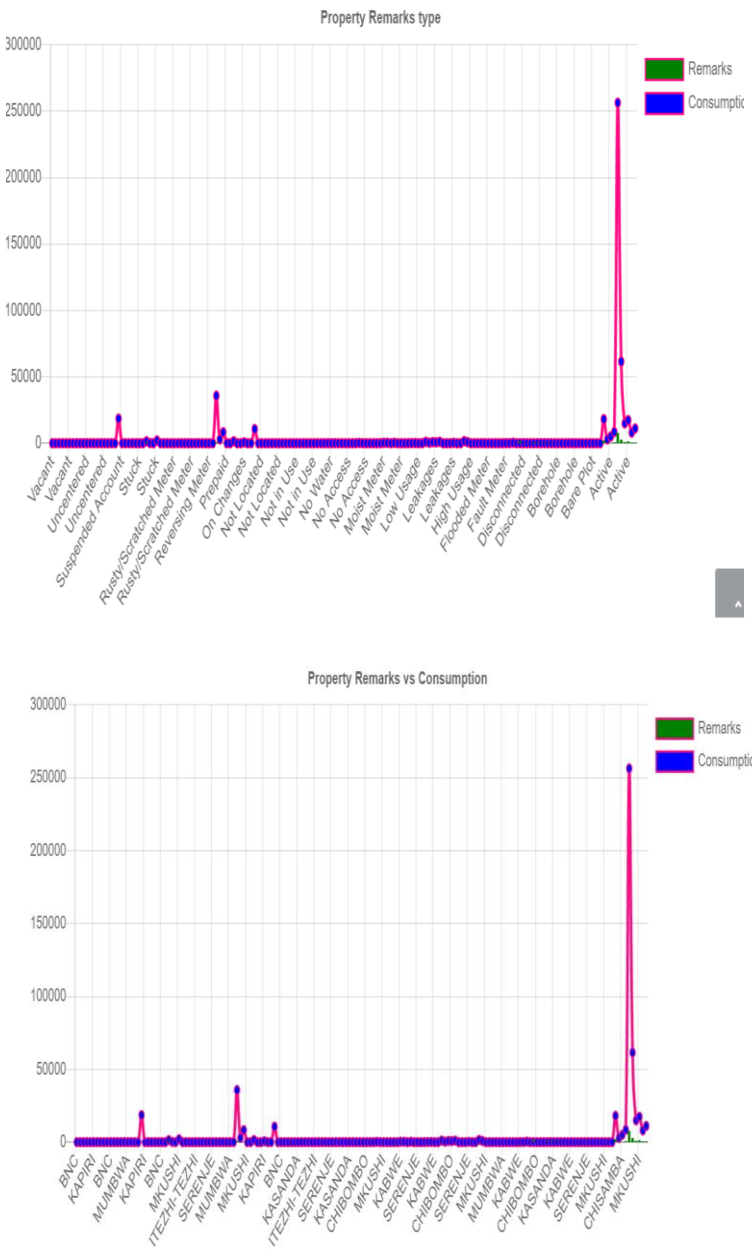

Fig 7 Sample generated graph for remarks by town and type.

The above represents a sample of the generated information and graphs after running the program to upload captured readings on the ground.

Map showing properties visited

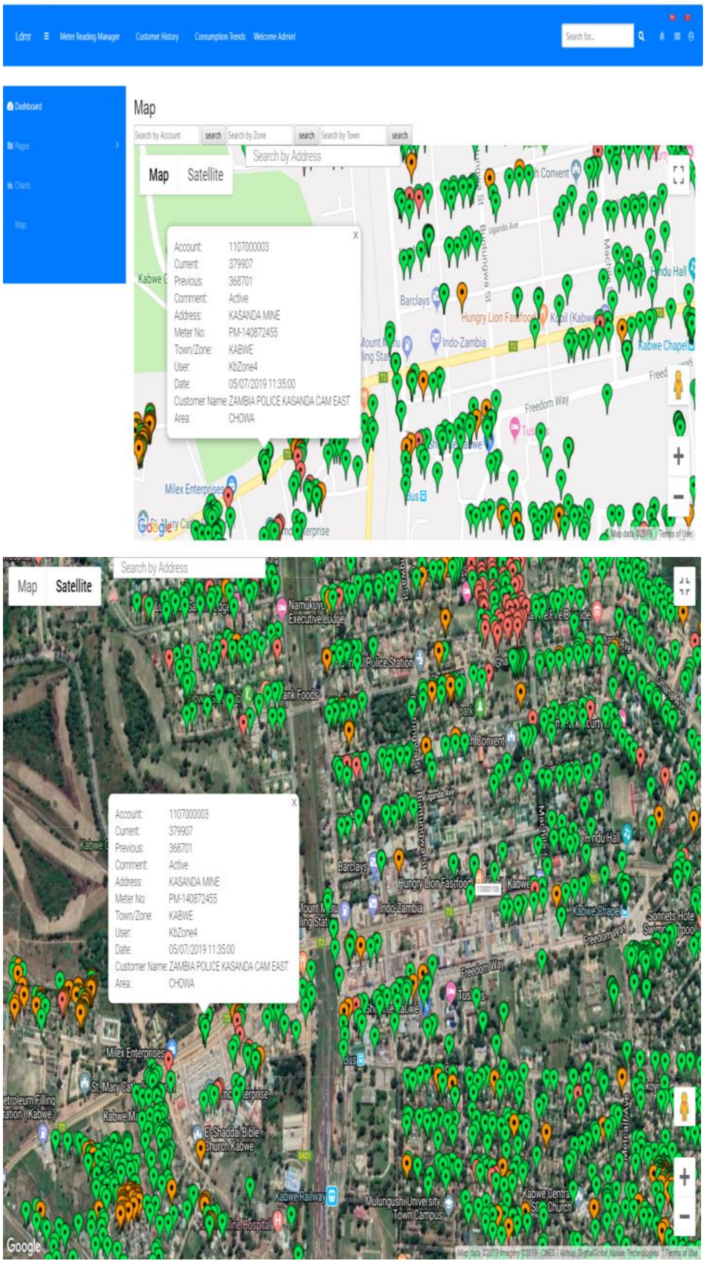

Fig 8 Map showing properties visited

The map in figure 8 shows the properties visited by the meter readers in real time. The green marker indicate working meter, the orange markers indicate faulty meter and the red markers indicate a disconnected property.

Android Application

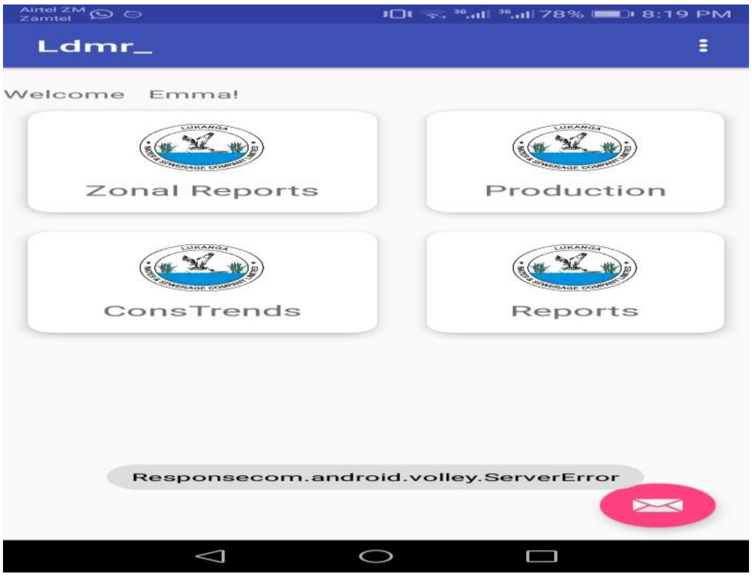

Fig 9 Main dashboard

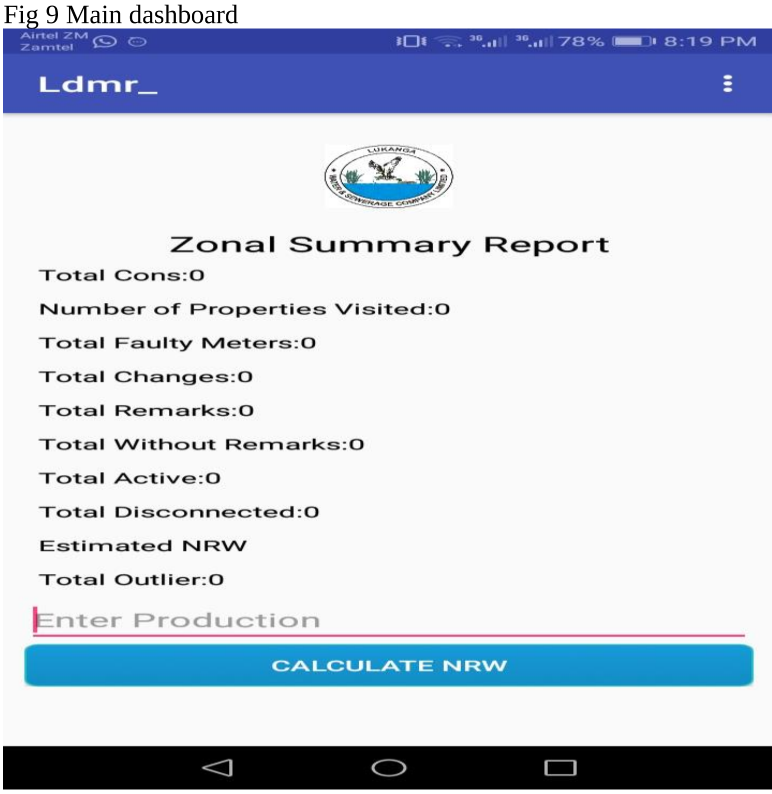

Fig 10 Zonal summary report

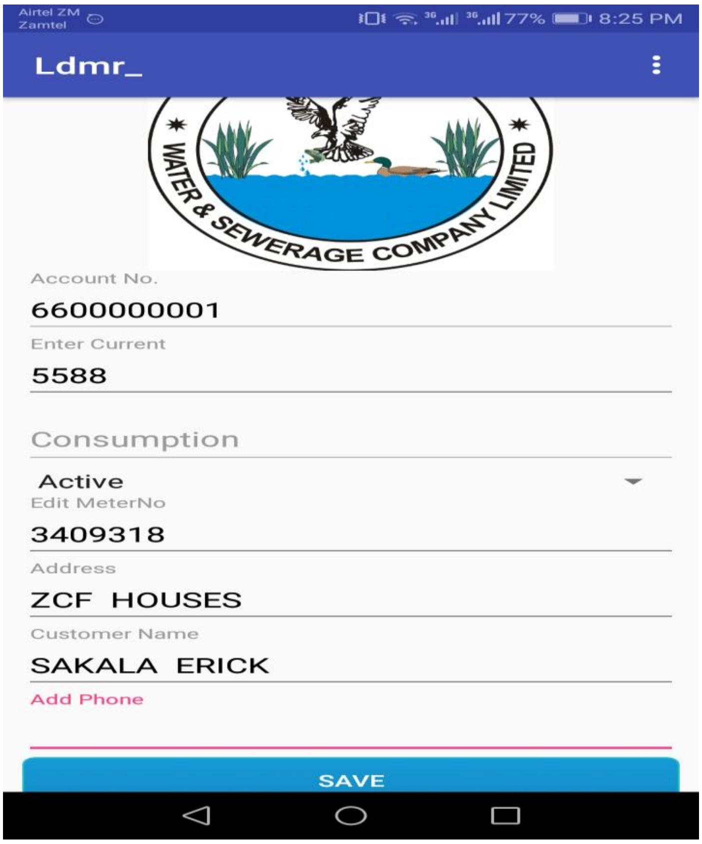

Fig 11 Capturing readings

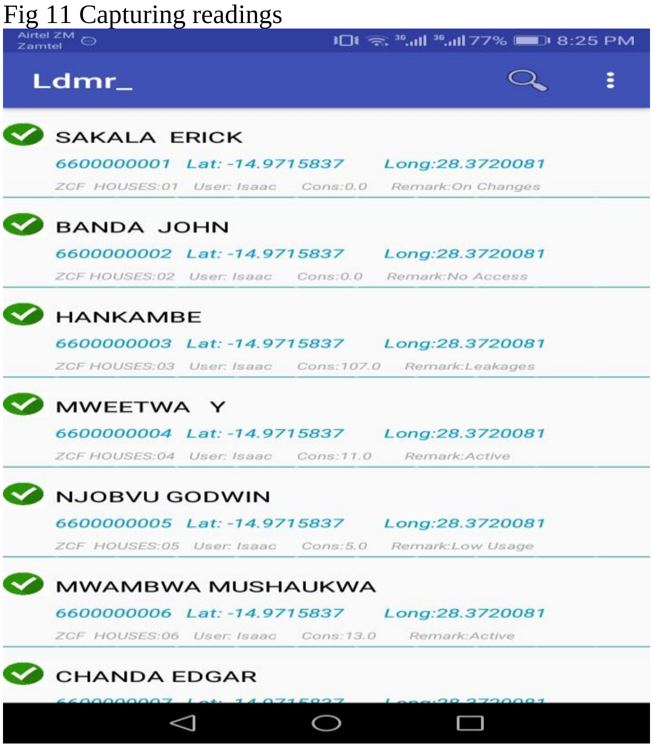

Fig 12 Readings list

Fig 13 Customer monthly consumption

Evaluation

The usability evaluation was conducted over a period of 2 to 3 months and in 9 different districts. The users were allowed the freedom to perform the tasks first during the test phase and then during the pilot phase.

In order to validate our model, users included a combination of different stakeholders among them customers and meter readers who accessed the mobile application via a web browser and android phone and completed an after-test questionnaire. The following where the tasks involved in the test:

Web Application

i) Accessing the web application (All users)
ii) Locating information by zone, town (Supervisors, Meter readers)
iii) Finding consumption by town, zone and global(Supervisors, Meter readers)
iv) Viewing graphs on dashboard (Supervisors, Meter readers)
v) Editing, Deleting, Creating (Administrator)
vi) Note down the challenges (All users)
vii) Recommend possible solutions (All users)

Android application

i) Accessing the android application (All users)
ii) Viewing graphical usage by account (Supervisors, Meter readers, Customers)
iii) Initialising and Capturing readings(Supervisor, Meter readers)
iv) Clearing readings(Supervisor)
v) Uploading readings(Supervisor, Meter reader)

The users where randomly picked among the most likely beneficiaries of the mobile application for meter readings for water utility companies in Zambia.

Conclusion

Design Science Research Process (DSRP) model developed by [16] has been frequently used within information systems research. The DSRP is intended to meet three objectives: (1) to be consistent with prior literature; (2) to provide a nominal process model for doing DS research and (3) to provide a mental model for presenting and appreciating DS research in information systems.

Heuristic for Uploading Readings and Images

Step 1: Start
Step 2: Declare variables
Readings, count, db, requestQueue, session Object;
Step 3: Initialise variables and Read
db=new DatabaseHandler (this);
requestQueue=volley.newRequestQueue (this);
Step 4: Create the post request (Android Volley)
Step 5: For loop to loop through all the accounts
Loop
For (reading rd: db.getAllByUser (user) {
Save reading to the server
Step 6: get the image to upload
Step 7: if (img.Exists) {
Step 8: Convert image to string
Save image to server
Step 9 } else {

No photo exists

}
}
Step 10: Display message “photos/readings uploaded or there was an error”;

Heuristic for Initializing Readings

Step 1: Start
Step 2: Declare variables
Readings, count, db, requestQueue, sessionObject, URL;
Step 3: Initialise variables and Read
db=new DatabaseHandler (this);
requestQueue=volley.newRequestQueue (this);
sessionObject=user.getUsername ();
URL=url.getUrl (sessionObject);
Step4:Create get request(Android Volley)
Step 5:while loop to loop through the response
While (count<response.length ()){
Get the accounts from server by sessionObject
Create the readings object and save the object onto the android phone database.
}
Step 6: Display message “readings initialised or error occurred”;

Heuristic for Capturing Readings

Step 1: Start
Step 2: Declare variables
Readings, count, db, sessionObject, Camera, Image, GPS, button;
Step 3: Initialise variables and Read
db=new DatabaseHandler (this);
image=image.createImageFolder ();
SessionObject=user.getUsername ();
Camera=camera.getRequest ();
Step4:button.click (){
Step5: Open the camera and get a photo of the meter
Step6: If (photo.IsSaved ()) {
Get data from form and save to readings object.
Display message “readings saved successfully/error occurred”;
Step7 :} else {
Don’t save the readings data
}
}
Step8: Go back to readings list and select another account to capture.

Heuristic for Analysing Readings

Step 1: Start
Step 2: Declare variables
Readings, count, db, Town, User, Zone, Global;
Step 3: Initialise variables and Read
db=new Database (this);
reading=new Reading ();
User user=user.getUsername ();
Town town=town.getTown ();
Step4: OnPageLoad (loadReadings ()),
Step5: analyseReadingsTown ();
analyseReadingsUser();
analyseReadingsZone();
Step6: exportReportsToExcel();

Assumptions of test

Assumption includes:

i. The datasets to be used are assumed to be complete and usable practically.
ii. The experiments assume the datasets are being derived from live environments.

Usability Test

Usability testing is an important aspect of software development whose objective is to enhance user experience benefits, outlining choices and the limiting of the failure and oversights for users [21] [22]. In order to achieve the goal of good usability, systems require building a suitable design. Various developmental ease of use assessments should be done to all software interactions before the application gets discharged. Indeed, even after it has been discharged, a few follow-up ease of use assessments should in any case be executed also. This is outfitted towards dispensing with the disappointments and issues identified with the outline from the viewpoint of the clients and the ease of use issues that will follow in real use of the application. The outcome is that the users get important, viable, effective and satisfying application consequently [22] [23].

Tools

The users, where given a URL to the meter reading web application which was accessible via a web browser of their choice. An apk for android application was also installed on the users smartphones.

Experiment

Users included a combination of different stakeholders among them customers and meter readers. All users accessed the mobile application via a web browser and the generated apk from android which was installed on their phones. The following were the tasks involved in the test:

Web Application

viii) Accessing the web application (All users)
ix) Locating information by zone, town (Supervisors, Meter readers)
x) Finding consumption by town, zone and global(Supervisors, Meter readers)
xi) Viewing graphs on dashboard (Supervisors, Meter readers)
xii) Editing, Deleting, Creating (Administrator)
xiii) Note down the challenges (All users)
xiv) Recommend possible solutions (All users)

Android application

vi) Accessing the android application (All users)
vii) Viewing graphical usage by account (Supervisors, Meter readers, Customers)
viii) Initialising and Capturing readings(Supervisor, Meter readers)
ix) Clearing readings(Supervisor)
x) Uploading readings(Supervisor, Meter reader)

VII. Results

The demographic information is as follows: Purposive sampling was used and we received 36 responses while conducting our research and were distributed as shown in (Figure 18: Responses by district). The response from target users of the usability test consisted of 75% meter readers and 25% customers as shown in (Figure 19: Responses by user type).

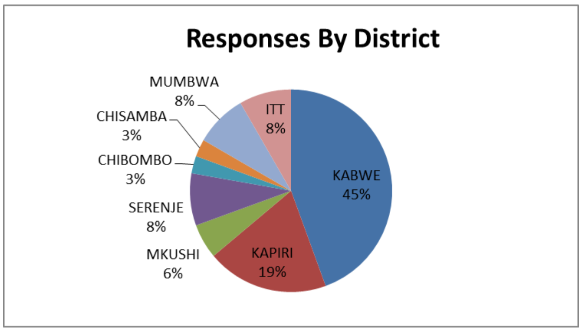

Fig 18 Responses by district

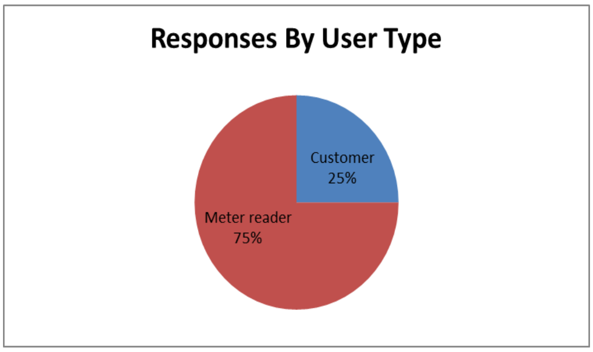

Fig 19 Responses by user type

Usability factors

The usability test was split into three (3) main areas namely: perceived ease-of-use (Ease-of-use), perceived flexibility (Flexibility) and perceived information accuracy (Information Accuracy) as shown in Table 2: Usability factors.

TABLE I
Usability factors

Usability factor	**Variables measured**	**Reference**
Ease of use	Accessibility, Reliability and Availability	[21] [23]
Flexibility	Easy To Capture Readings, Easy To Update Readings, Easy To Search Properties, Easy To Upload and Easy To Analyse.	[23][24]
Information Accuracy	Information clear , Information accuracy and	[23]

Perceived Ease-of-use

Most of the users indicated they found the mobile application framework to be very good and that it was very easy to access,highly reliable and available with the information needed for management decision (Figure 20:Ease of-use).

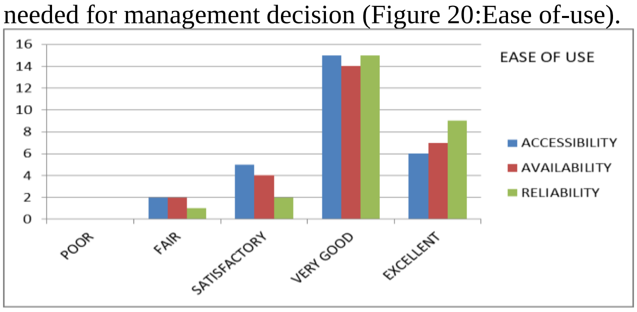

Fig 20 Ease of use

As can be seen, the majority of the participants agreed that the application was easy for them to use.

Perceived Flexibility

The majority of the users indicated they were happy with the flexibility of the mobile application framework for meter readings (Figure 21: Flexibility). This means that users were satisfied with the way the mobile application framework was designed.

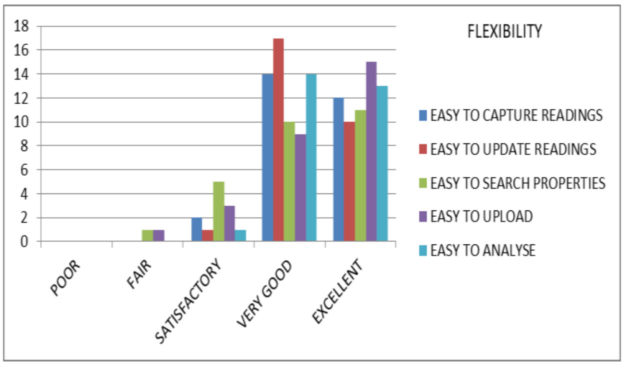

Fig 21 Flexibility

Perceived Information Accuracy

Majority of the users indicated they agreed that the mobile application framework for meter readings provided very clear and accurate information as shown in (Figure 22: Information Accuracy).

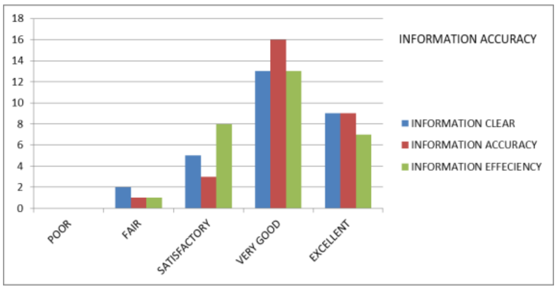

Fig 22 Information accuracy

VIII. Discussion

The main focus of this study was to develop a mobile application for meter reading for water utility companies in Zambia so as to improve efficiency and service delivery in the water sector. This study reviewed several other solutions that have been developed over time in the quest to find solutions for the manual meter reading problem, review literature identified some gaps, which further fuelled the relevance of this study into finding a solution that could work in the context of Zambian water utility sector.

This research designed a low cost solution for the manual meter reading problem customized to the local environment and easily integrates with the existing infrastructure for all water utilities in Zambia. The water business requires regular monitoring of customers as they can engage in illegalities such as illegal reconnections and by-passes if not monitored.

With this application the meter reader is able to monitor customers properties in his/her area regularly when picking readings and provide proof of visitation through GPS and picture of the property or meter. Most of the solutions reviewed lacked the analysis component and visual monitoring of the meter readers as they picked readings.

This study would have been even more informative if the usability was to be extended even to other water utility companies in Zambia. However, with the results obtained from this study, the application can help water utilities in Zambia bill correctly, monitor staff productivity, increase customer satisfaction and easily resolve complaints as there will be proof (GPS and Photo) for every reading taken.

IX. CONCLUSION

In this research, we have presented the problem of manual meter reading which is faced by all water utility companies in Zambia. The mobile application for capturing meter readings was successfully designed and meter readers and customers are able to capture and send readings to the server for further analysis. The application is able to provide evidence and proof of visiting the customer property through GPS coordinates, picture of the meter and time when the property was visited. In addition supervisors are able to monitor customer readings in real time.

The web application has a number of customized reports for water utility company and its customers. Customers are able to view their consumption graphical usage at any time anywhere in the comfort of their home. A Water utility company is also able to generate, filter and export reports by town, zone, account and customer name. These reports can be exported in different formats like csv, pdf, excel and word. The generated reports are used by management to make informed decisions and resolving of customer complaints.

A Water utility company and its customers are able to analyse and monitor customer meter readings using a web application and an android application.Using the android application Water utility company and its customers are able to view graphical usage for a period of 12 months and the web application has a dashboard, graphs and a map. On the dashboard accounts are automatically flagged with a color code depending on the comment provided by the meter reader and a summary is generated by zone and by town on various comments submitted.Users can also filter reports by town, zone, remark, date, account and many other attributes of the customers. The web application is also used to monitor the progress of each meter reader in the field using a map and the graphs. For example one of the graphs produced is the productivity graph which shows the number of properties visited in a given period of time. The markers on the map are displayed using different colours depending on the comments provided by the meter readers. The photos of the meter have eliminated manipulation of readings and the problem of meter readers not visiting the property. The application was also used for database cleanup.

This study also evaluated the mobile application on three user experience main areas namely, perceived ease-of-use, perceived flexibility and perceived information accuracy. The results showed that the application provided very good user experience to most of the users who participated in the study. Most of the users perceived that the mobile application satisfied their needs in terms of the three usability qualities evaluated in the study. However, only the minority of the respondents had issues with the application.

The designed application has been able to solve the manual meter reading problem by eliminating manipulation of readings and the problem of meter readers not visiting the properties. It has also cut down on the meter reading cycle creating more time for analysis of data by all users and providing proof of readers visiting the property through a picture and GPS coordinates. The application is easy to use, provide accurate information and it is excellent when it comes to uploading of data and analysis of readings.

X. FUTURE WORKS

Future work will include further dedication in testing the mobile and web application in other water utility companies in Zambia. Security aspect for the entire mobile and web application needs to be addressed. Further enhancing the mobile application by adding Optical Character Recognition (OCR) functionality for extracting images from the meter and adding support for automatic meter reading (AMR).

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