M-Agriculture recording system for milk producers in Kenya: a case of Uasin Gishu County

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Declaration

I declare that this work and has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

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…………………………..   Signature

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Approval

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Dedication

I dedicate this work to my lovely wife Bernice who has been my rock and encouragement throughout the research and to my young son Edward, may you grow to appreciate this work and endeavor further.

Abstract

Managing milk production efficiently is a key factor to the development of the dairy industry in Kenya. The availability of milk production information is a major challenge when it comes to management which has led to a number of trials by the Kenya dairy board (KDB) to standardize milk recording. The milk recording schemes have not been successful due to various factors such as cost of implementation, technology limitations, time constraints, the large number of small scale farmers and the education levels of the farmers. This means that information that can be used for management, analysis and even prediction is more or less nonexistent. The standardization of milk recording in developed countries engineered by the International Committee for Animal Recording (ICAR), has seen huge developments in the dairy industry of the member countries. This shows the positive effect in the good management practices that should be emulated by the developing countries such as Kenya. Although technological advancement can be viewed as a constraint, studies have shown otherwise with increase in adoption of technologies in the developing countries such as mobile phone technology. In Kenya there has been a steady increase of mobile subscribers which has penetrated to even the remote parts of the country. This growth has largely been due to ground breaking innovations e.g. mobile money transfer which has seen more people depend on mobile phone services for their daily activities. Kenya is seeing more and more mobile phone related innovations in various economic sectors, agriculture included. M-agriculture which is the use of mobile phone technology in agriculture including the dairy sector, can be used to solve the problems such as milk management. Using M-agriculture as a solution to milk recording in Kenya can enable standardization and create availability of milk production information for management, analysis and even prediction. This thesis focuses in developing an M-agriculture data collection system for the dairy farmers which provides a solution for management as well as curation of the much needed milk production information for the dairy industry.

Acknowledgment

I am highly appreciative to the Almighty God for all his wisdom and grace that has seen me though the writing of this thesis.

My sincere appreciation to Prof. Ismail Ateya and the Master of Science in Information Technology class of 2014 for their academic support in the writing of this thesis.

Abbreviations/ Acronyms

DRSK	-	Dairy Recording Service of Kenya
EAMRS	-	East Africa Milk Recording Service
ERD	-	Entity Relationship Diagrams
KDB	-	Kenya Dairy Board
KMR	-	Kenya Milk Records
MDG	-	Millennium Development Goal
SMS	-	Short Message Service
GSMA	-	Global System for Mobile Association
SaaS	-	Software as a Service
KNBS	-	Kenya National Bureau Of Statistics
DFMIS	-	Dairy farming management information system

Definition of Terms

M-agriculture - This is a part of e-agriculture, referring to delivery of agricultural services by use of mobile communication technology. These technology includes portable devices such as mobile phones, smartphones, PDAs or tablet devices (Brugger, 2011).

Cloud Computing- The ability to access files, data, programs and other services from a Web browser through the Internet hosted by a 3rd party provider and paying only for the computing resources and services used (Kim, 2009).

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Chapter 1: Introduction

1.1 Background of Study

Milk recording organizations were formed as early as 1895 at Venjen in Denmark (Johansson, 1961). From then the recording trend spread rapidly and is now an important part of countries with advanced dairy industry (Lindström, 1976). In France between the year 1900 and 1910 the recording trials were run and as a result in 1907 a syndicate was formed in the Seine Maritime Department. Years later in 1924 twenty countries had started recording milk production with a total of 1.8 million cows recorded in the combined countries. By 1935 thirty-four counties had joined the trend which by then involved 14,000 professional testers, 285,000 farms and 4.5 million cows. The idea of standardizing milk recording internationally was first proposed as early as 1922 then again in 1925. The international institute of agriculture sent a request to countries concerned and received unanimous replies recognizing the need to standardize of milk recording methods. In march 1951 an organization designed to standardized milk recording methods was formed. The organization was named International Committee for Animal Recording (ICAR) (International Committee for Animal Recording, 2015)

In Kenya official milk recording started as early as the year 1949 and the scheme was known as East Africa Milk Recording Service (EAMRS), whose main objective was to provide information for farm management. Eventually it was shut down in the year 1970. In the same year a new scheme was formed named Kenya Milk Records (KMR) to provide milk recording service. Production of individual cows were recorded by the farmers daily on milk sheets and sent to the central office weekly. In 1994 KMR was dissolved due to financial issues. In the same year the Kenyan dairy farmers set up the Dairy Recording Service of Kenya (DRSK) for handling milk recording. This is the current organization which is providing milk recording service to farmers. By the year 1996 DRSK had recorded 10 492 cows in 120 herds with an average herd size of approximately 88 animals (Trivedi, 1998). DRSK is managed by the Kenyan government under the Kenya Dairy Board. The institution still provides the milk recording services in the same way to date (Kenya Livestock Breeders Organization, 2012).

Effective management of dairy milk production requires a good understanding of the dairy sector and the agricultural sector as a whole. In developing countries like Kenya whose economy is driven by agriculture, development is critical because it has direct significance in attaining the first Millennium Development Goal (MDG), which aims at eradicating extreme poverty and hunger, and the seventh MDG, which is to ensure environmental sustainability (Gichamba & Lukandu, 2012). The dairy industry in Kenya accounts for approximately 3.5 per cent of the country's GDP and 40 per cent of the livestock sector's GDP. The growth rate has been estimated to be between 4 to 5 percent per year and in 2013 it stood at 5.0 billion litres per annum (SNV KENYA, 2013). Milk production recording is the core source of data in the dairy industry. Milk recording organizations in developed countries clearly demonstrates that the productivity of animals could be increased through development of milk recording systems (Trivedi, 1998). Milk recording has always been in direct relationship with data processing and providing results for management decisions and on a more strategic level for selecting the herd and providing data to breeding value estimation for the breeding programs. In addition, the ready availability of reliable recorded information is now a daily part of management decisions on farms.

1.2 Problem statement

Acquiring of important information and keeping track of production requires good, timely, regular and accurate recording of farm data (Moran, 2009). Dairy farmers in Kenya have irregular and scanty recording practices leading to the lack of proper and accurate milk production information in the dairy sector (SNV KENYA, 2013). As a result, timely, accurate and reliable milk production information is not available to the farmers. This information is very useful to the farmer in improving the dairy breeds, marketing the produce, health monitoring and feeds control.

The challenge in collecting proper and accurate milk production information hinders the exploitation of Kenya's full potential to the economic contribution of the dairy sector. This thesis attempts to tackle the problem using available technology among farmers, such as mobile phones. Developing a M-agriculture system could enable the farmers to solve the problem. Dairy farming has become a time critical and information intense business and therefore accurate, reliable and well curated records are very important.

1.3 Research objectives

i. To identify the information needed for milk recording.
ii. To investigate the challenges of milk recording.
iii. To investigate the architectures, models and frameworks used for milk recording.
iv. To develop a M-agriculture milk recording system.
v. To test the system.

1.4 Research Questions

i. What are the information needed for milk recording?
ii. What are the challenges facing milk recording?
iii. What are the architectures, models and frameworks used for milk recording?
iv. How will the system be developed?
v. How can this system be tested?

1.5 Justification

Credible dairy sector strategies should be based on accurate data and information. The point has been made that current data used could be outdated and investors in the dairy sector rely on available data. Attracting strategic investors in the sector, which is necessary to transform the industry is based on accurate information (SNV KENYA, 2013). This clearly demonstrates the need for a reliable milk recording solution. By having regular, reliable and accurate records of production, fluctuations can be monitored. Decrease in production can be an indication of a problem which if detected early enough can be well handled. The records will also go a long way in planning and herd improvement.

This thesis aims at creating a recording system that will aid in the collection of accurate and reliable data for the dairy farmers and the dairy institution. The milk production data collected by the software will help in creating an accurate and available database to solve the milk recording problem within the dairy industry.

1.6 Scope and Limitations

As this research is based on one County (Uasin Gishu), there is the limitation of generalizing the findings based on a small sample size. The Kenyan dairy industry comprises of several dairy institutions and several dairy farms. It is extremely time and resource consuming to conduct a research on the whole of the dairy sector of Kenya and thus the findings of the research depend on the availability of data with reference to time and accessibility. The dairy farm has many areas that require recording e.g. feeding, production and breeding practices. This research focuses on collection of milk production records.

Chapter 2: Literature Review

The dairy farm is a complex system with many areas to manage in order to be profitable. There are few farms if any that can maintain profitability without balancing milk productivity, health of the animals, feeding and reproduction. Various Researches show that measurement and good farm management in the areas mentioned is vital to ensuring optimal performance of the farm and high economic returns. There is technology including mobile phones and internet available that makes it possible for professional and subsistence farmers to measure, manage and optimize the performance of the farm (Yaron, 2012). In the farm, management is very important, and it is therefore vital for the farmer to think outside the box. The practices done in the past by our fathers and grandfathers may not be able to secure business for the ever changing future. In this day and age, farms need to be run as a business, and therefore we need to embrace technology which have been proven to improve productivity of other businesses (Yaron, 2012).

This Chapter highlights the methods used in milk recording, architecture, frameworks, models and the penetration of technology such as mobile phones, smartphones and internet infrastructure in Kenya. It will show how these technologies can be used to solve the under laying problem of milk recording. Kenya is listed as one of the countries with a high growth of mobile phone penetration in its population. There is also an increase in the number of mobile phone based innovations with M-pesa from Safaricom among the leaders of the pack. The dairy industry has not been left behind with successful mobile phone based platforms and articles on m-agriculture showing the need to look at mobile phones as a potential solution for milk recording.

2.1 Milk Recording

Milk recording is done in a number of ways which can be divided into two broad categories, the Supervised and the Unsupervised (DIY) milk recording. Supervised milk recording involves recording being done by dairy experts trained by the dairy regulating board(recorder) e.g. in Kenya it is done by the DRSK (Kenya Livestock Breeders Organization, 2012). The recorder goes to registered dairy farms, records milk weights and takes milk sample for analysis. The recorder also records any changes in the farm status such as new, sold or died animals. Due to the large number of dairy farms, supervised recording is time consuming and an expensive endeavor, therefore the farmers are charged for each recording session. The dairy institutions have devised schemes that try to make it easier for the recording officers and cheaper for the farmers. A number of recorder based schemes are available depending on how many visits you require per year. The farmers are given the option of choosing the number of times the records will be collected depending on how much they are willing to pay for the exercise (Kenya Livestock Breeders Organization, 2012).

In the DIY The farmer takes their own measurements and supplies the data to the dairy institutions. The Field Technicians will pick-up the samples and recorded milk information and sends this to the laboratory for analysis and processing (Zottl, et al., 2015).

Even in 2015, paper is still the most common way to do milk recording. But entering the data on farm directly to the database (via online access or by transmitting a data file) using a laptop or PC has reached a similar level. As a single method, hardware PDAs or data handlers have the same spreading as Laptops. As a very favorable way of entering the data to the database of milk recoding automated data exchange will be the hot issue for the rest of the decade either with milking robots, stationary electronic meters in the milking parlor or farm management software (Zottl, et al., 2015). Figure 2.2.1 highlights on the technologies used and their levels of popularity in the dairy industry.

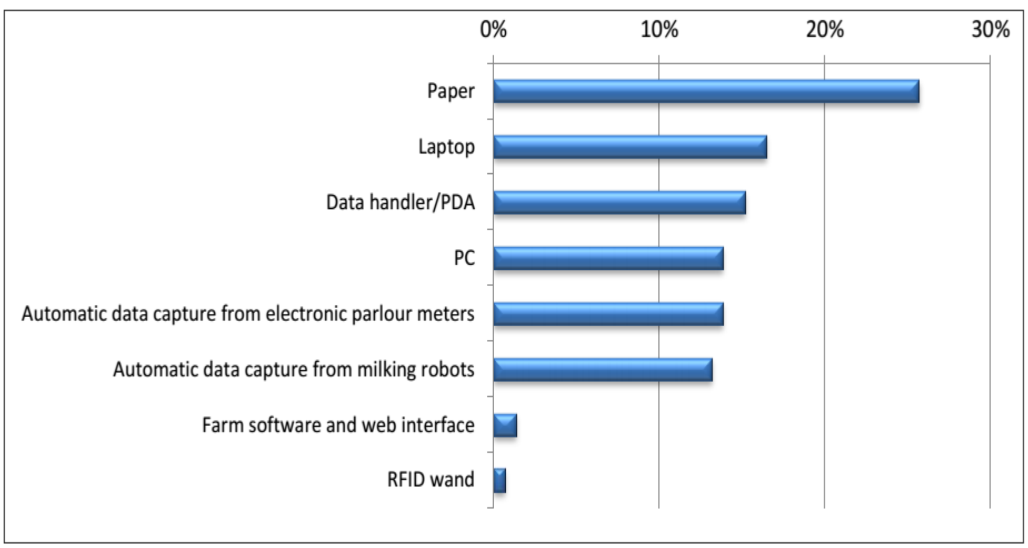

Figure 2.1 The tools used for data capture in dairy farms *(Zottl, et al., 2015)*

With the penetration of mobile technology in Kenya as discussed in the next section, M-agriculture systems could be effectively used to replace paper, laptops, PCs and PDAs as a method for milk recording in Kenya.

2.2 Mobile Phone Technology in The Agricultural Sector

The mobile industry's penetration level is now high enough for sustainable digital service business models. Presently, mobile technology is the primary vehicle for accessing digital services and the Internet (99 per cent of Internet subscriptions, around 16 million people, access the Internet through mobile devices). Low priced mobile phones along with affordable airtime have led to increased growth in mobile subscriptions, even among the poor (GSMA, 2014). As a result, there is a high penetration of internet in Kenya, approximately 70% of the population have access to the Internet (M&C Saatchi Mobile, 2013).

Smartphones account for a sizeable proportion of the mobile market in Africa. The smartphone industry is continuing to grow as smartphones are becoming cheaper and therefore more affordable for consumers. In Kenya, 13% of mobile owners use smartphones. The African market for mobile phones has been estimated to be the second largest after China, and the fastest growing in the world (M&C Saatchi Mobile, 2013). Further, it is predicted to grow on average by 40% each year until 2017. Currently, smart devices account for approximately 15% of the mobile market in Africa, and is predicted to account for up to 40% of the market in the next five years (M&C Saatchi Mobile, 2013). The mobile web, SMS and Android application are the most widely used mobile based technology in the Kenyan survey (GSMA, 2014).

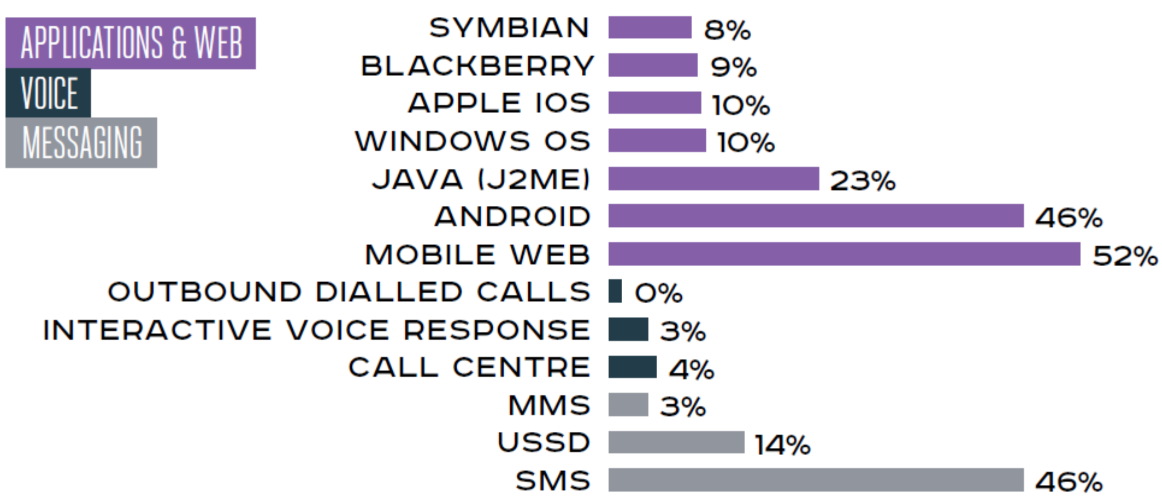

Figure 2.2 Kenya ICT & Mobile Entrepreneur Survey *(GSMA, 2014)*.

In Kenya big mobile companies are edging towards smartphones due to the decrease in the smartphone prices (M&C Saatchi Mobile, 2013). As the prices of smartphones continue to decline, there is an increase in the number of smart devices in the African market. The competition among the smartphone manufacturers has greatly increased leading to the development of cheaper smartphones for the African market (GSMA, 2014). The development of the mobile phone industry shades light to the future of the technology which is therefore creating unparalleled opportunities for digital entrepreneurship. Agriculture is one of the sectors that need to benefit as it is the backbone of Kenya's economy. The dairy industry should tap in to this steadily growing investment opportunity which can be a potential solution to problems experienced in the sector.

2.3 M-Agriculture Architecture

M-agriculture refers to the delivery of agricultural services via mobile communications technology. The mobile communication technology includes all kinds of portable devices like basic mobile phones, smartphones, PDAs or tablet devices (e.g. iPad). M-agriculture also involves gathering relevant data through mobile technologies. (Brugger, 2011). These technologies vary in complexity and agents involved, depending on the service offered, this include low, medium and high complexity systems.

The low complexity systems push automatically generated information one way (e.g. prices and weather forecast) or offer information that is stored in a database. The Medium complexity systems include location based services for decision support based on local climate and soil information (e.g. crop disease warnings). The complex part of the system is the content generation, but it still relies mainly on one-way communication (Brugger, 2011). The High complexity systems are two-way systems that provide feedback and advice individually (e.g. remote diagnosis), administration of business processes and individual transactions (e.g. insurance policy registrations, individual information for farmers or traders on sales, quality, inputs, etc.) or enable user-generated content. These systems usually include the use of smartphones and intermediaries for the communication with farmers (Brugger, 2011).

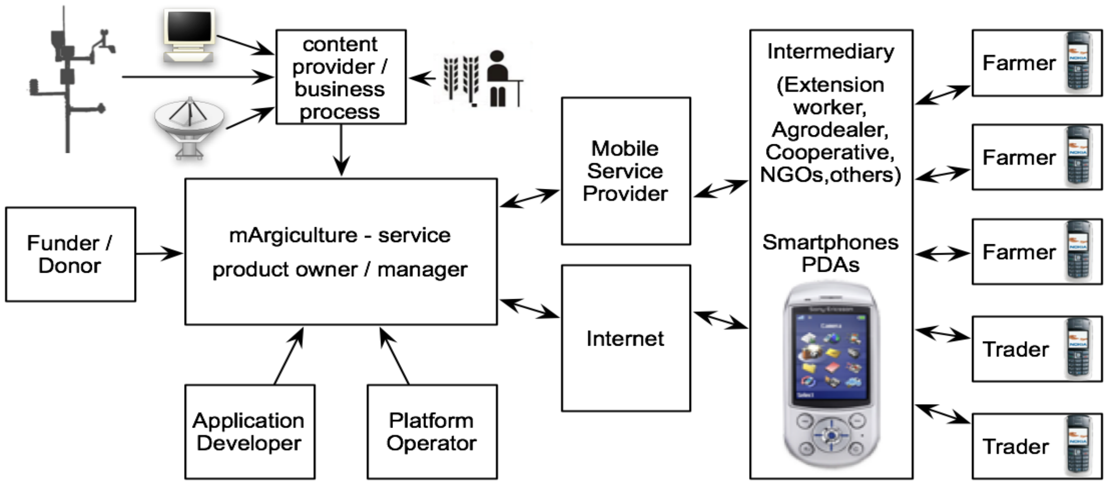

Figure 2.3 Two-way m-agriculture Architecture *(Brugger, 2011)*.

2.4 MobiCrop Distributed Offloading Architecture

The size of the data can exceed the limit of a mobile device and the number of queries can result in the burdening of the mobile CPU. This architecture includes offloading of data to free the device's resources. The business logic layer is moved to the middleware layer hosted in a cloud computing environment. Network component for sending and receiving data from the middleware is incorporated in the mobile stack (Lomotey & Deters, 2014). The device can be connected to the cloud via WIFI or 3.5/4G. The mobile device only stores incoming data into the local data storage temporarily to use in displaying data in case of connectivity loss.

The middleware, which is a Software-as-a-Service (SaaS), has two network interfaces. One end connects to the mobile and the other to the cloud storage server. The middleware processes the requests/data and sends it to the mobile device. The cloud storage keeps all the information required in the database which includes all the tables, images, and text in this database (Lomotey & Deters, 2014).

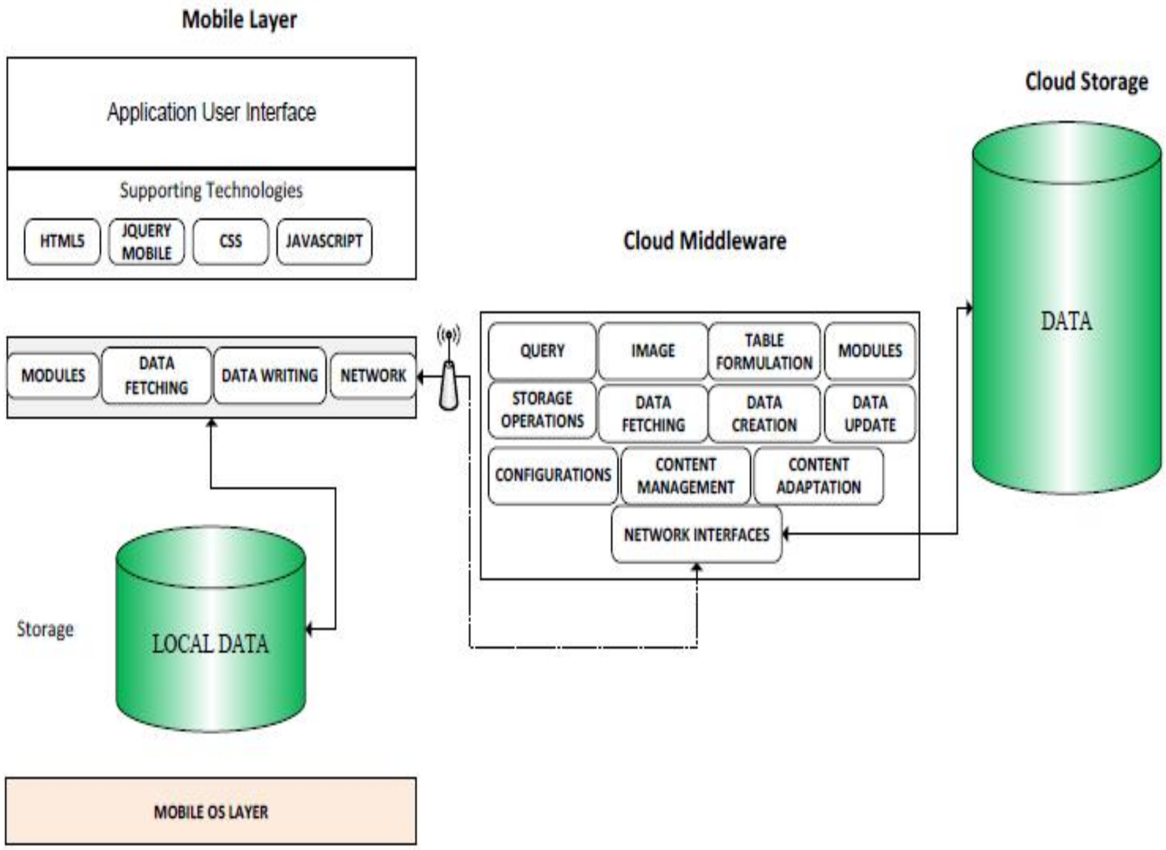

Figure 2.4 MobiCrop Distributed Offloading Architecture *(Lomotey & Deters, 2014)*.

2.5 Enterprise Mobile Service Architecture (EMSA)

Enterprise Mobile Service Architecture (EMSA) is a new enterprise architectural approach for mobile system integration. Enterprise mobile services encompass existing enterprise services, Web applications, Cloud services, and specific mobile services. The EMSA is a hybrid architectural style composed of enterprise mobile computing (EMC), enterprise SOA (ESOA), as well as enterprise Cloud service architecture (ECSA). The FedEx mobile architecture maps to a concrete EMSA style architecture. The diagram below shows the FedEx architecture (Tang, Tsai, & Dong, 2013).

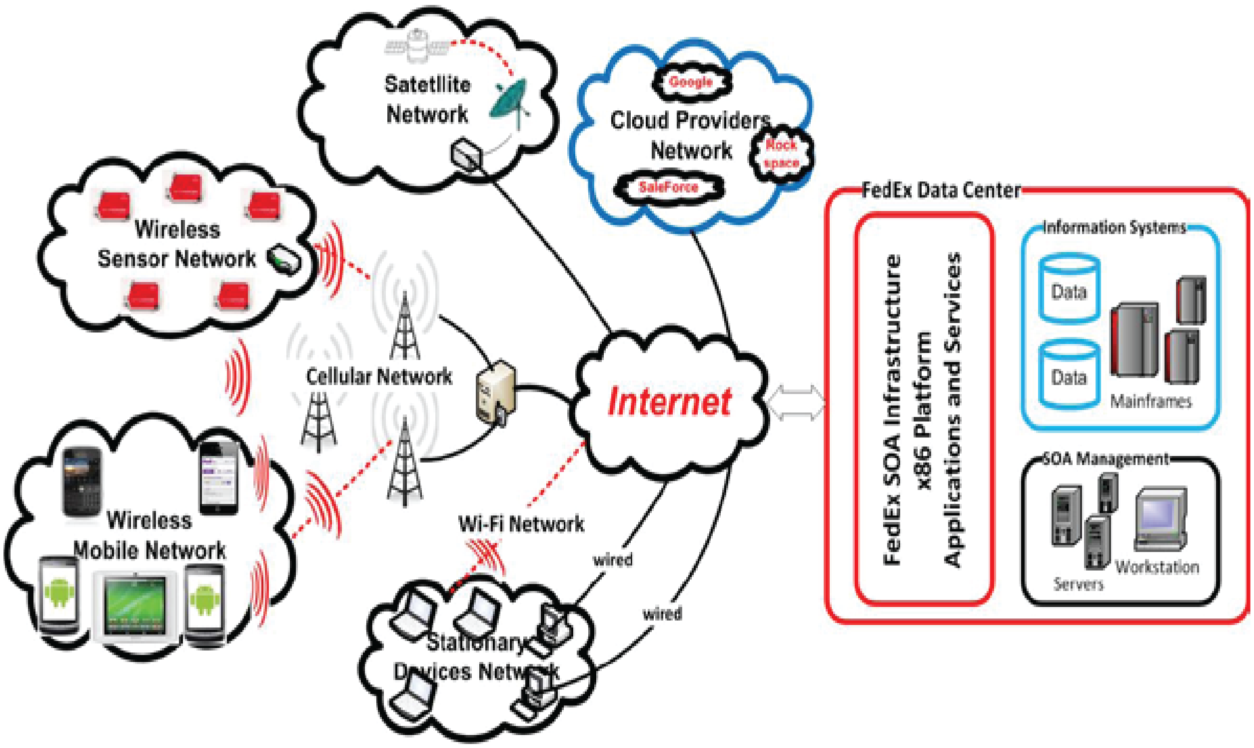

Figure 2.5 FedEx Enterprise Mobile Service Architecture *(Tang, Tsai, & Dong, 2013)*

2.6 M-Kulima Model

Some of the vital factors that determine components of a favorable m-agriculture architecture include infrastructure, type of devices and user knowledge. The suitable mobile device to be used is selected based on the information that is being transmitted. When transmitting multi-media files, such as images and video, the mobile devices require to have more memory and processing speed than mobile phones that are designed for only text. The components of the mobile agriculture architecture must be easily integrated with other platforms (internet, mobile and desktop).

Another determining factor is the bandwidth which affects the type of data being transmitted in the network. Consequently, adjustments on the business and technical requirements of the application have to be made to accommodate any specific needs of the whole agriculture mobile architecture (Gichamba & Lukandu, 2012). The m-kulima model designed by Gichamba & Lukandu, 2012 in their paper "A Model for designing M-Agriculture Applications for Dairy

Farming" considers the mentioned factors. The illustration Figure 2.5 below shows the m-kulima model of m-agriculture.

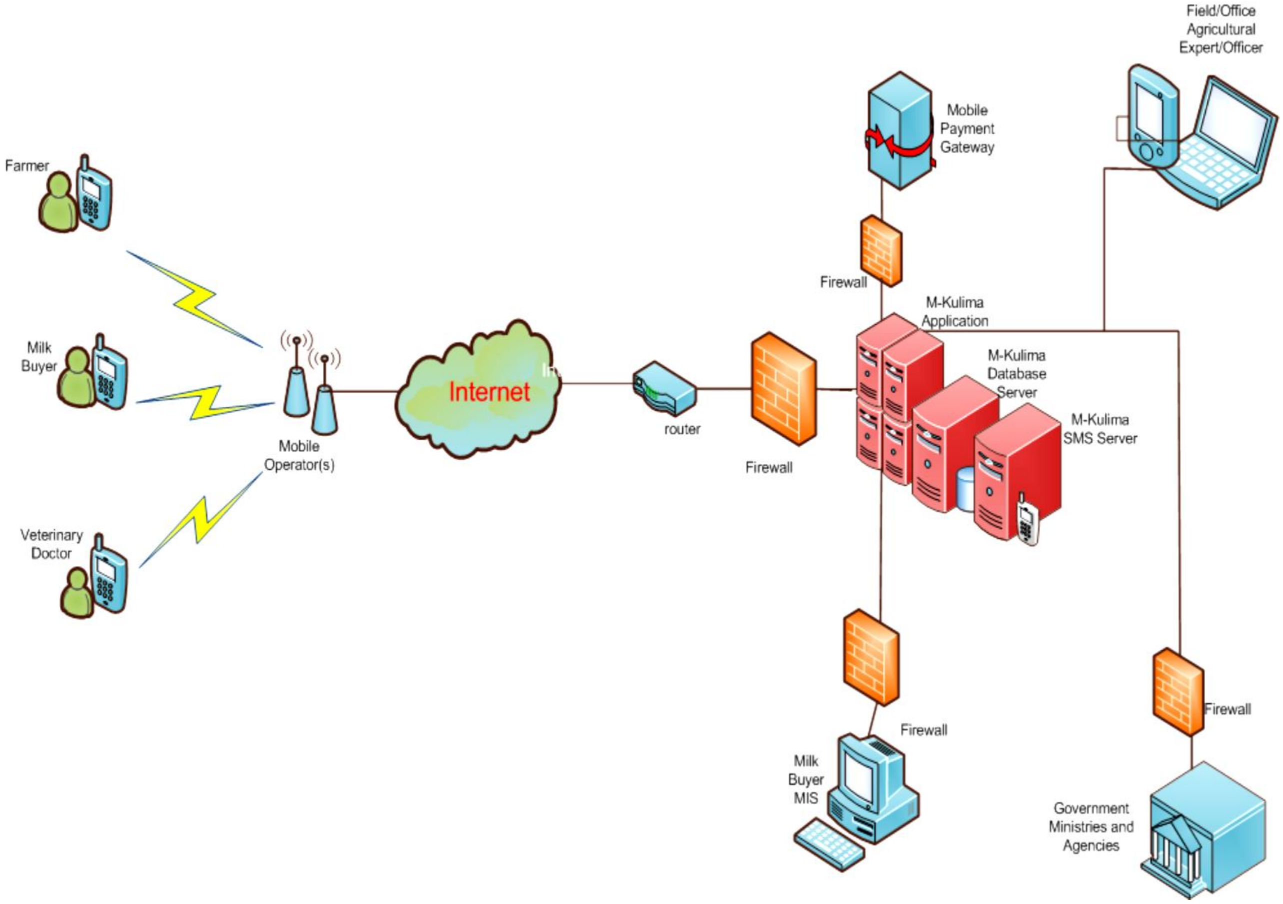

Figure 2.6 M-Kulima model for designing and implementing mobile applications in dairy farming *(Gichamba & Lukandu, 2012)*

2.7 Mobile Applications Development Framework (MADF)

MADF was developed by Unhelkar and Murugesan (2010) for enterprise mobile applications. This framework provides a systematic and comprehensive solution to mobile applications development and maintenance. MADF brings together elements of software architecture, design, infrastructure and information accessed across multiple sources. It considers the usage of communication infrastructure, e.g. TCP and IP.

The framework also suggests the usage of mobile standards (2G, 2.5G, 3G or 4G), Bluetooth and Wireless VoIP technologies. (Unhelkar & Murugesan, 2010) The framework brings out important aspects that should be considered in developing mobile applications that can handle complex business logic using a middle tier, transfer data back and forth over the mobile network and also facilitate data storage to a database. It also allows multiple access to the application's backend either from a single mobile application or a suite of applications. MADF presents a good reference point towards implementing mobile applications and gives clear pointers on the basic components of a mobile applications development model (Gichamba & Lukandu, 2012).

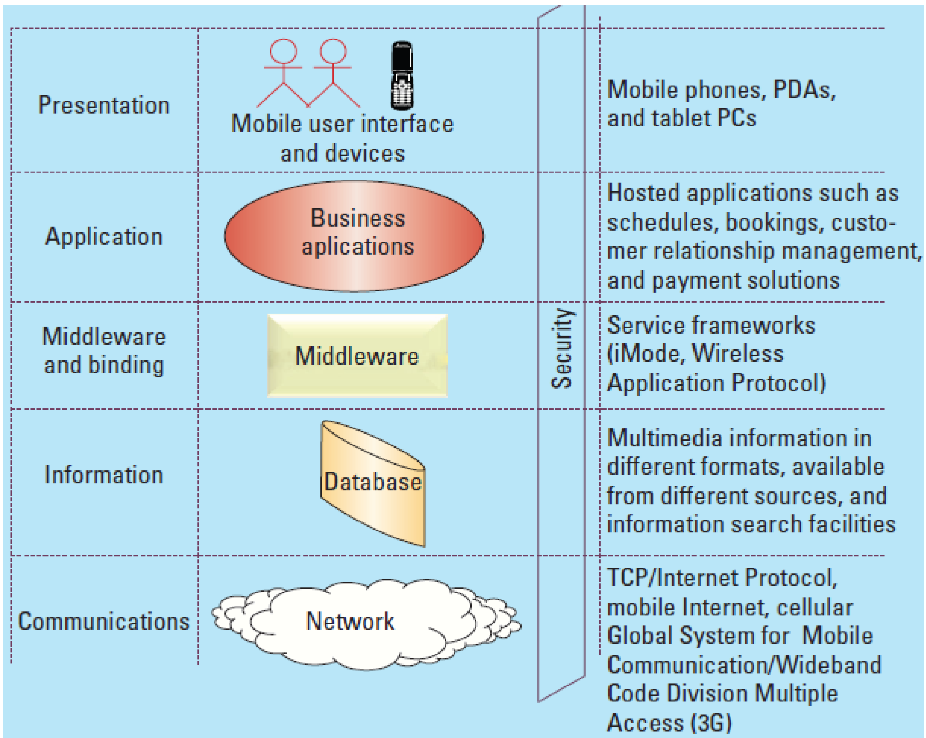

Figure 2.7 The six layers of the enterprise Mobile Applications Development Framework *(Unhelkar & Murugesan, 2010).*

2.8 Conceptual Model

The conceptual model involves creating a multi-platform system model that involves the use of cloud based environment. The system should be able to serve mobile device users as well as desktop computers and laptops. The diagram below shows the general architecture of the proposed system.

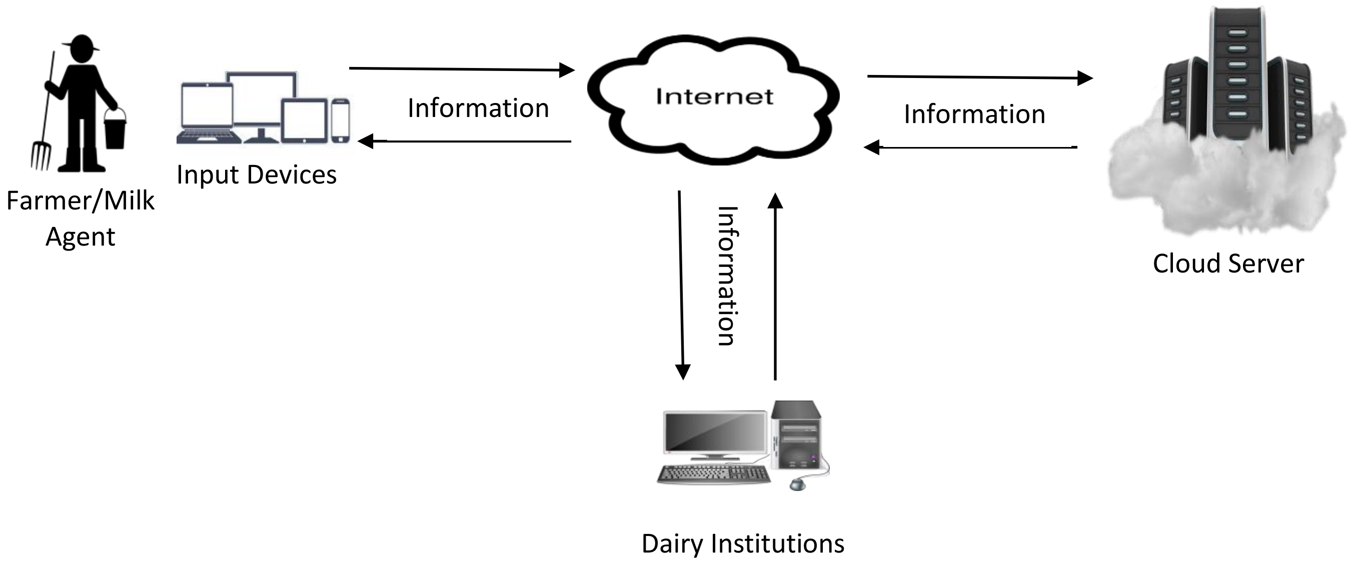

Figure 2.8 Architecture for proposed system

The system depends on the mobile technology for the general input of data which is then stored in a cloud based server. The application is internet based and also located at the cloud server. The users will be accessing the services of the application on need basis via an internet connected device. The basic reports such as delivery reports will be dispatched by an SMS server while detailed reporting tools will be accessed via the internet module. The below diagram represents a more detailed model of the proposed system.

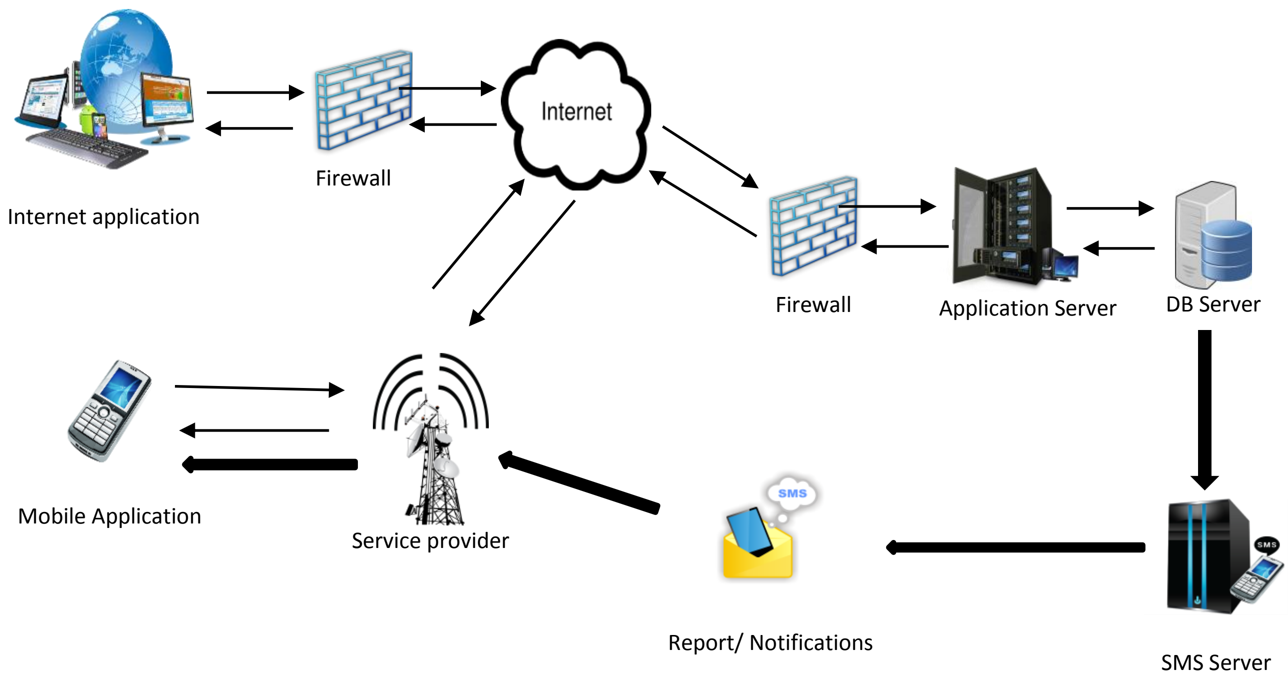

Figure 2.9 Proposed System Conceptual model

Chapter 3: Research Methodology/Design

3.1 Introduction

This Chapter introduces techniques, methods and strategies used in the research. The research design is defined with the scope and the limitations of the design. This section also looks into the analysis of methods that are used in the research. The most suitable design, data collection and testing methods are also highlighted.

This research uses a hybrid data collection method mixing both qualitative and quantitative methods. Quantitative research is basically measurement of quantity/amount involving generation of data in quantitative form which is subjected to quantitative analysis. The research mainly uses an inferential quantitative research method because of the sample population. On the other hand, qualitative research method which involves quality or kind, aims at using interviews to discover motives and desires of the sample population (Cooper & Schindler, 2014).

The research design is both analytical and applied research methods. The research uses already available facts and information from the dairy industry hence an analytical research. The research aims at solving the information gap in the dairy industry by providing a data collection system for effectively collecting the information. The research design method therefore is action or applied.

3.2 Application Development Methodology

The waterfall model is used for the development of the M-agriculture Recording system for milk producers. This methodology is considered as the classic style of software development which clarifies the application development process in a linear sequential flow. This means that any phase in the development process starts when the earlier phase is completed. Figure 3.1 shows how the development of this application will follow the waterfall model (Tatvasoft, 2015).

Figure 3.1 The waterfall Application Development Methodology *(Tatvasoft, 2015)*.

3.2.1 Feasibility Analysis

Feasibility analysis aims at assessing strengths and weaknesses of a project and give directions for the improvement of the project. The nature and components of feasibility studies depend primarily on the areas in which analyzed projects are implemented (Ostapowicz, Ziółkowska, Kaim, & Kozak, 2011).

The evaluation of technological and system requirements refers basically to issues related to the type, availability and quality of the, data sources, methods of data processing, analyzing, and visualizing, software (Ostapowicz, Ziółkowska, Kaim, & Kozak, 2011). The evaluation of legal requirements implies the rules of publishing and using data, software and methods. The software used for coding such as PHP and MySQL database are open source while the ozeki message server requires registration. The project involves the participation of the public by involving the farmers in the development.

Two components are important in the evaluation of economic requirements; the cost of data or software procurement and the cost of employing workforce for specific tasks. The evaluation of requirements related to the schedule concerns the estimation of time necessary to complete respective parts of a project, e.g. data procurement and processing.

3.2.2 Research Design

The applied or action research has two major phases which is the planning phase and the execution phase. There are four stages within the two phases, which include definition, design/plan, implementation and reporting/follow up. During the planning phase the scope is defined and a research plan developed. In the second phase the implementation and monitoring of the plan which include design, data collection and analysis. The researcher then does the follow up and the reporting activities. Figure 3.2 shows the phases and the stages of this research design. Figure 3.3 shows a more detailed breakdown of the phases (Bickman & Rog, 2008).

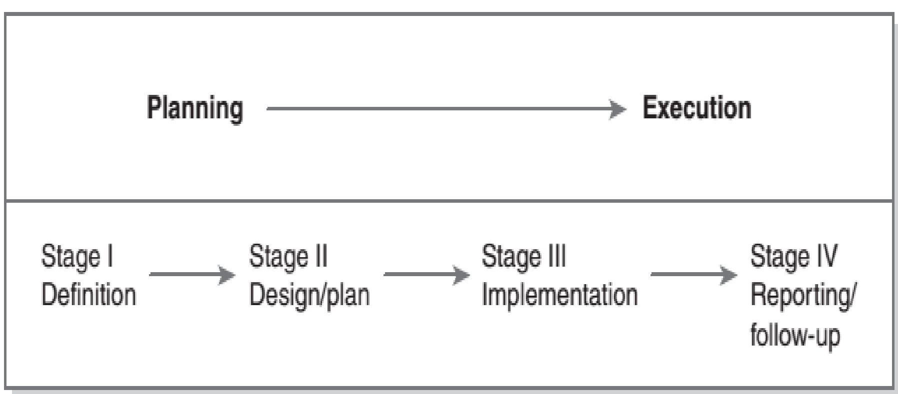

Figure 3.2 Stages in applied research *(Bickman & Rog, 2008)*

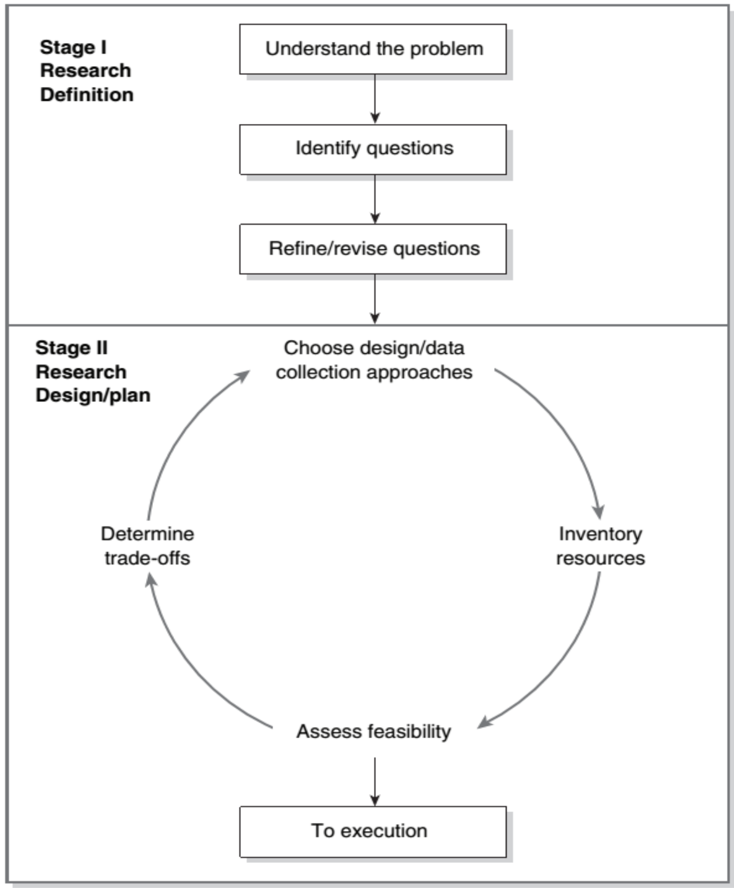

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Figure 3.3 Stages in applied research *(Bickman & Rog, 2008)*

The purpose of research design is to make sure that information obtained enables the researcher to effectively address the problem logically. In social sciences research, obtaining information relevant to the research problem generally entails specifying the type of evidence needed to test a theory, to evaluate a program, or to accurately describe and assess meaning related to an observable phenomenon. (Gorard, 2013)

3.2.3 Location of Study

The area of research is Uasin Gishu County which is the targeted location divided into three areas, including Eldoret West, East and Wareng, which are the sample units. This is due to the availability of a good number of dairy farms within the area and the knowledge of the researcher of the general location.

3.2.4 Target Population and Sampling

The population and sample size is a representation of the whole population therefore the sample has to be as accurate as possible. The budgetary constraints inhibit the use of a very large sample size and accessibility of the farmers is restricted due to the sparsity of the rural population which constitute the larger part of the dairy farmers' population. The Rift Valley province constitutes of the largest population of livestock estimated at 7,479,807 cattle, 9,079,380 sheep and 11,750,521 goats. Dairy livestock in the Rift Valley is highly concentrated in the Uasin Gishu county (KENYA NATIONAL BUREAU OF STATISTICS, 2010) hence the choice of research.

The total estimated livestock population of Uasin Gishu County as recorded by KNBS 2010 is 566,217 as shown in Table 3.5. The total cattle population is 295,104 comprising of the total of the three areas (KENYA NATIONAL BUREAU OF STATISTICS, 2010). Small scale dairy farmers who are the majority of dairy farmers typically keep 2 or 3 dairy cows (Wanjala & Njehia, 2014). Using 3 dairy cows as a measuring unit with a population of 295,104 cattle, the approximate farmers' population in Uasin Gishu county is 98,368. Therefore, the total population for this research is 98,368 farmers with 28,473 dairy farmers in Wareng, 36,636 dairy farmers in Eldoret West and 33,258 dairy farmers in Eldoret East.

Table 3.1 Livestock population of Uasin Gishu County as recorded by KNBS 2010

Area	Cattle	Sheep	Goats	Total Livestock
Eldoret East	99,774	95,778	22,796	**218,348**
Eldoret West	109,909	75,332	14,856	**200,097**
Wareng	85,421	55,837	6,514	**147,772**
Total	**295,104**	**226,947**	**44,166**	**566,217**

Selection of the sample size of this population depends on various factors which include cost, time, desired level of precision, the desired level of confidence and the degree of variability.

(Yamane, 1967) provides a simplified formula to calculate sample sizes. This formula is used to calculate the sample size for this research. When this formula is applied to the population with a 90% confidence level and precision level of ±10% assumed for the calculation, the sample size attained is 99 farmers. The sample size from the population which is 99 farmers that will be used for data collection. To ensure a reliable accuracy level the population is divided into three units which are used as the clusters of the sampling. The method used for sampling in this thesis research is Cluster sampling. The three areas in the population i.e. Eldoret East, Eldoret West and Wareng are the cluster units. In each units Convenience Sampling is used to get the samples. Each area will therefore have 33 farmers representing the stratified unit and in turn 99 farmers will represent the population.

3.2.5 Data Collection and Procedure

This project uses both quantitative and qualitative data collection methods for collection of the data from the farmers. The quantitative data includes information such as number of farmers with smart phones, PDA devices and computers. The most suitable data collection method for this data is the questionnaire which is filled by the farmers in the sampled population. For collection of this data, the questionnaires use closed questions with an option for the farmer to select the appropriate answer. This type of questionnaire is able to approximate the number of farmers with smartphones, tablets, laptops and desktop computers. It's also able to establish whether there is internet connectivity. The questionnaires will also be used for feedback from the farmers during the testing stage of the system development (Cooper & Schindler, 2014). Information such as the approximation of population size and distribution have been retrieved from books and articles. Also information concerning this research from historical researches will be useful in the data collection (Cooper & Schindler, 2014).

Information which is useful to the research such as the ability of the farmers to use the system. An interview usually involves one-on-one questioning between an interviewer and an individual. The interview can also be done over the telephone or via the internet. But considering the educational level of the population, the face to face questioning would be the most suitable for this research (Cooper & Schindler, 2014). The data collection in this research also involves observing the operations of the farmers to obtain information needed for the development of the system. Information including how the farmers are currently collecting dairy data are able to be collected in this way (Cooper & Schindler, 2014).

3.3 Application Design Requirements

The system application design implemented in this research involved the using of UML diagrams to design the system. This involved creation of use case diagrams, Data flow diagrams, collaboration diagrams, class diagrams and database modeling using Entity Relationship diagrams.

3.3.1 Activity Diagrams

Activity diagrams are UML diagrams demonstrating the sequence of activities from start to finish showing the decision paths that exist in the progression of events contained in the activity. (Felici, 2009). In this thesis document the sequence of events involves the farmer delivering the milk to an agent or a milk institution were the milk is recorded into the system. The record is then used for further sales of the milk and for the generation or reports for the farmer. Figure 4.9 shows the flow of activity for the system.

3.3.2 Data Flow Diagrams

A data flow diagram (DFD) is a visual representation of information flow within a system. A well represented DFD clearly depicts the system requirements graphically. In this research the level 0 DFD is created to show how the various actors which includes the Farmer, milk agent/ institution, client and the system administrator interact with the system. The level 1 DFD shows a more elaborate interaction which includes how data flows into the database. The level 2 DFD shows an even more elaborate set of processes within the system and their interaction.

3.3.3 Use Case Diagrams

The system design looks at the main actors and how they interact with the system. A use case describes a sequence of actions that provide something of measurable value to a person, organization, or external system; that plays a role in one or more interactions with the system (Ambler, 2004). The general course of action within the system involves the farmer delivering milk to the milk agent where the quantity of the milk is recorded with the time details. The system is centralized and thus has an administrator/supervisor who controls the system. The milk delivered is then sold to the clients as different milk products. Section 4.8 shows the actors and the activities they carry within the system.

3.3.4 Class Diagrams

The class diagram describes the static structure of the symbols in the system. This shows the association of classes arranged in hierarchies sharing common structure and behavior. The classes define attribute values carried by each symbol instance and the operations that each symbol performs. The Figure 4.15 shows the relationships of the various classes which will be used to form the database system of the thesis project.

3.4 System Implementation

The hardware required includes the server the internet router and coding workstation complete installed with the required software. The server includes the database server, application server, web server and the SMS server. The coding is done in PHP 5.4 using Adobe Dreamweaver IDE.

3.5 System Testing

System testing is the process of evaluating a system or its components, to find out whether it satisfies the specified requirements. This means executing a system to identify any errors, gaps or missing requirements as compared to the actual requirements. ANSI/IEEE 1059 standard, defines testing as a process of analyzing a software item to detect the differences between existing and required conditions (that is defects/errors/bugs) and to evaluate the features of the software item. In this research the researcher has incorporated white-box testing and manual testing.

3.6 Data Analysis

In this this research data analysis is done using the deductive approach of data analysis. This is because although the data collection uses both qualitative and quantitative methods of data collection, the quantitative data is the larger component. The other reason for a deductive approach is the time limitations of the study (Nigatu, 2009). The qualitative data collected is given numeric values and hence converted to quantitative data for the deductive data analysis. The research uses three elements common to all analysis, this includes data reduction, data organization and data explanation and verification.

Data reduction is the process of simplifying, selection, organization and abstracting the raw data collected. This process will be on going through out the qualitative data collection. Data reduction reduces number of data records by eliminating invalid data and provides summary data and statistics at different aggregation levels. The research uses Inferential analysis to draw conclusions on the results of the data collected. This will help the researcher to determine the meaningfulness of the results (Holm-Hansen, 2008).

Data explanation and verification refers to drawing conclusions from the results. This means stepping back and considering what the results mean and their implications. This section of the research Involves stakeholders by reviewing findings and preliminary conclusions with them prior to writing a formal report. The research also aims at considering practical value, not just significance (Holm-Hansen, 2008).

Chapter 4: System Design Architecture

4.1 Introduction

This Chapter focusses on the results analysis and the system design. The results analysis involves analyzing the data collected from Chapter 3. The M-agriculture recording system for milk production uses a web based mobile application as a front end for recording of data and a web portal for information management and analysis. The process involves recording of daily production of milk from the farmer into the system. The information is store in a centralized cloud database to be analyzed and accessed via the internet.

4.2 Data Analysis and Results

In this section the results of the data analysis are presented. The data was collected and then processed in response to the problem statement addressed in Chapter 1 of this document. The primary objective spearheaded the collection of the data and the subsequent data analysis. The goal of the thesis is to develop a data recording and management system for the dairy farmers. The objectives have been accomplished. The findings presented in this Chapter demonstrate the need for the M-agriculture Recording system for milk producers in Kenya. It also demonstrates the reasons for the selection of the technology used for solving the problem.

4.3 Response Rate

Ninety-nine questionnaires were initially sent to random dairy farmers in Uasin Gishu county. 40 of the questionnaires were sent via google forms while 59 were hand filled by the farmers. 8 questionnaires sent via google forms were not completed leaving only 32 valid responses. Form the 59 which were hand filled 4 were considered unusable. The unusable response was due to partially unfilled forms or blank forms. The total number of valid responses were 87. From 99 forms sent and 87 valid responds, therefore the response rate was 87.88%.

4.3.1 Age of Respondents

The survey asked the farmers for their age so as to ascertain the average age of the proposed users. The average age can be an indicator of acceptance of the system. The survey shows that years of the total respondents 48% consists of farmers with the age of 35 to 50 years of age, 25 % are between 25 to 35, 25% of age ranging from 50 to 65 years and 5% above 65 years.

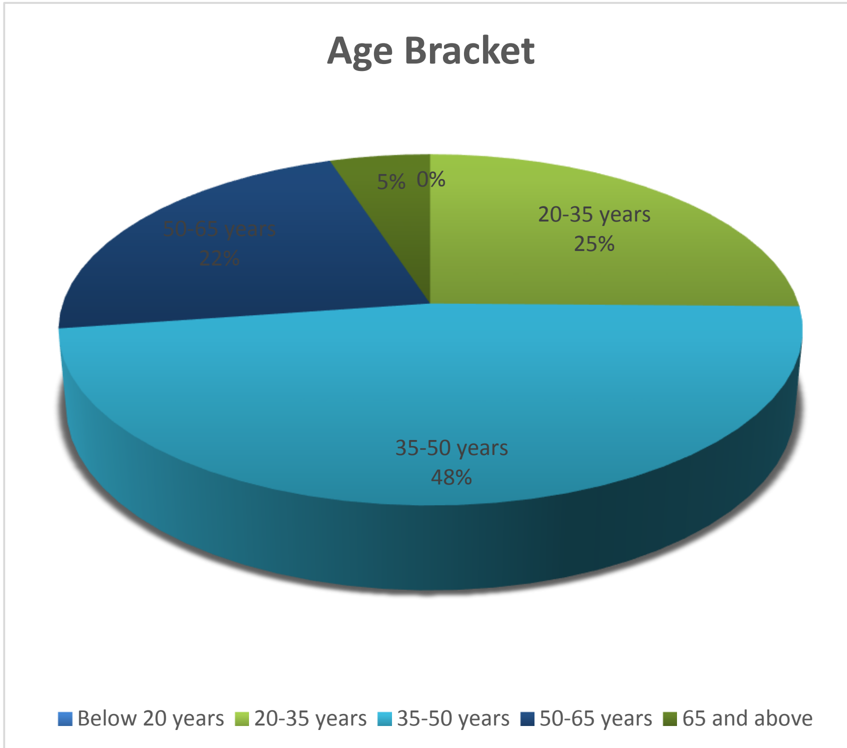

Figure 4.1 The age ranges of the respondents.

4.3.2 Area of Residence

To get a distributed point of view from the farmers the respondents were from different clusters which represented different areas. The different areas gave different rate of feedback as indicated in Figure 4.2. Eldoret East consisted of the largest population of respondents which is 33%, Eldoret West with 29% Eldoret North with 27% and Wareng with 11%.

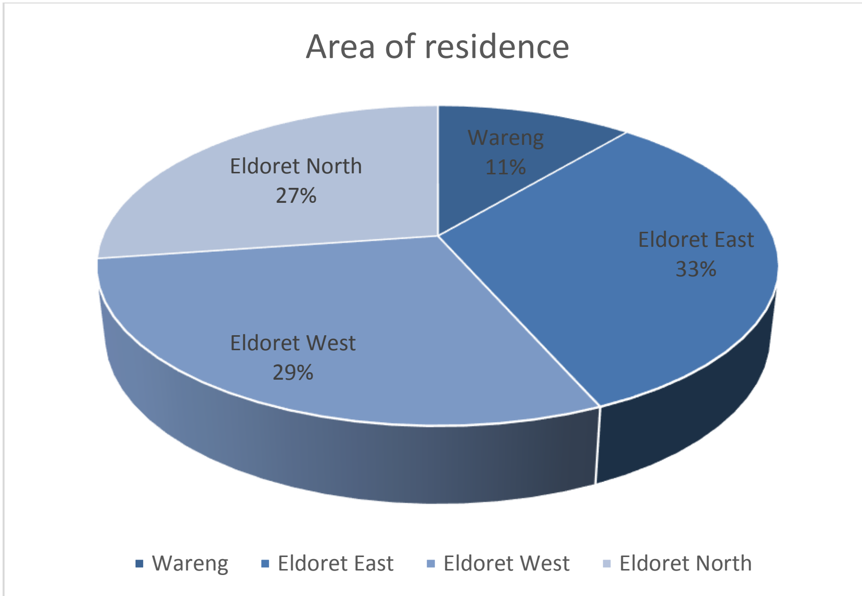

Figure 4.2 The cluster distribution of the respondents.

4.3.3 Mobile based application for milk recording

The survey asked the farmers about their willingness to try mobile based applications as a means of recording milk production. 84% of the farmers who responded to the questionnaire are willing to use mobile based applications for milk recording while 16% are not willing.

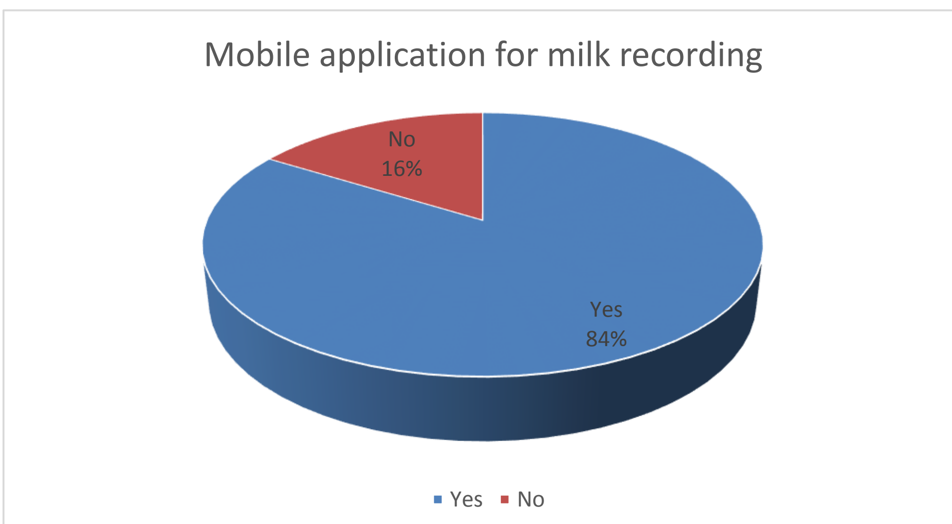

Figure 4.3 Respondents willing to use mobile applications for milk recording

4.3.4 Availability of Mobile Phones and Smartphones

From the survey on the number of users who own mobile devices, the findings show that 100% of the respondents own a mobile phone. The number of smartphones owned by the respondents was 23(71.9%) as indicated by the google survey and 45(82%) from the manual survey. The total number of respondents with smartphones was 68(78%).

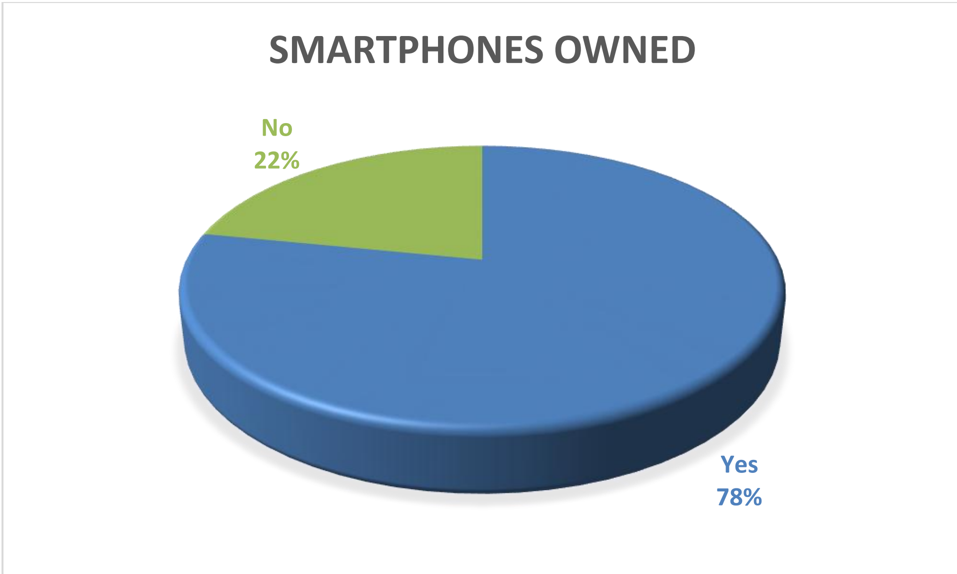

Figure 4.4 Chart representation of the number of smartphones owned.

4.3.5 Level of Education

The level of education is very important to show the ability of the farmers to be able to use the information. The system being developed is mobile based and it is essential to ensure that the users are able to use the system. From the findings done by the survey via google forms 26(81.3%) of the respondents have reached tertiary level of education, 3(9.4%) respondents selected other and 3(9.4%) selected secondary level. From the finding of the physical questionnaires 30(55%) selected tertiary level while 15(27%) selected secondary level, 5(9%) selected primary level and 5(9%) selected other. A total of 56(64%) selected tertiary level of education, 18(21%) selected secondary level, 8(9%) selected other and 5(6%) selected primary.

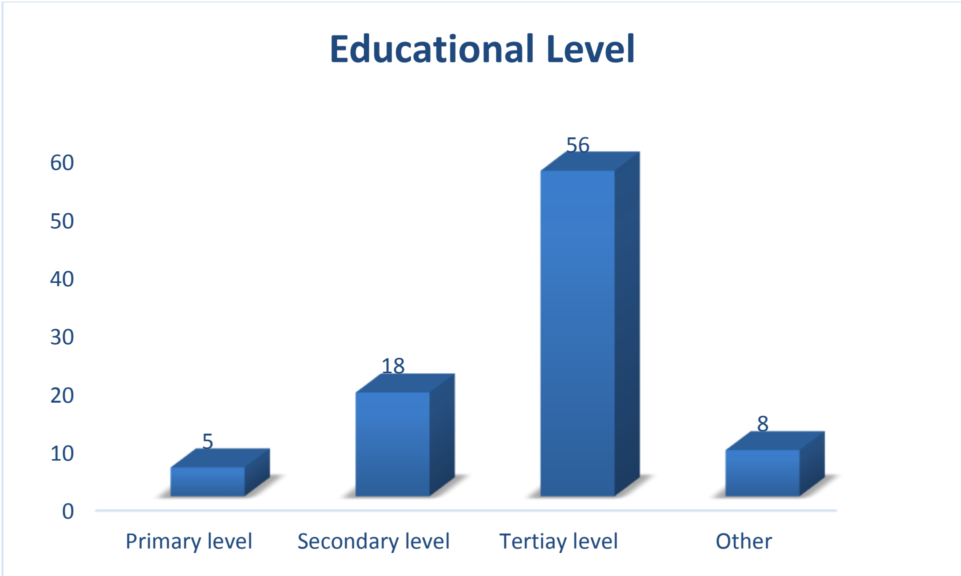

Figure 4.5 Graphs representing the levels of education.

4.3.6 Milk Production Records

The respondents were asked if they keep milk production records and according to the google survey 23(71.9%) keep records on milk production and 9(28.1%) do not keep the records. Findings from the physical questionnaires shows that 40(73%) of the respondents do not keep records and 15(27%) keep records.

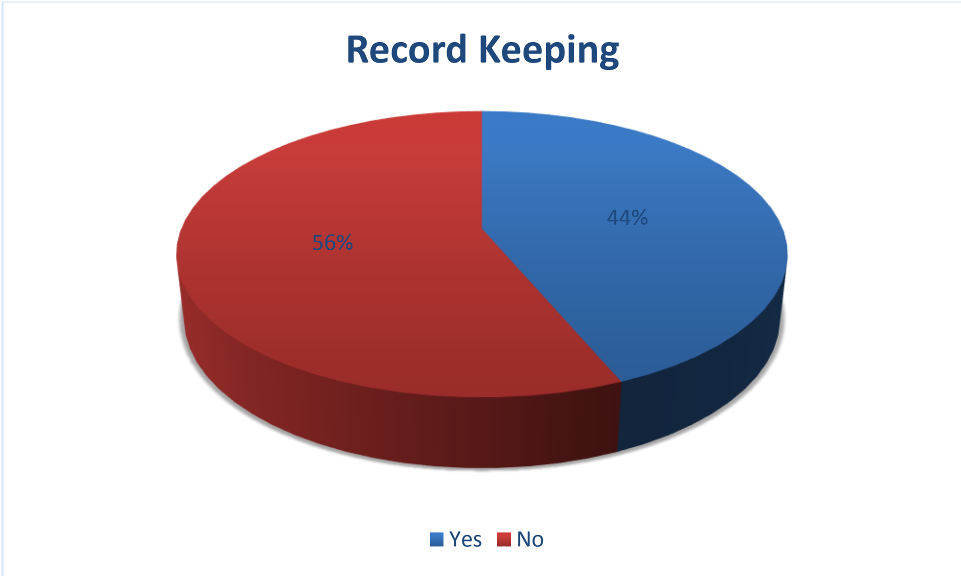

Figure 4.6 Chart representation of the number of milk production record keeping.

4.4 Application Requirements

Requirement specification includes the functional and the non-functional requirements for the system. Functional requirements describe the processing by the new system, the inputs and outputs of the system and the data that must be managed by the system. Non-functional requirements describe how well the system supports the functional requirements. This may include: Performance criteria, Reliability requirements, Security considerations, Usability requirements etc. (Mylopoulos, 2004).The functional requirements for the system includes the following:

i. The system should be able to add a new Farmer/dairy company and log him/her to the system.
ii. The system should be able to record deliveries from farmers and save them in MySQL Database.
iii. The system should be able to organize the data from the database and display records.
iv. The system should be able to analyze and create charts of the milk records.
v. The system should be able to search for specific historical records.

The non-functional requirements include the following:

i. Usability Requirements- The graphical user interface of the system should be user friendly and can be comfortably used and understood by the users.
ii. Security considerations – The system should ensure that the user accounts and the records are secure from intrusion and or damage.
iii. Reliability requirements – The system should be available at any time that it is required and the information should be up to date and accurate.

4.5 Application Design Architecture

Figure 4.7 shows the architectural requirements of the M-agriculturerecording system which includes the software requirements and hardware requirements for both the server side and client side of the system.

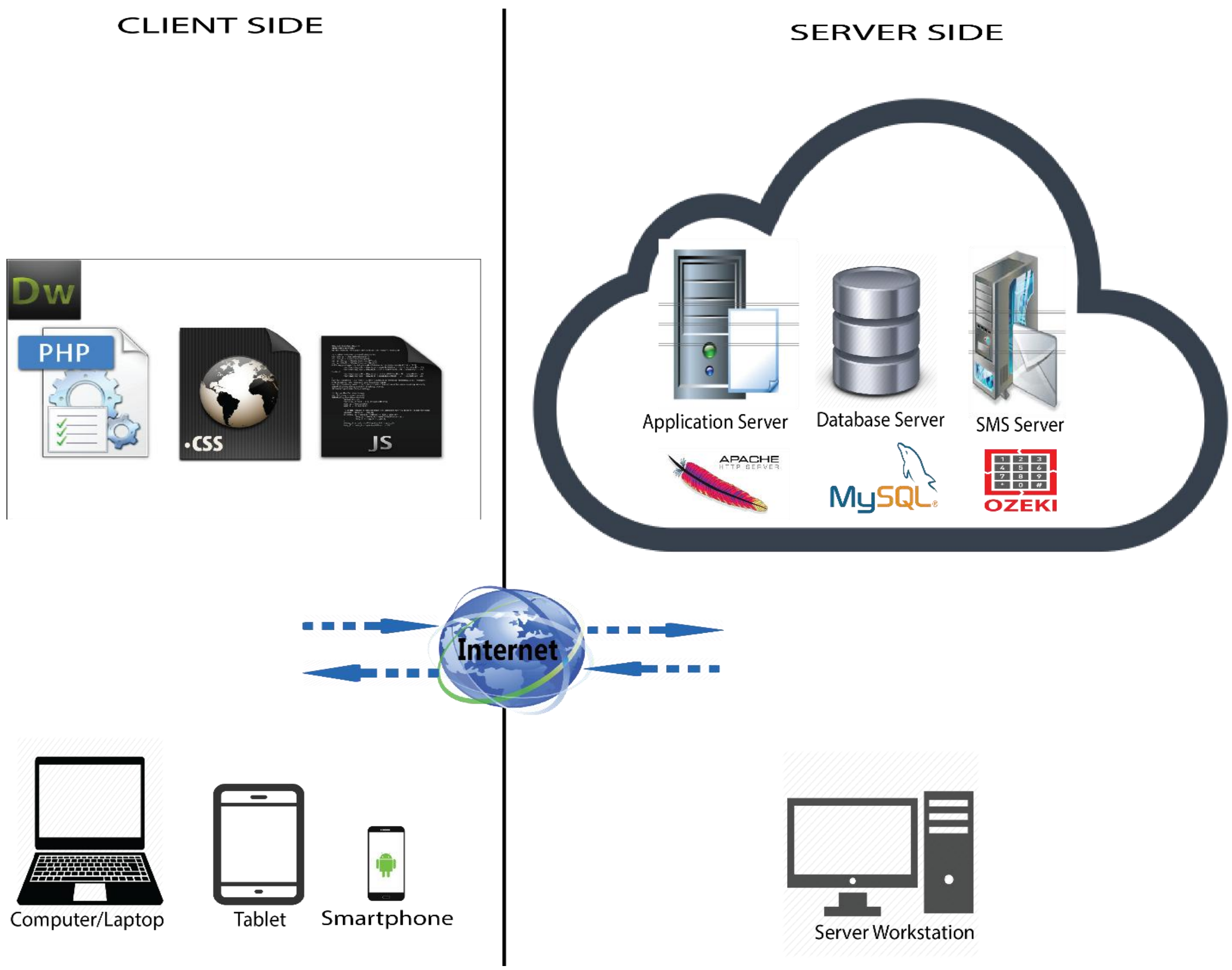

Figure 4.7 Architecture showing Software and Hardware Requirements for the Client and Server side.

The system is a web based application that is compatible with smartphones, tablets, laptops and desktop computers. The database system is cloud based and centralized giving flexible access to records and analysis. The cloud server is available via the internet making it accessible throughout the globe.

4.6 Server Side Architecture

The server is a web configured server preferably Linux based with a configured static IPv4 and Domain Name System (DNS). Due to the cost and availability of static IP addresses the system is configured using the available dynamic IPv4 and the Dynamic Domain Name System (DDNS). This allows for connectivity via the internet. The DDNS services are provided by DNS companies such as DynDNS which offer the DDNS services. Figure 4.5 below shows how the server is configured.

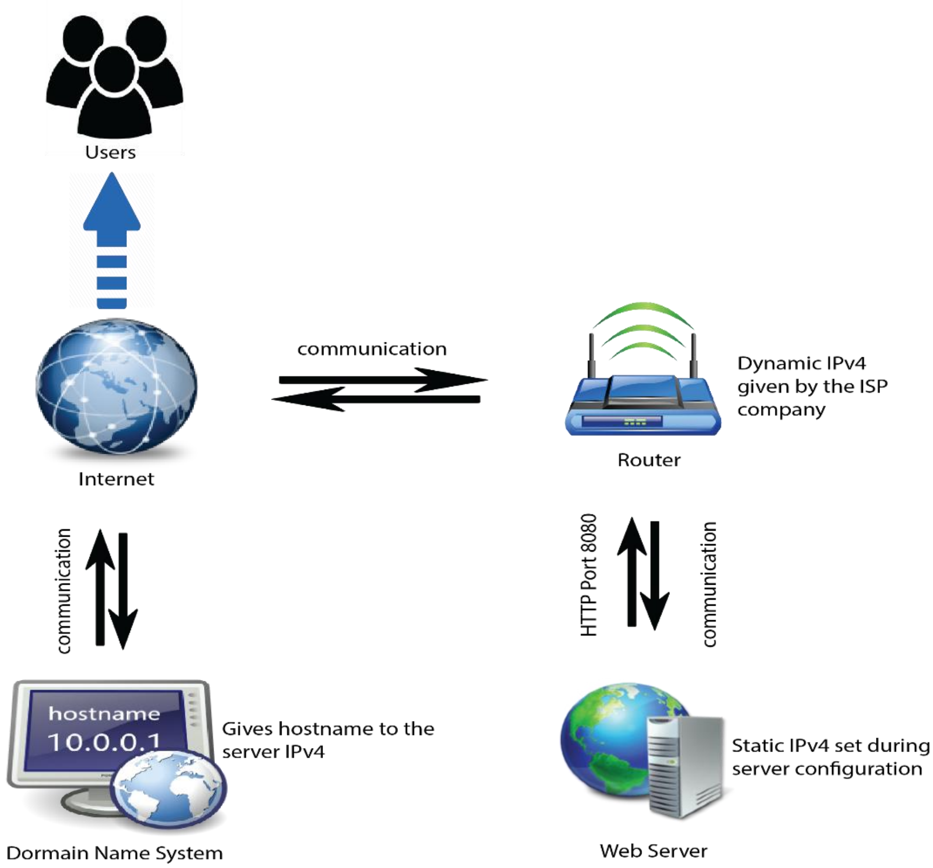

Figure 4.8 Server side configuration of the M-agriculture Recording system for milk producers.

The database system which is SQL based runs on the server with the application server and the SMS server for reporting.

4.7 Activity Diagrams

In UML an activity diagram is used to display the sequence of activities. Activity Diagrams show the workflow from a start point to the finish point detailing the many decision paths that exist in the progression of events contained in the activity.

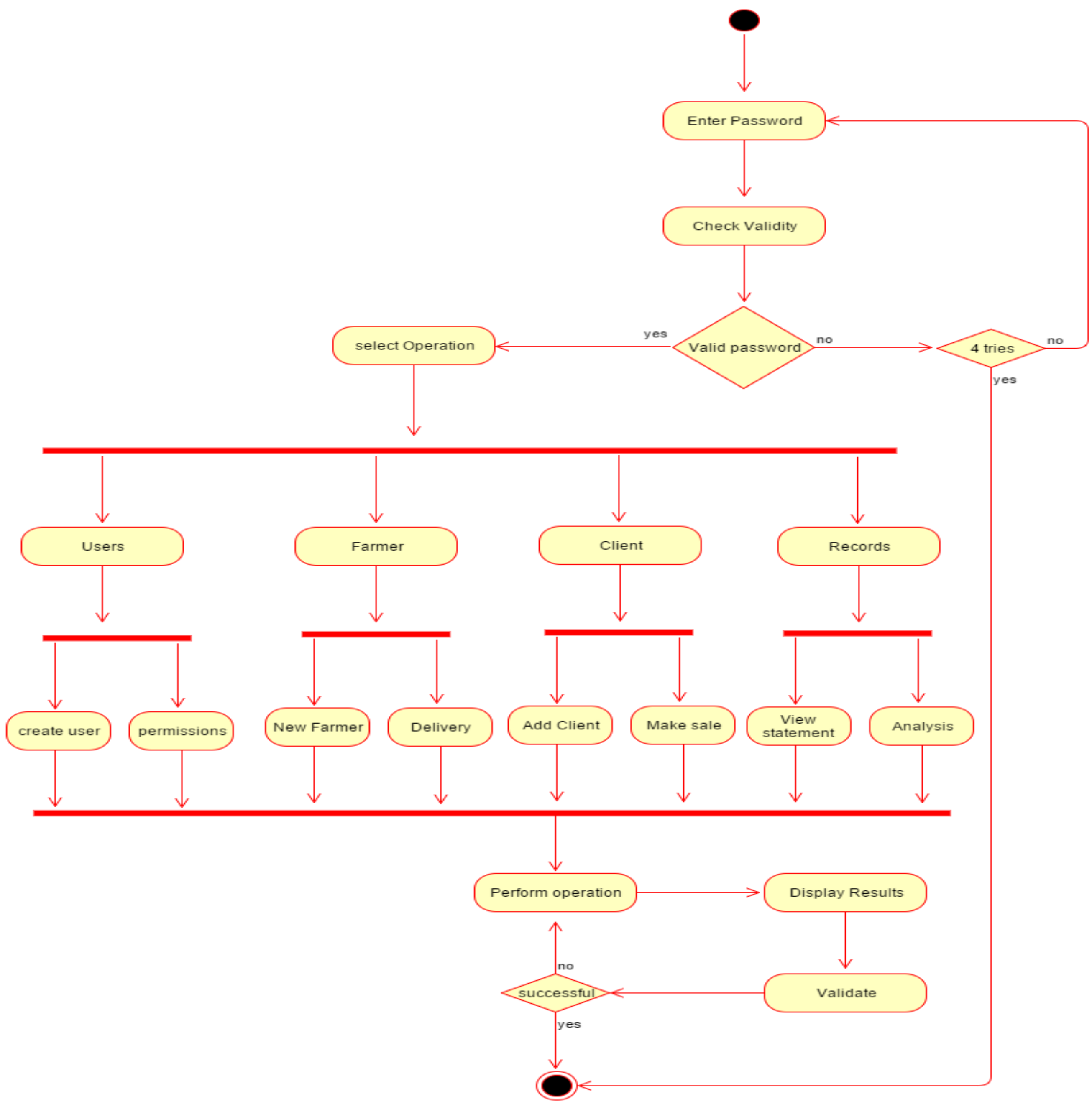

Figure 4.9 Activity Diagram for Administrator.

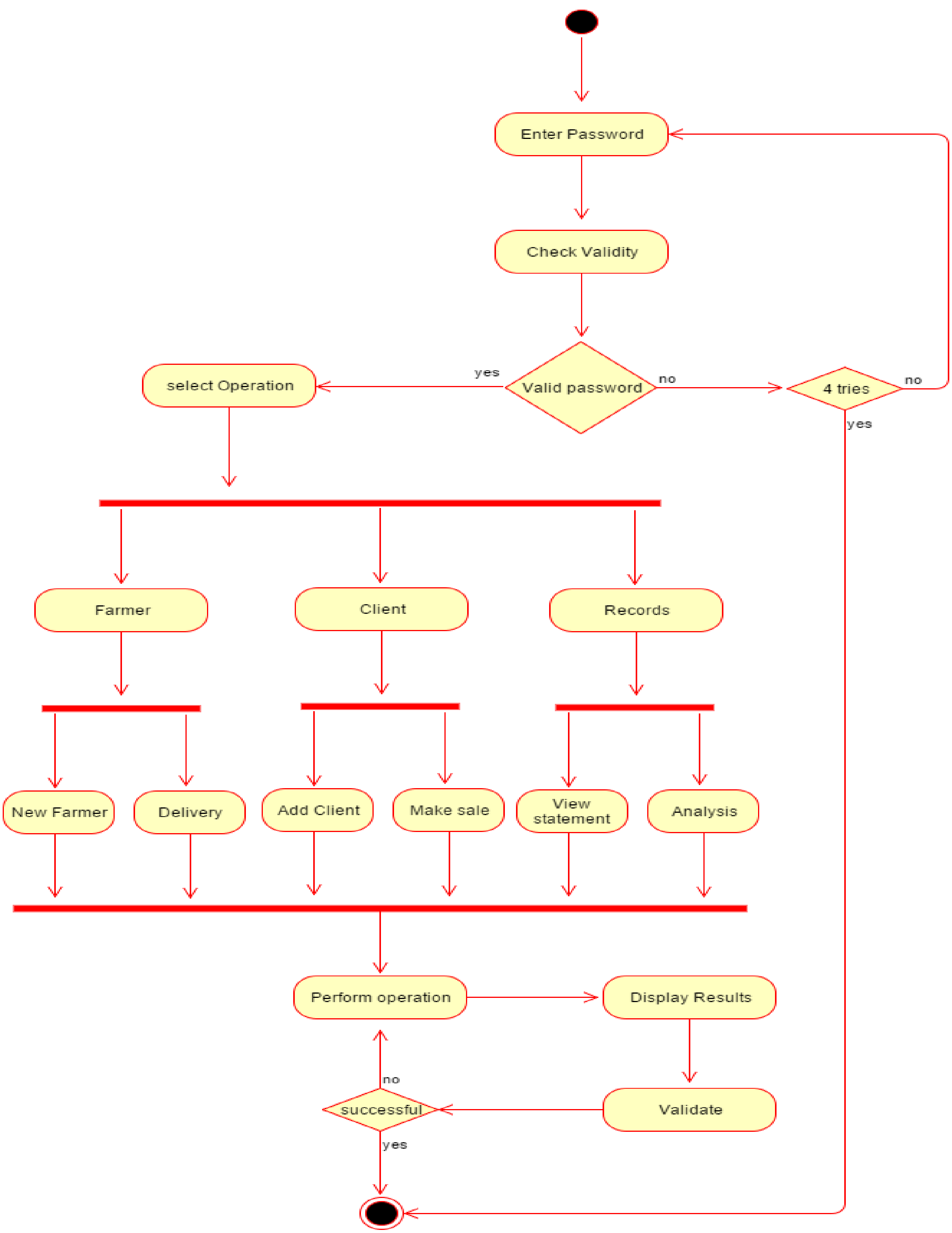

Figure 4.10 Activity Diagram for Supervisor.

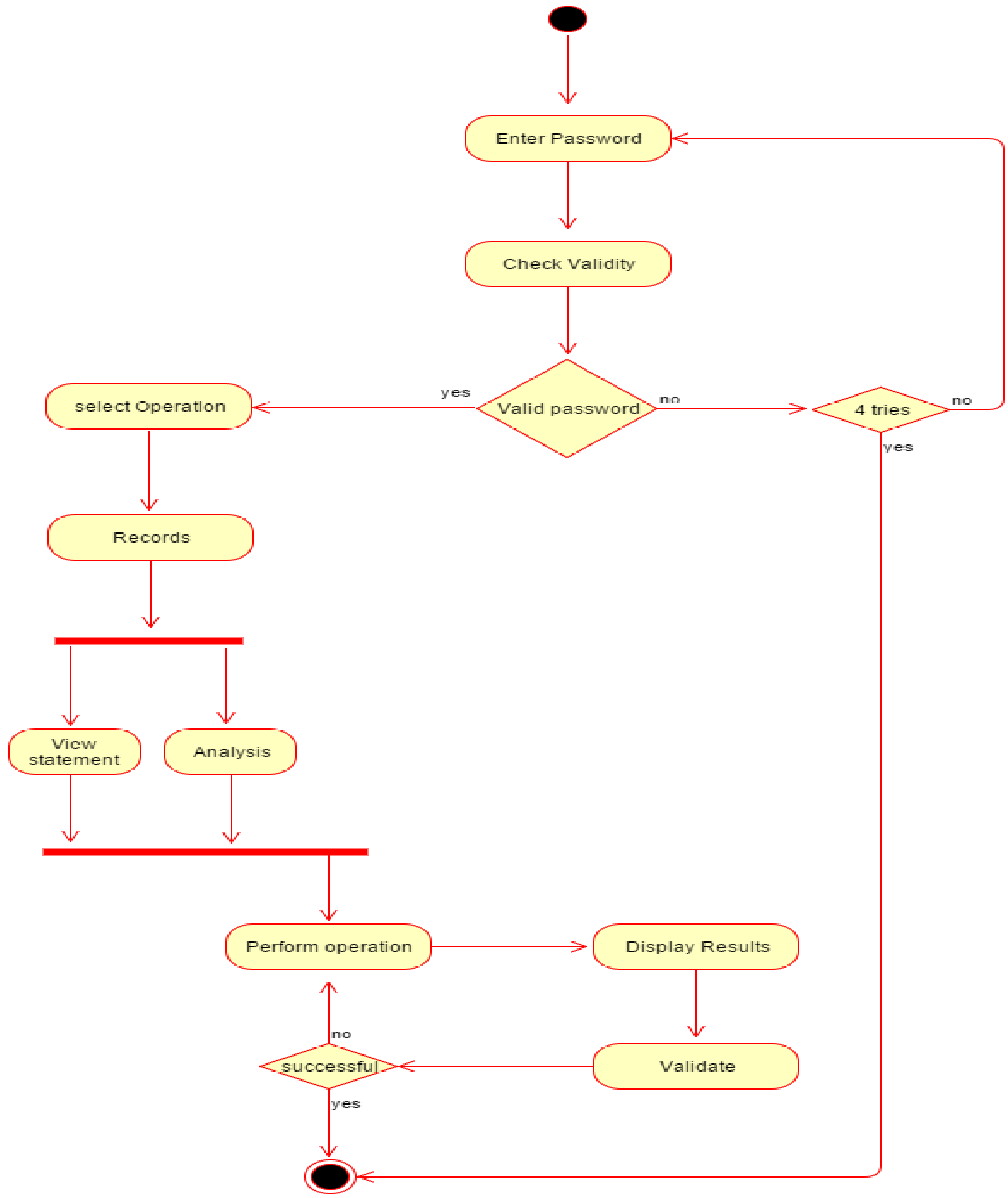

Figure 4.11 Activity Diagram for User.

4.8 Use Case Diagrams

The system design looks at the main actors of the system and how they interact with the system. In the M-agriculture Recording system for milk producers in Kenya the actors include:

Farmers, Input clerk, Institutional users, supervisors and administrators. The actors, their goals for the system and the use cases are listed in Table 4.1.

Table 4.1 List of actors, goals and use cases.

Actor	**Goal**	**Use cases**
Farmer	View records in the system Search for specific records View the reports	▪ View Records ▪ View Reports ▪ Search Records
Institutions/Agents	▪ Add new farmers to system ▪ View records entered ▪ Add new deliveries daily ▪ Process sales for clients ▪ Generate reports	▪ Add farmers ▪ View records ▪ Add deliveries ▪ Process sales ▪ Generate reports
Administrator/Supervisor	▪ Supporting actor for all the cases. ▪ Manage user accounts, permissions and support the users.	▪ Add/Remove Farmer ▪ Add/Remove Product ▪ Add/Remove Client ▪ Add/Remove Agent

The interactions of the actors and the use cases are shown more clearly by the use of the use case diagram which is illustrated by Figure 4.9. A use case describes a sequence of actions that provide something of measurable value to a person, organization, or external system that plays a role in one or more interactions with the system (Ambler, 2004).

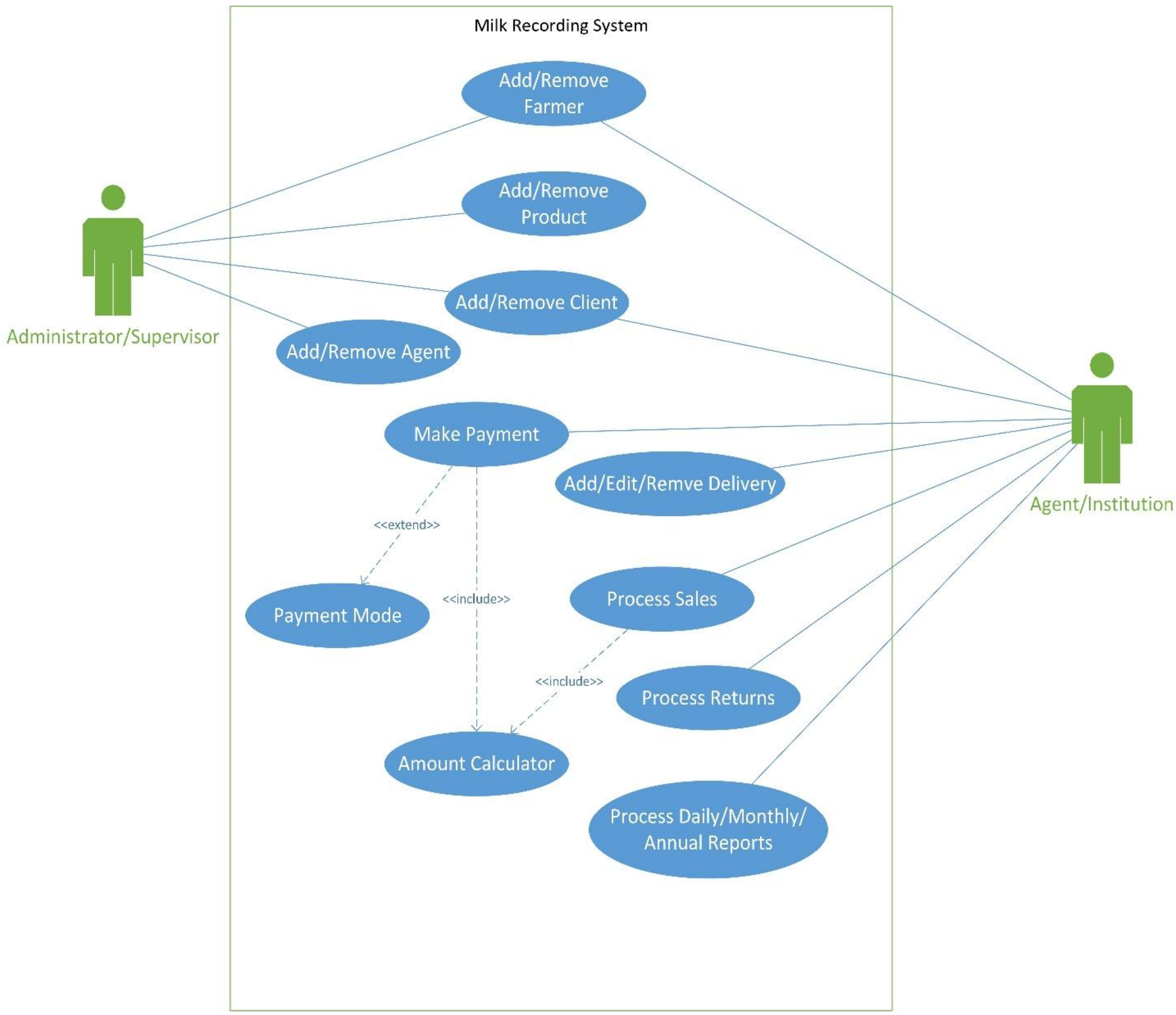

Figure 4.12 Use case diagram for the administrator and the agent of the system.

4.9 Data Flow Diagrams

The dataflow diagrams represent the flow of the data from level 0 DFD which shows the general context of the system as displayed in Figure 4.10. Figure 4.11 represents level 1 DFD which has more details as compared to level 0 and Figure 4.12 shows the level 2 DFD.

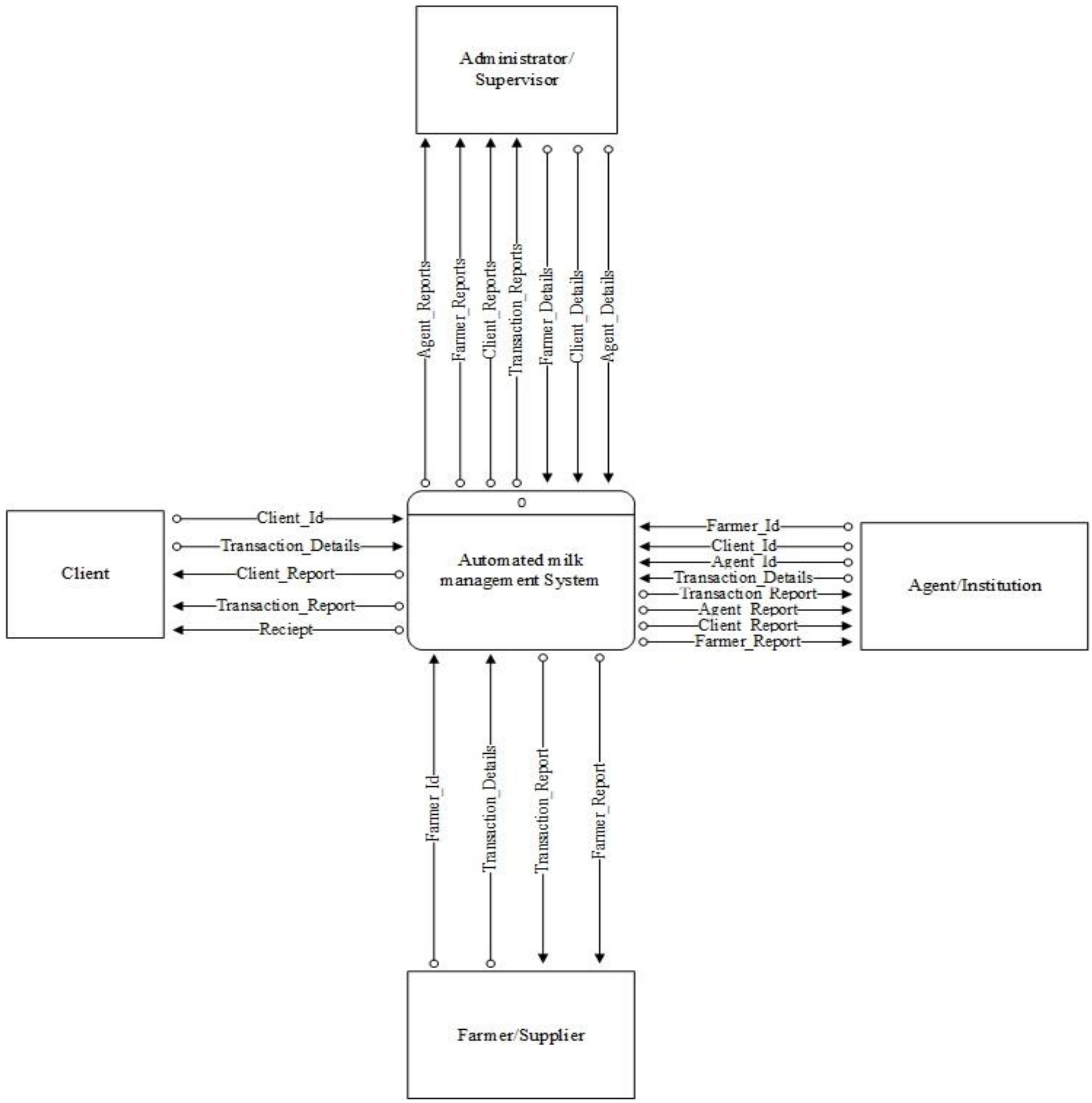

Figure 4.13 Context diagram for the M-agriculture Recording system for milk producers.

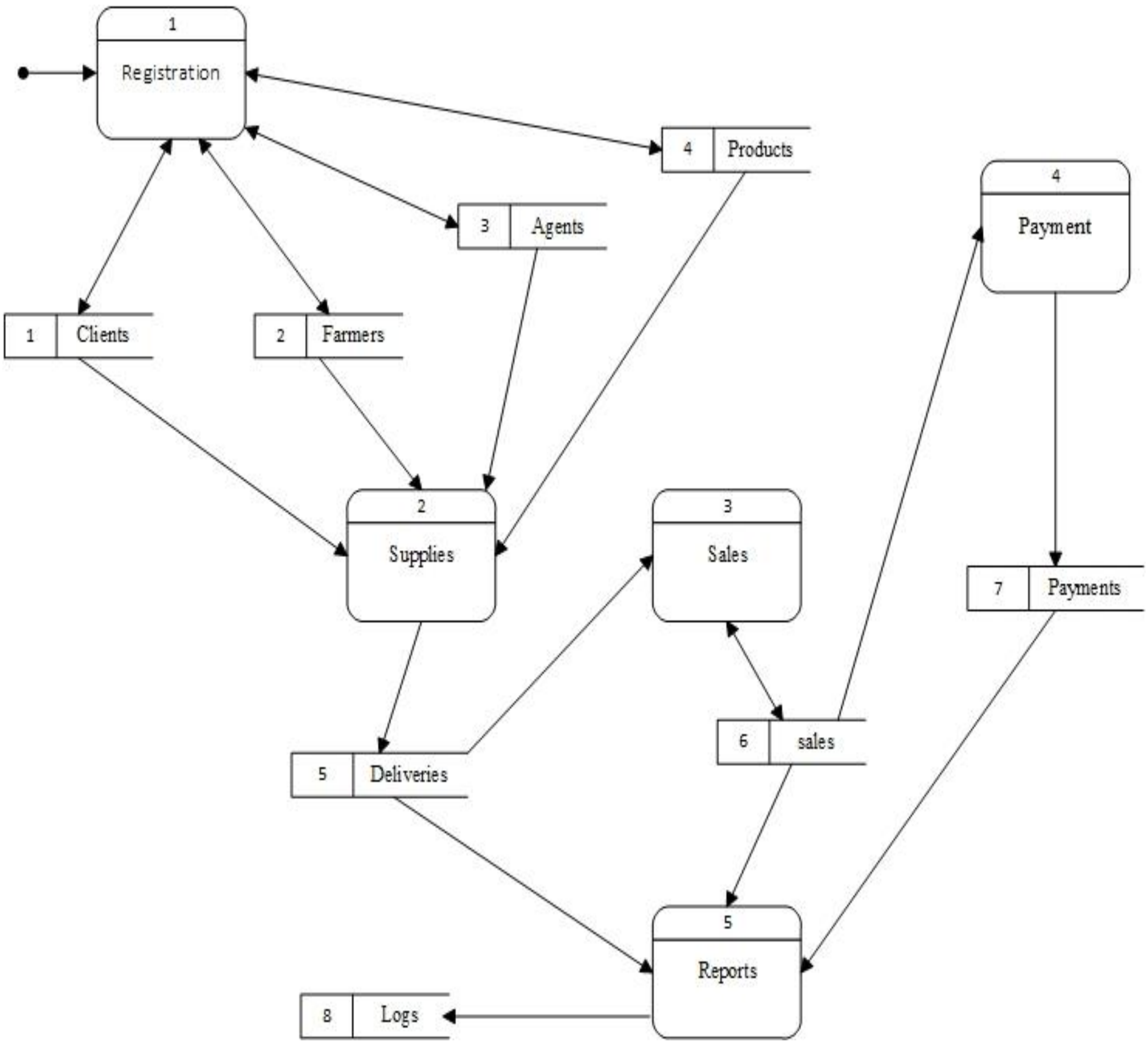

Figure 4.14 Level 1 Data Flow Diagram for M-agriculture recording system.

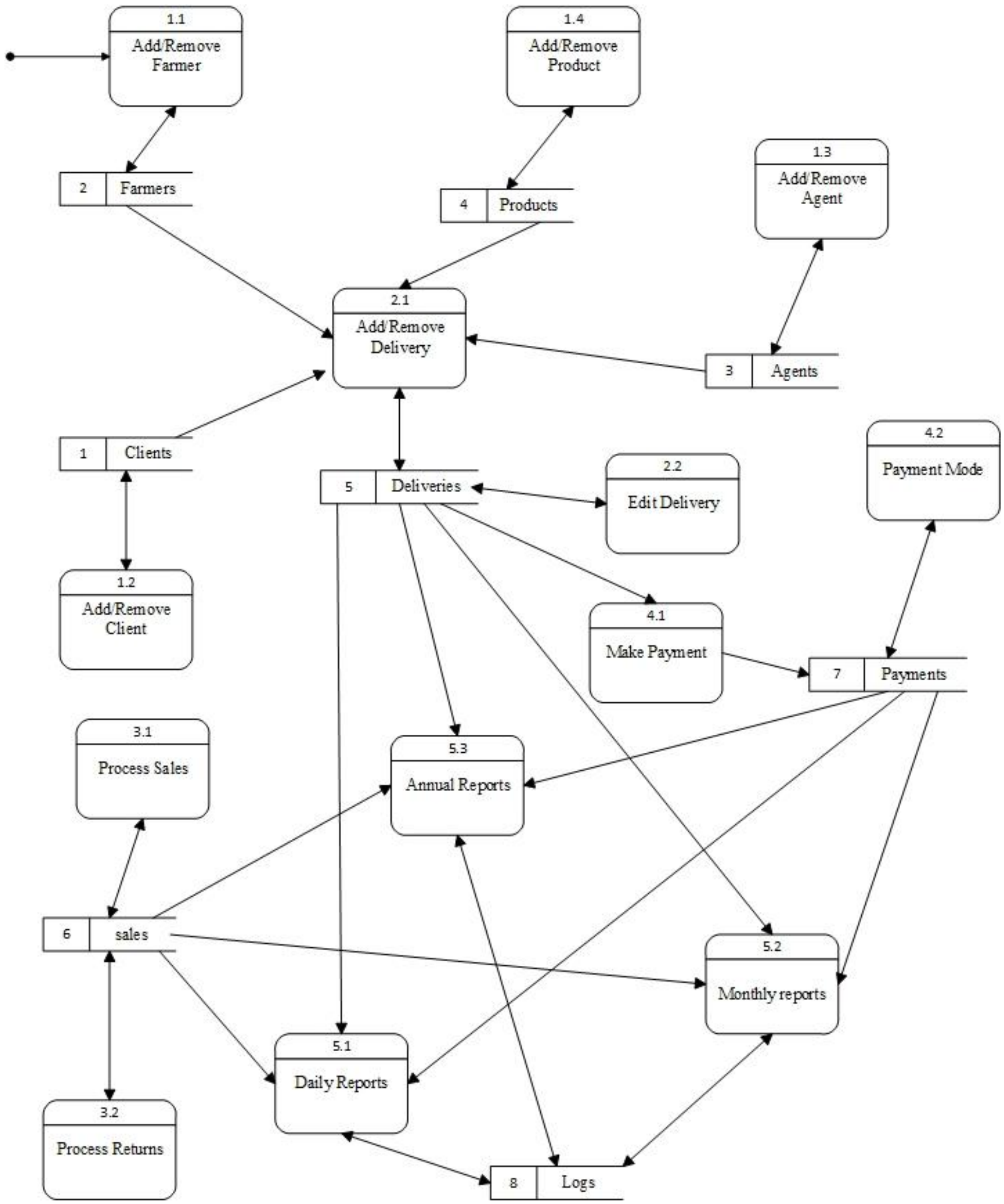

Figure 4.12 Level 2 Data Flow Diagram for M-agriculture recording system.

4.10 System Sequence Diagram and Collaboration Diagrams

The purposes of interaction diagrams are to visualize the interactive behavior of the system. Figure 4.13 shows the process of delivery in the system and how the process takes place from the point when the farmer delivers the milk and how it is updated to the system.

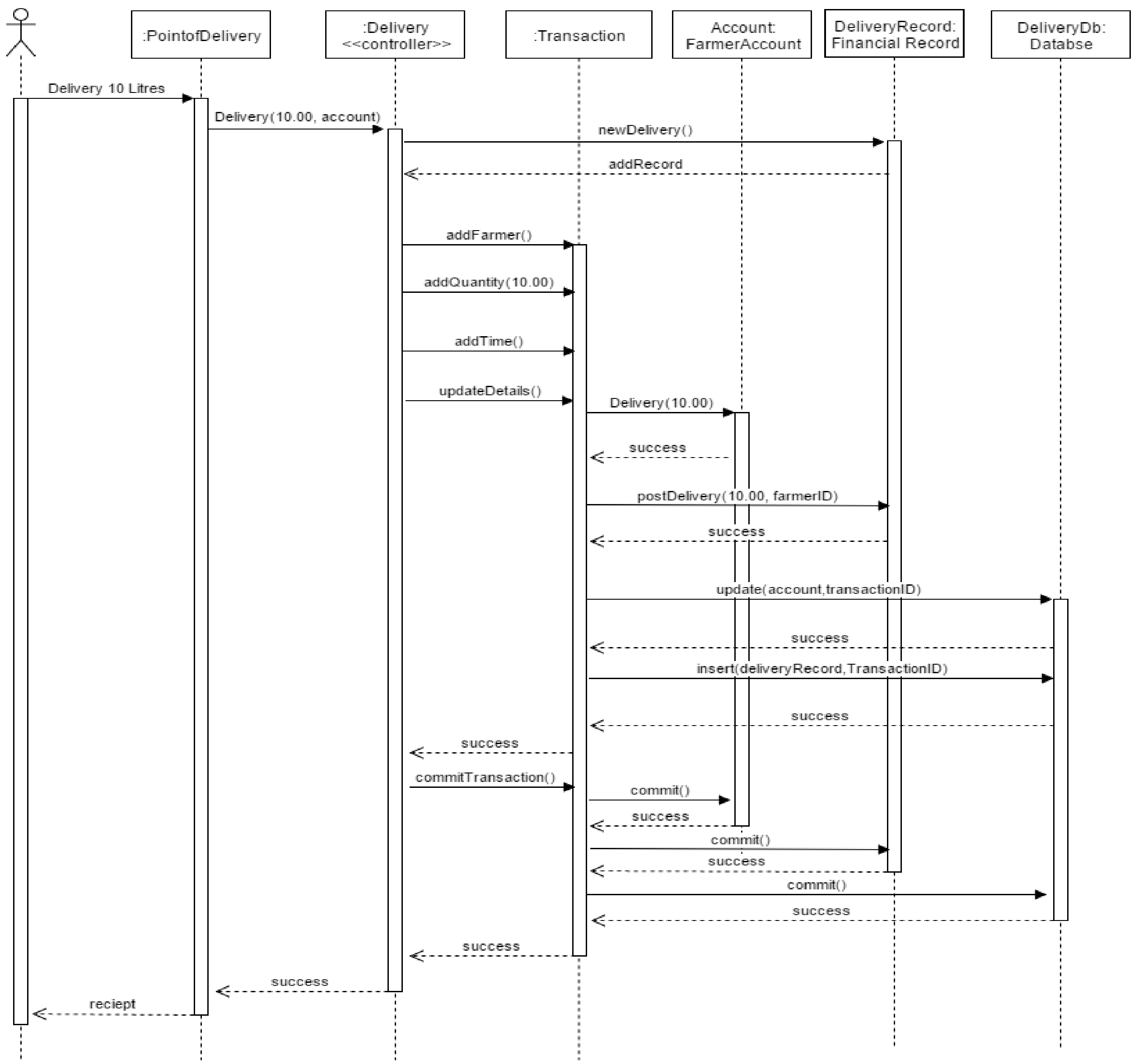

Figure 4.13 Sequence diagram for the M-agriculture recording system

4.11 Entity Relationship Diagram

The Entity Relationship diagram represents the information that is captured by the database. This guideline shows how the database is designed and the relationship between the entities. Figure 4.13 shows the Entity Relationship Diagram.

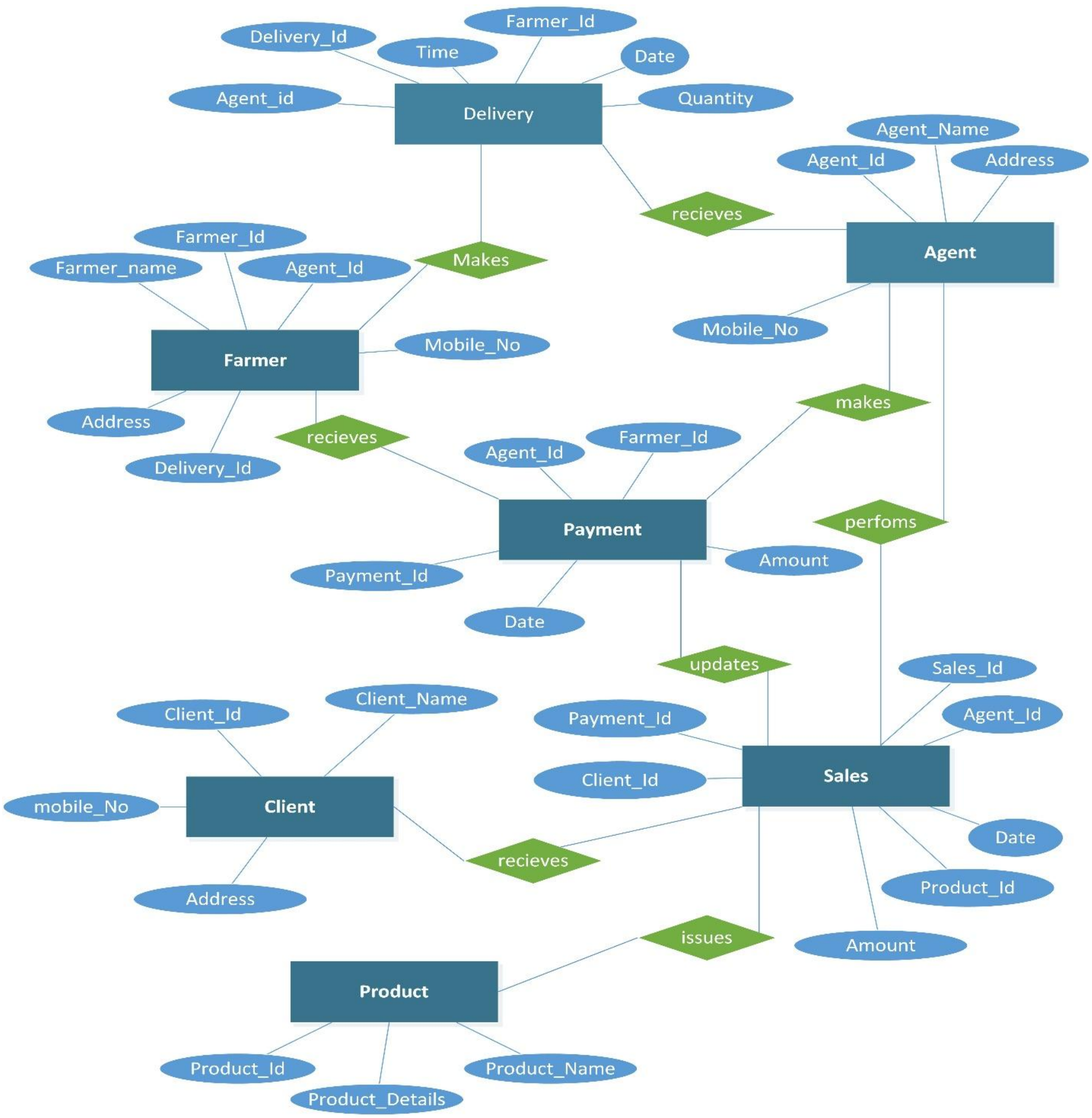

Figure 4.14 E-R diagram for the M-agriculture Recording system for milk producers.

4.12 Class Diagrams

The class is a representation of the tables in the database as displayed by Figure 4.15 below.

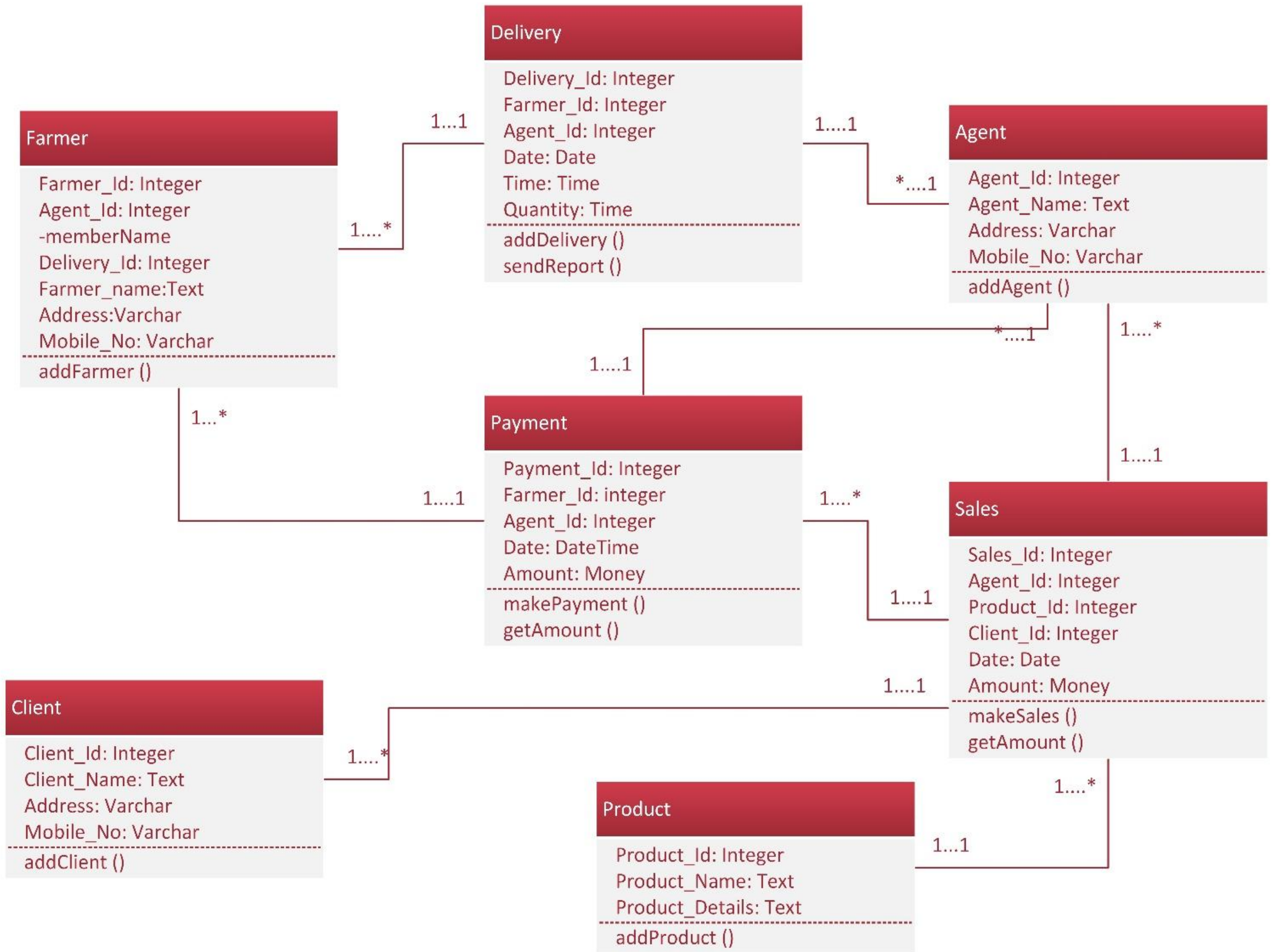

Figure 4.15 Class diagram for the M-agriculture Recording system for milk producers.

Chapter 5: Implementation and Testing

The implementation phase is the phase of the project during which the actual physical work is performed and an executable software is developed. This includes setting up of the hardware equipment, installation of required software and coding the actual software. In Chapter 4 the requirement, architecture and the design of the system has been done. In this Chapter the hardware configuration, installation and the coding is done.

5.1. Hardware Installation and Configuration

The hardware required includes the server the internet router and coding workstation complete installed with the required software. The server includes the database server, application server, web server and the SMS server. The best way to select the appropriate hardware configuration for the SMS server is to calculate the number of messages you need to send and receive and to determine the average message throughput (message per minute MPM or message per second MPS). The system is configured to use 50 MPS to 200 MPS configured on the Ozeki message server. This is due to the limited processing ability of the available server; this ensures that the processor can handle the message interchange.

5.2. Graphical User Interface Design and System Coding

The coding and GUI design is done in PHP 5.4 using Adobe Dreamweaver IDE. The structure of the code follows the description in Chapter 4 considering the flow of information as indicated in the UML diagrams. The main functionality of the system which includes data collection and reporting are now actualized. The user levels including supervisors, administrators and basic users are established and generated. The system is basically a dairy farming management information(DFMIS) system linking the dairy institutions with the dairy farmers therefore different access levels are needed for the system.

5.2.1. System Access Levels

The access levels refer to the users who will be accessing the system on different levels and for different purposes. The basic user for the system allows for access of user specific information such as delivery statements. The user does not have access to any other recorded information except his/her own. When the basic user is created the user ID is linked to the specific farmer record giving the user access to the record.

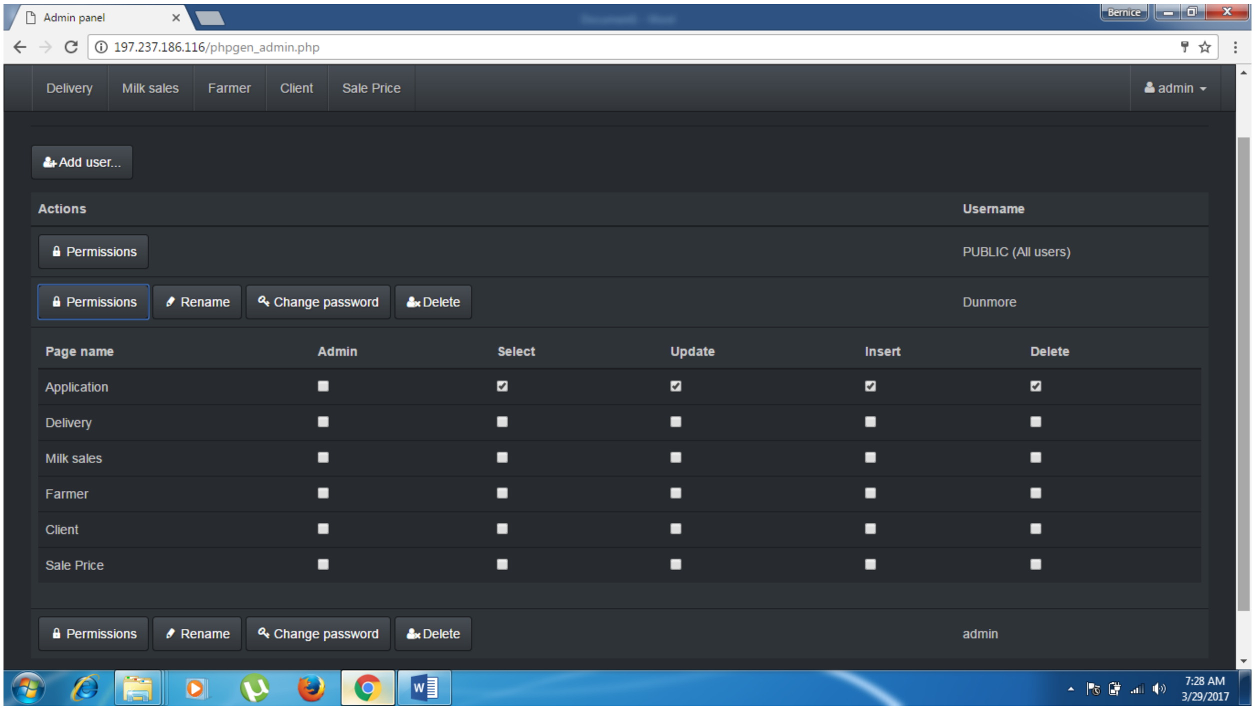

Figure 5.1 Users and the functionalities as viewed by the administrator

The administrator user as shown by Figure 5.1 has multiple functionalities which include creating of more users for the system. The administrator is also allowed to add new items including new institutions, branches, farmers and sales. The administrator's function also includes managing the various aspects of the system including the users, branches, reports, members, sales and deliveries. The main task which is unique to the administrator user is the management of other system users which includes adding, modifying and deleting the users. The system has four stages when creating a new user which includes; adding the user basic information, institutional information, account information and completion.

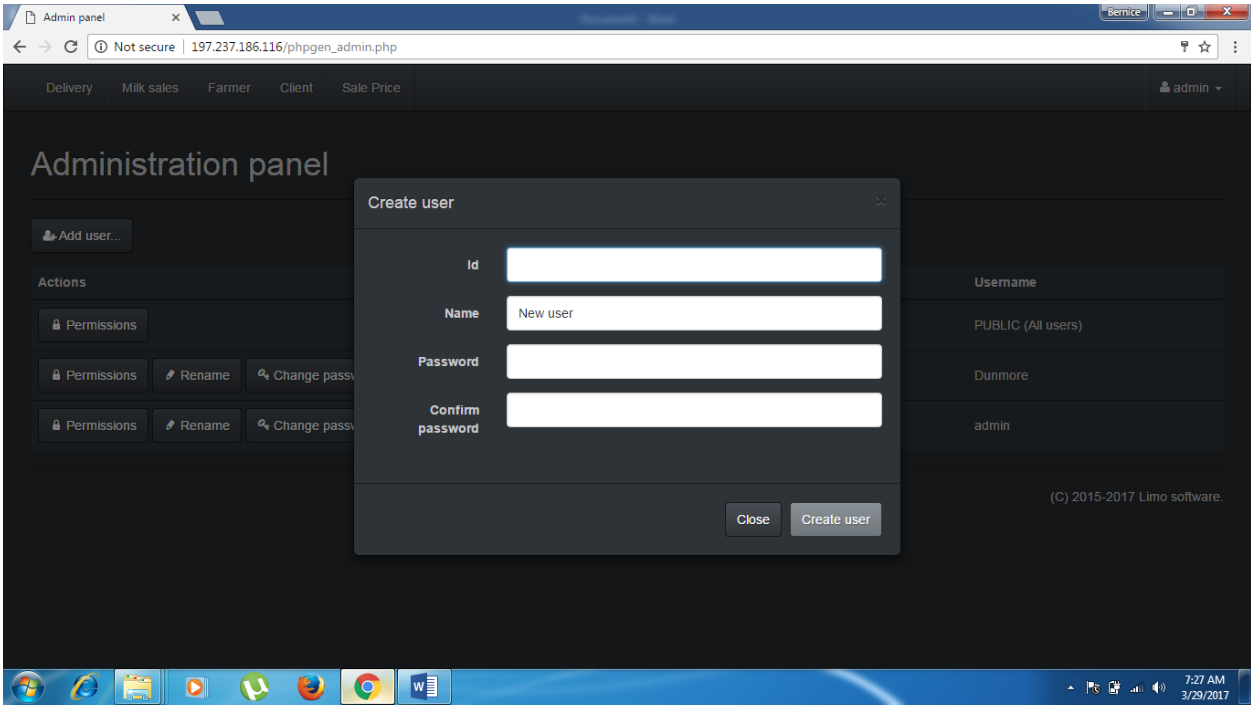

Figure 5.2 Administrator creating a new user for the system.

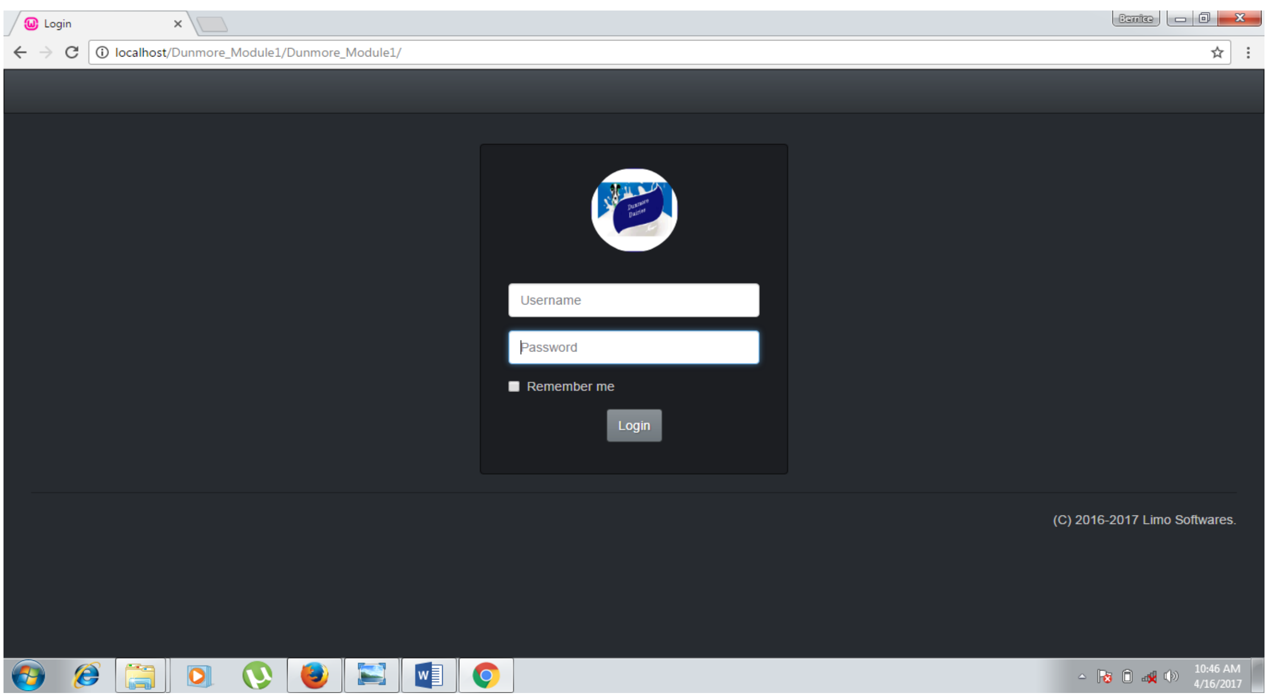

Figure 5.3 User login interface screen.

The system has data entry users which are basically the main daily users for feeding the system with the delivery records. The data entry users include the basic user whose function is to enter the records only and the supervisor who can manage the daily delivery records. Figure 5.2 shows the administrator adding a new user and Figure 5.3 shows the log in screen for the user.

5.2.2. Record Input and Search Function

This system is a data collection tool therefore the main functionality is to input data from the milk deliveries and to view records from previous entries. When the dairy milk is delivered to the institution using the M-agriculture recording system the software stores the record and sends a report to the farmer of the delivery details via SMS. When a user of the system wants to check a record of previous deliveries or the trend of production, then the search and the reporting functions are used. When doing the daily delivery, details of the transaction are recorded in the delivery screen as shown in Figure 5.4. The transaction details include Farmer Id, Price, Date, Time and Quantity.

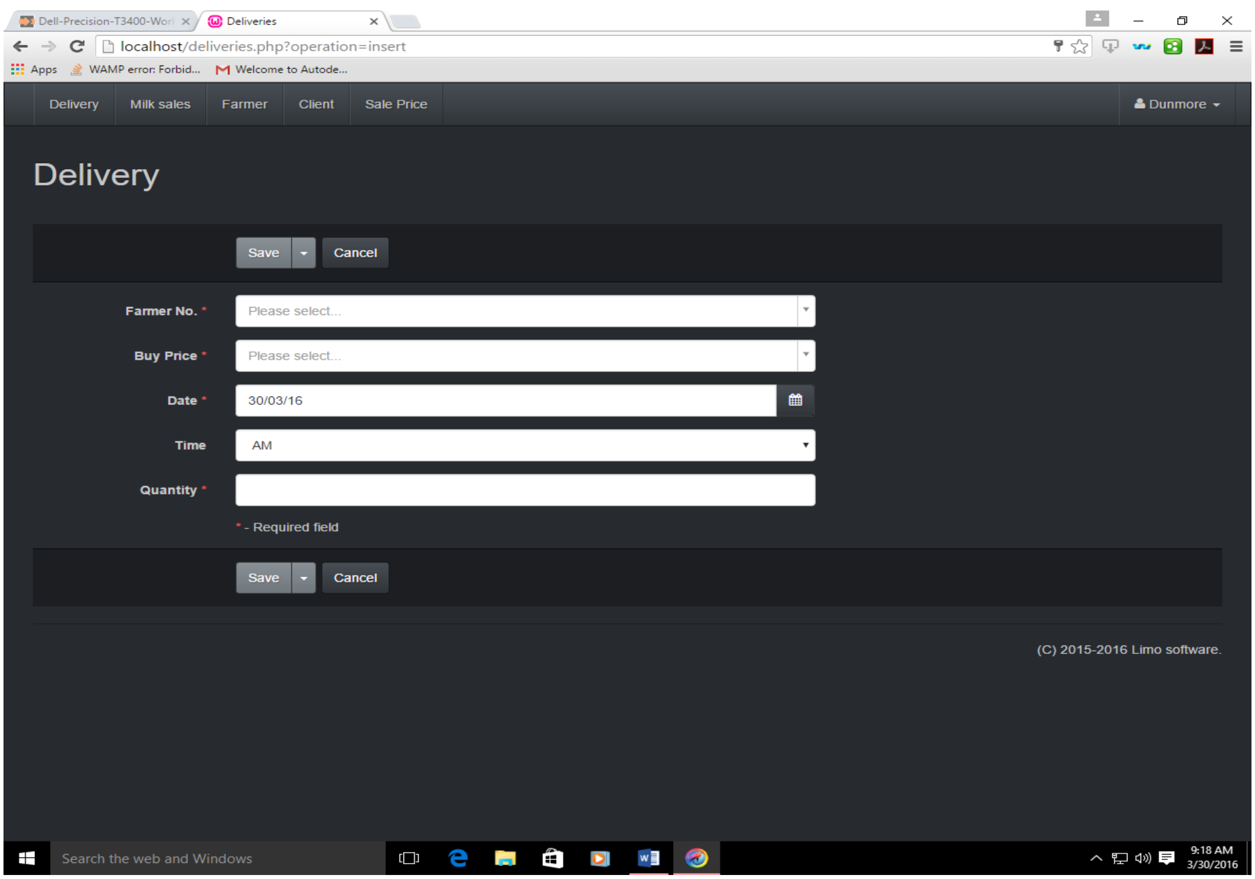

Figure 5.4 Delivery data input screen for supervisor user.

Creating new farmers into the system also requires entry of data, which include entering of all farmer's details required by the system. Figure 5.5 shows how the system user enters new farmers into the system.

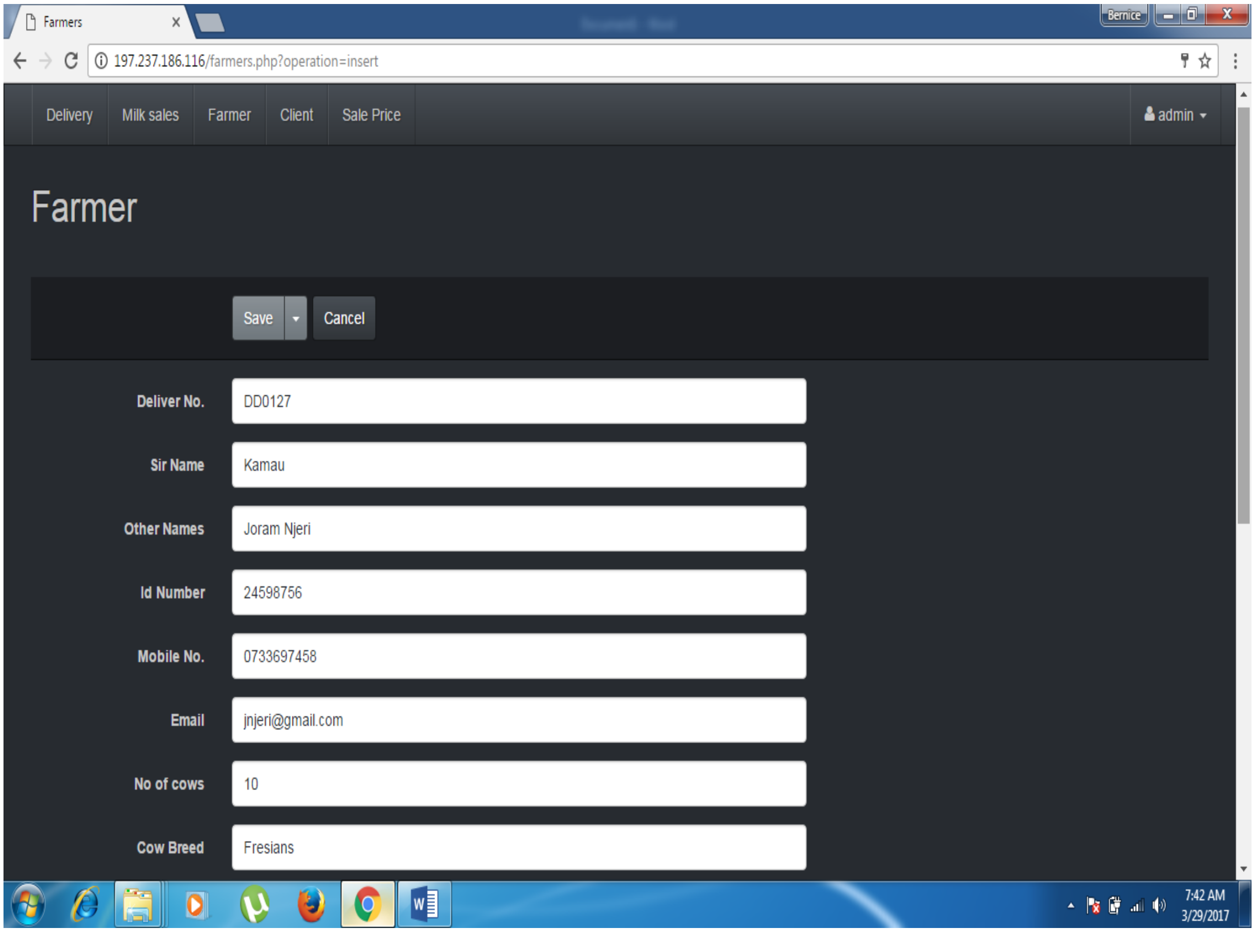

Figure 5.5 Add new farmer function graphically displayed.

After the required information is input into the system, the information is stored in the database and can be displayed in the system inform of tabular displays showing the important information of system. The tables show the list of recorded farmers, delivery and the sales. The information in the database is dated and thus when displayed the records are arranged by default using the date as the system reports. Figure 5.6 shows the sales report as displayed on the sales page of the system for Dunmore dairy as from 29/2/2016 to 10/03/2016. The report has been arranged per client records. The system offers options for exporting to Excel or PDF and also printing the selected records.

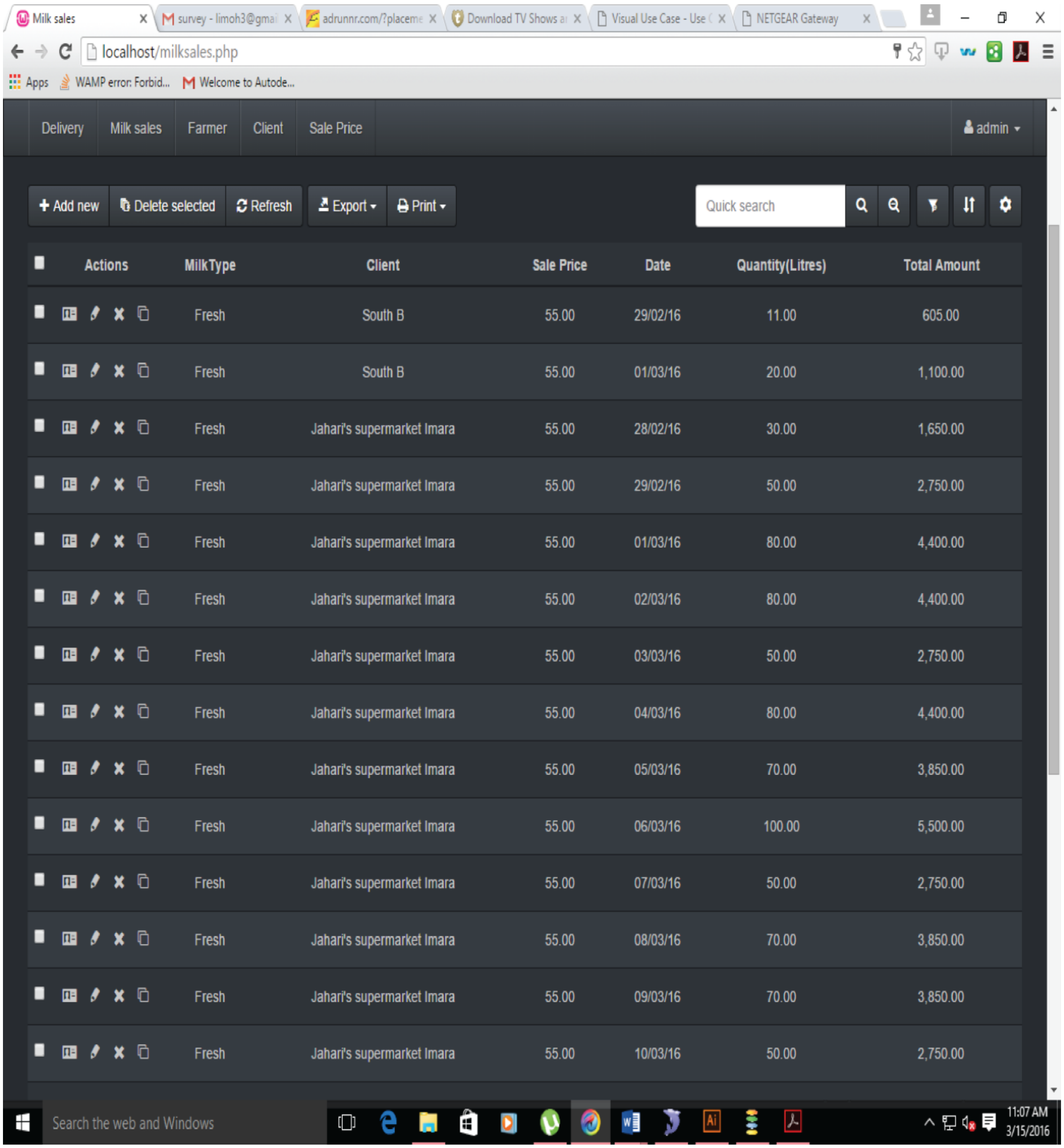

Figure 5.6 Sales report displayed from the database.

The system can at a single time be handling a bulk of information for the daily transactions which make it hard to find specific records when needed. Therefore, an elaborate search function is needed to filter and to search for records. Appendix C display search functions used by the system for filtering and searching through the records. The searching includes simple search algorithm which allows the user to search key words as shown on the next Figure 5.7.

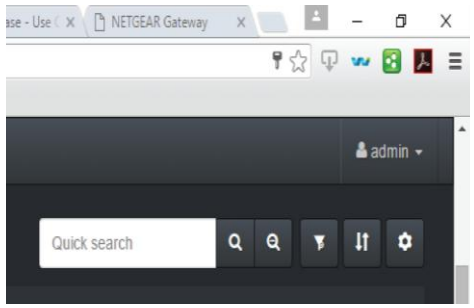

Figure 5.7 Quick search function display.

For more variety of searching options including multiple records, the filtering function is used to select the range of records needed by the user. Figure 5.8 shows how the system users use the filter function to search for records. The filter builder gives the user a selection of the fields to use for filtering for example if a user wants to filter by date. The second field on the filter builder gives the user the option of creating a range, this can include Equals, Greater than or Less than. The last entry is for the actual search parameter i.e. what the user wants to search for. Example to search for records for 5/3/2016, the user selects Date as the first parameter, Equals as the second and 5/3/2016 as the last parameter. This means that the system will search for all records which have the date 5/3/2016.

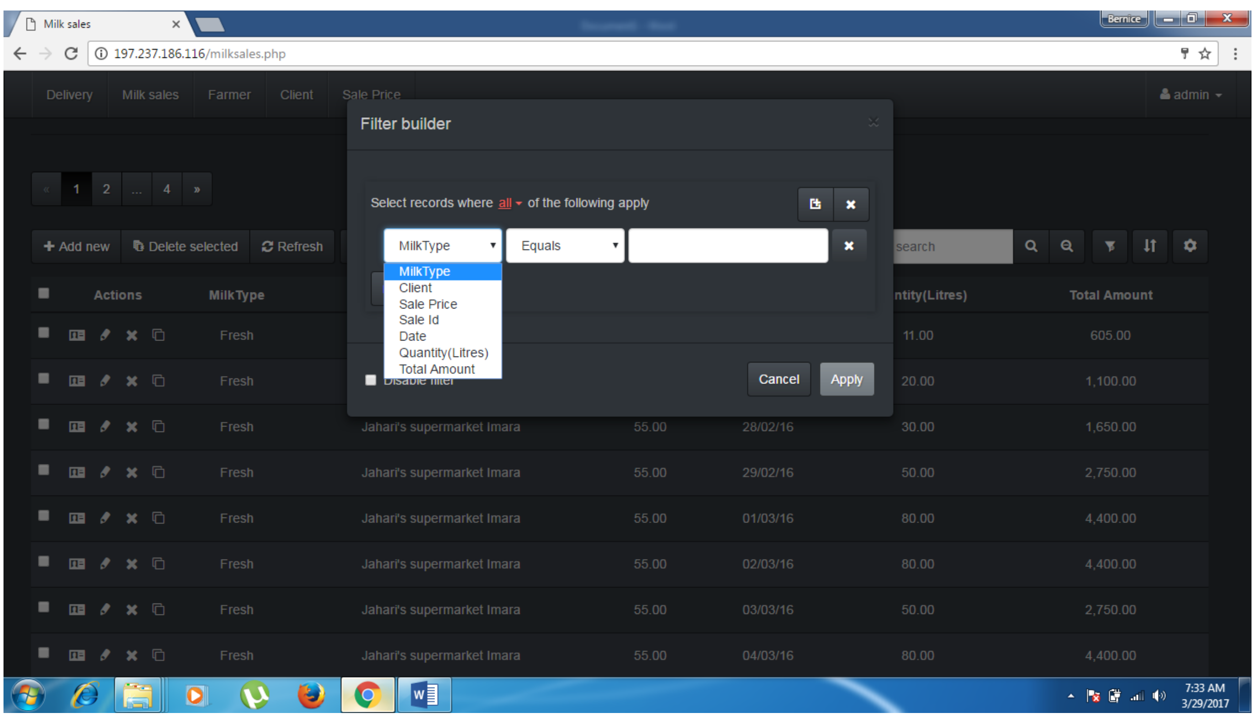

Figure 5.8 The filter search function for locating a range of records.

The function for arranging the records also aids in finding records, by arranging the records e.g. by Date of by Client, the user can be able to easily peruse through the records when manually searching or for printing purposes. The system offers the user functions for altering the display page to suit the needs for the particular time. The Figure 5.9 below shows how the system allows for users to tweak the GUI for the report display.

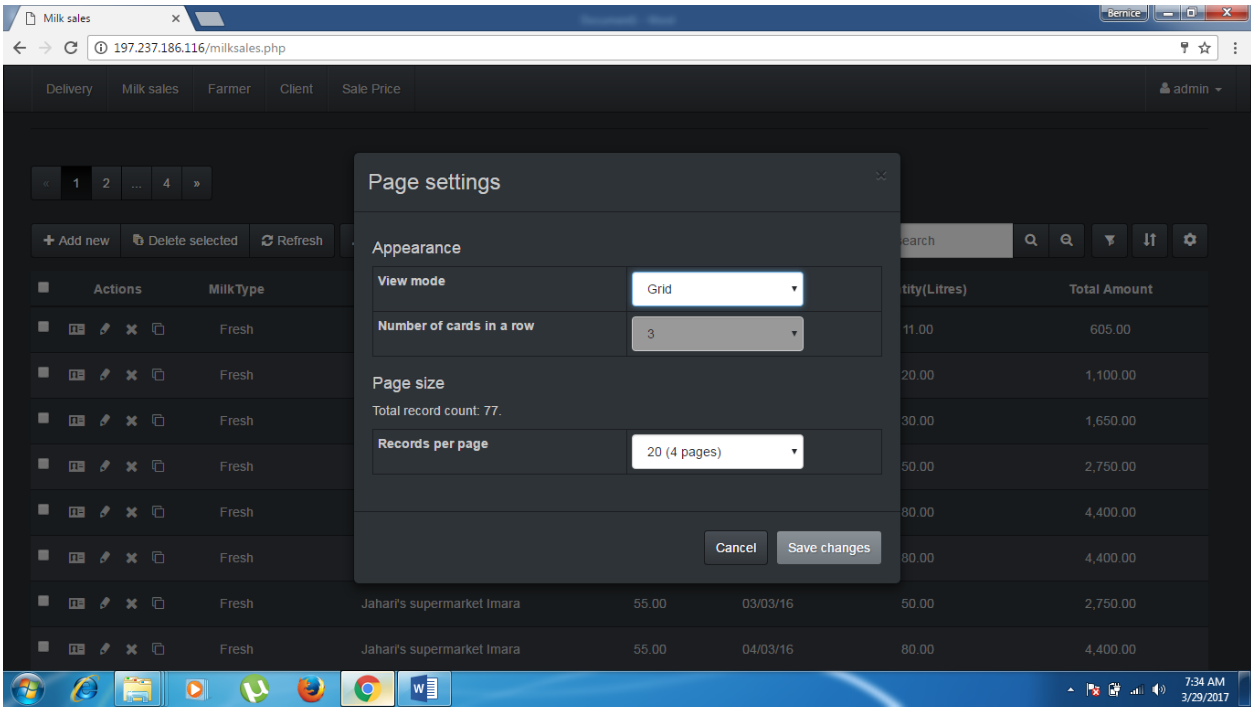

Figure 5.9 Page display settings controlling the view and size of the reports.

5.2.3. SMS Reporting Function

The system uses SMS to alert the farmers on milk delivery. The SMS system uses a GSM modem with a local communication Sim card with Ozeki message server. The message server is linked with the MySQL database via a Trigger function which alerts the message server whenever a new delivery is made. Figure 5.10 shows the Ozeki message server display window showing the GSM modem connection.

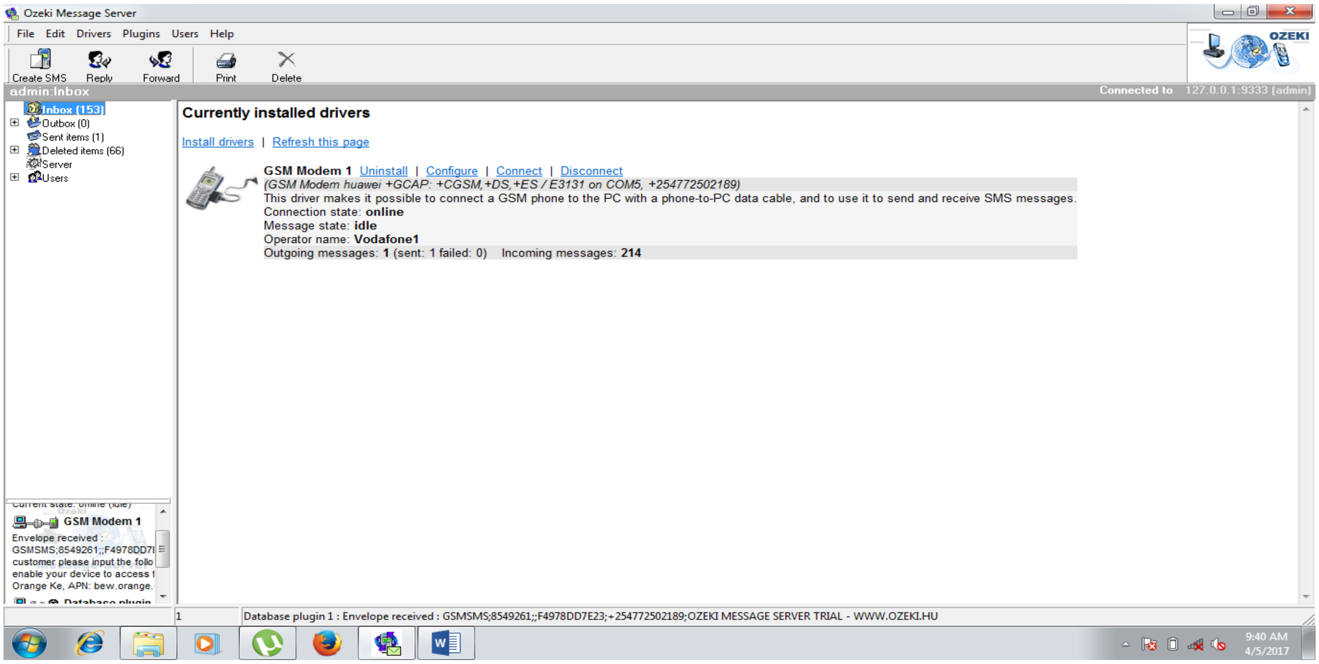

Figure 5.10 GSM modem configuration on the Ozeki Message server.

The SMS server is also connected to the database server by a connector on the SMS server. The Figure 5.11 below shows the connection on the SMS server and Figure 5.12 shows the trigger function in the database for triggering the SMS.

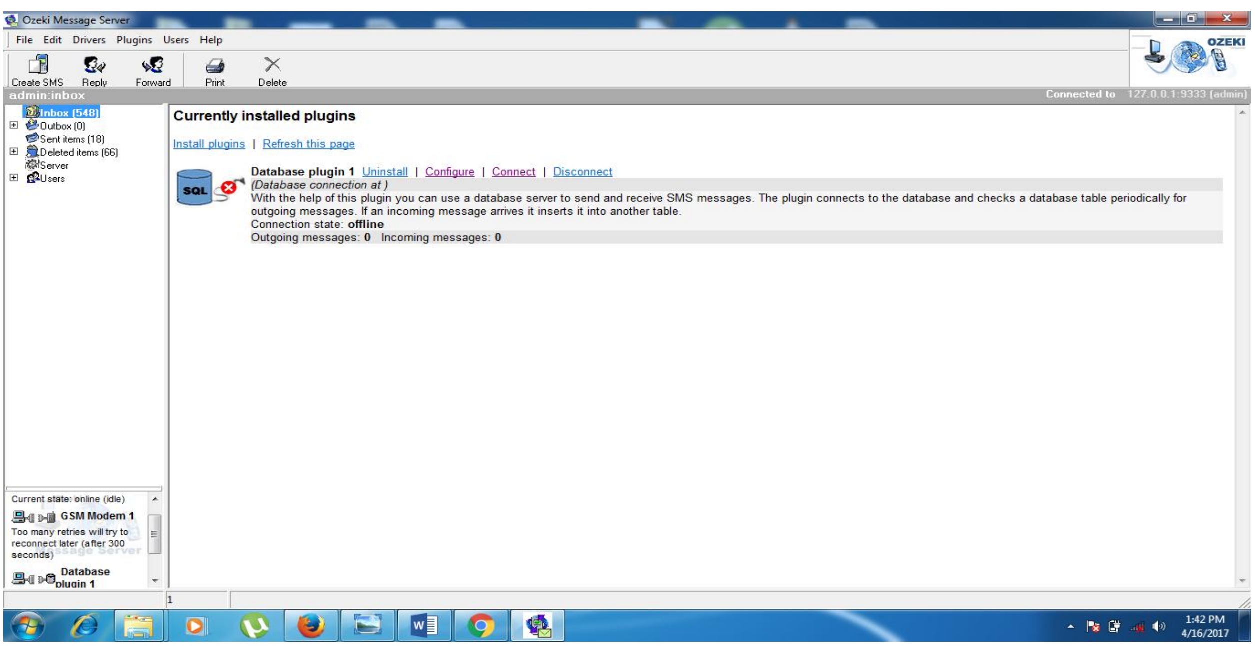

Figure 5.11 SQL database configuration on the Ozeki Message server.

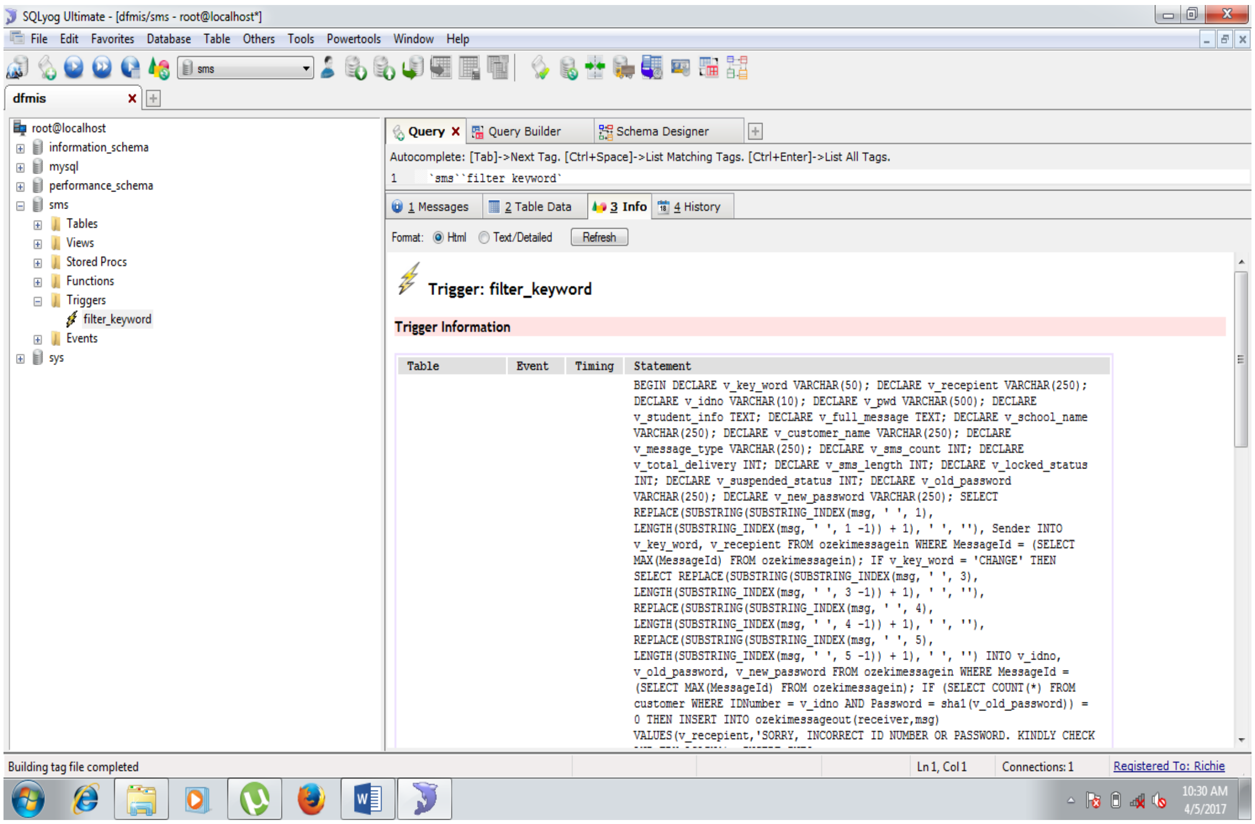

Figure 5.12 SMS Trigger in the MySQL server connecting to the Ozeki SMS server.

5.3. System Testing

The system was developed using the waterfall model which means that the serialized approach offered by the waterfall model is used. The waterfall model starts off with the definition of requirements which feeds into the system and software design phase, which establishes an overall system architecture and involves representing the software system functions in a form that can be converted into executable programs.

In the implementation and testing phase, the software design is converted into executable programs and each unit is tested individually. After the testing, the units are integrated and then the system testing is carried out. An initial version is created to enable user evaluation at an early stage in the project (initial prototype). Intermediate versions of the system are then developed, each one attempting to improve on the previous one. Lastly, the final version is developed and presented to the user.

5.3.1. Unit Testing

This type of testing is performed by the developer before the setup is formally tested. Unit testing is performed by the developer on the individual units of source code assigned areas. The goal of unit testing is to isolate each part of the program and show that individual parts are correct in terms of requirements and functionality. The M-agriculture recording system code is divided into sections with different functionalities which when integrated form the main program. These units include the security functions, reporting functions, delivery functions, add functions, search functions, messaging function and the database functions. The testing is done on the individual units to ensure that they are functioning as expected.

The search module contains the search, arrange and filter functions. One of the system units tested include the search unit, of which the code can be seen in the Appendix C. The graphical implementation of the quick search function is shown in Figure 5.13.

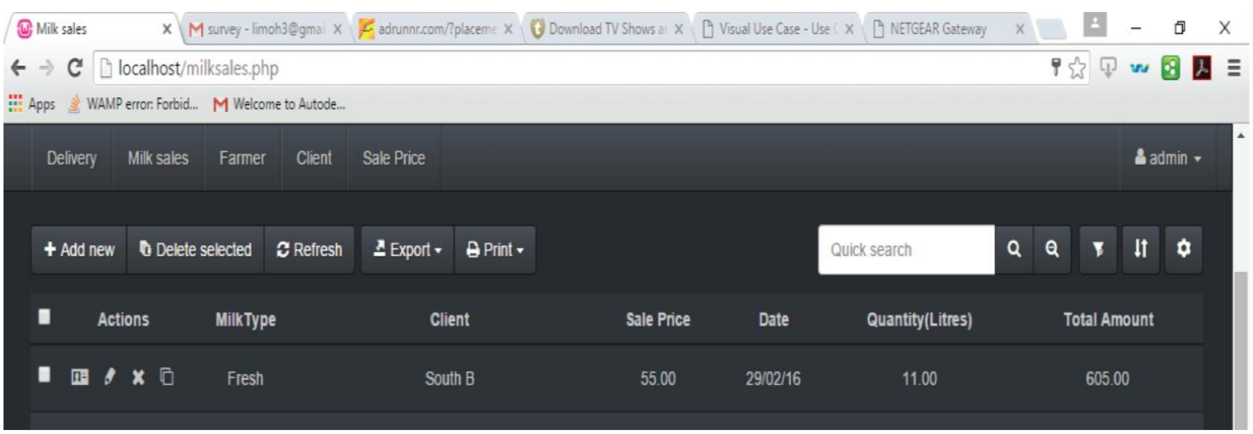

Figure 5.13 The Quick search, arrange and filter functions as shown on the interface.

As shown on Figure 5.13 quick search displays a single record got from the search word that is if the search word is specific enough such as the quantity in this case.

Another unit in the system that is tested is the user control module which include the user login security. Figure 5.14 shows how the system acts when invalid entry to the login screen is entered. The system checks the database for the right user name and password, if the user enters wrong password the system displays an error message as displayed in the figure.

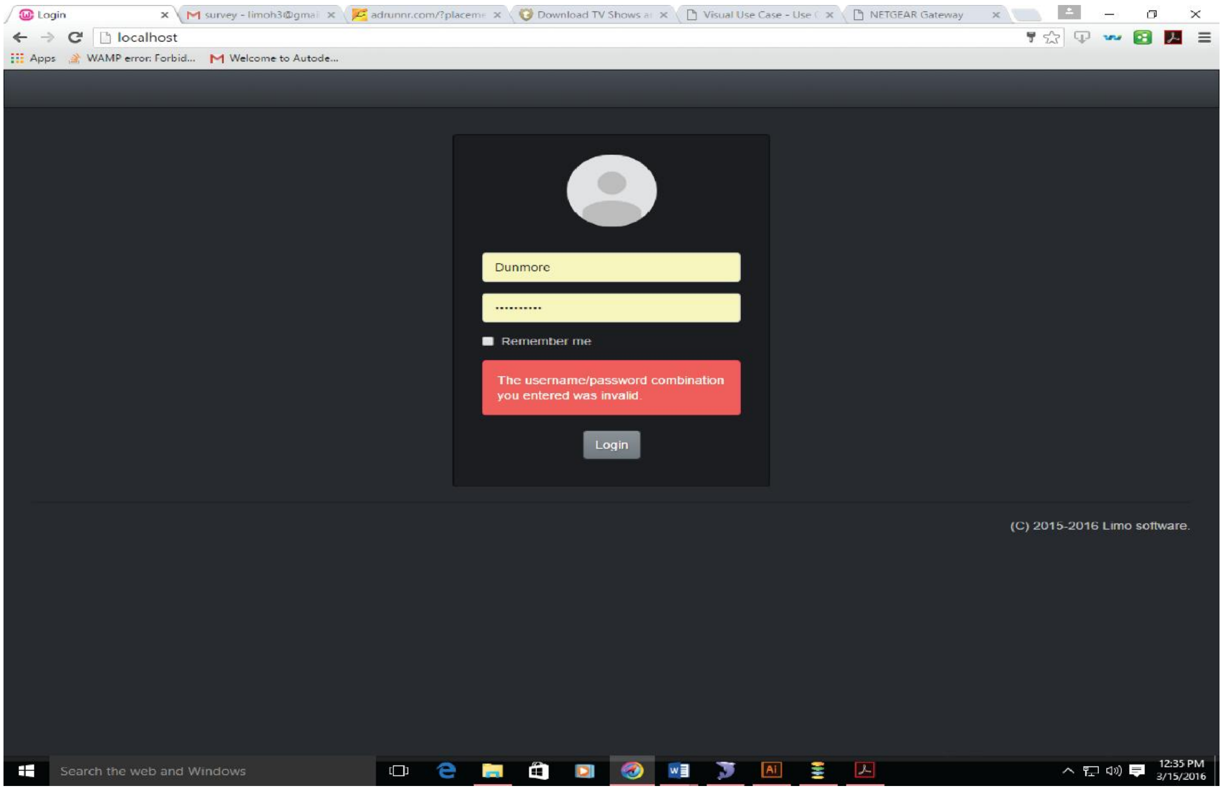

Figure 5.14 System user login security test.

The system has input validation functions used to validate the data entry fields this means that when the user enters invalid entries the system responds. The tests have been done to the delivery module of the system to ensure that all input fields are validated. Figure 5.15 and 5.16 show the validation error messages. Figure 5.15 shows how the system responds to conflicting input from the interface and the database. This ensures that if there is a code error leading to the input to conflict with the matching field in the database, the system gives an error feedback. Figure 5.16 displays the system error when the field validation functions detect an invalid input e.g. the quantity field only accepts numerical values. When any other values other than numerals is input into the quantity field, the system displays an error message.

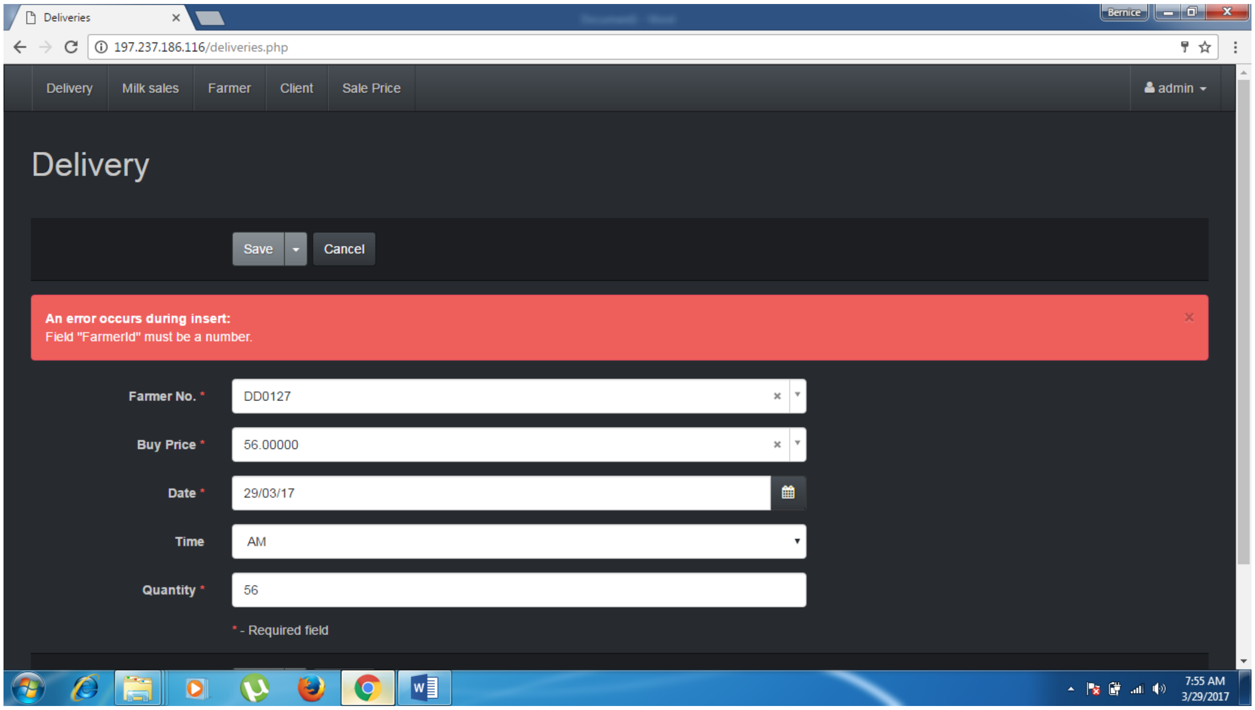

Figure 5.15 Error message when values conflict with database requirements.

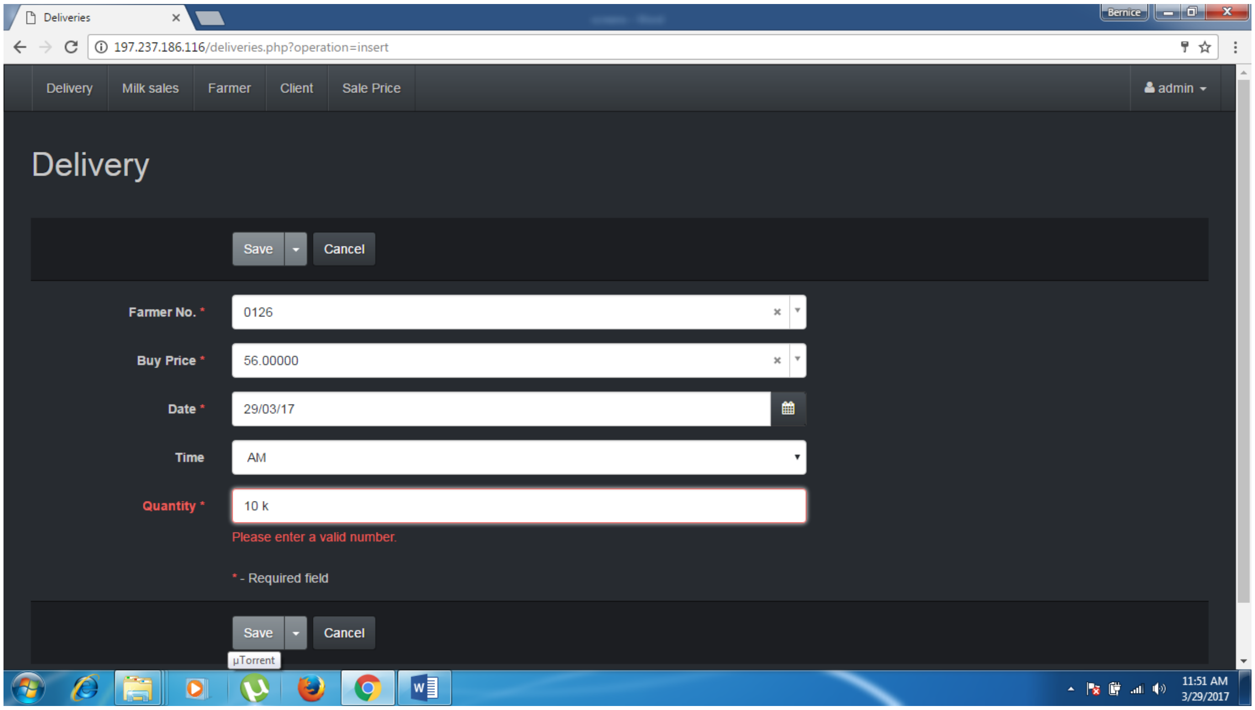

Figure 5.16 Testing for invalid type data entry.

The other unit tested include the fetch function which picks values from the database to be displayed in the program. Fetch values can be used for selection during input to avoid errors as shown in Figure 5.17. This is because the user has to be aware of all the choices available while entering data such as the clients when doing the sales. The figure below shows how the sales module uses the fetch function to select the clients when making sales.

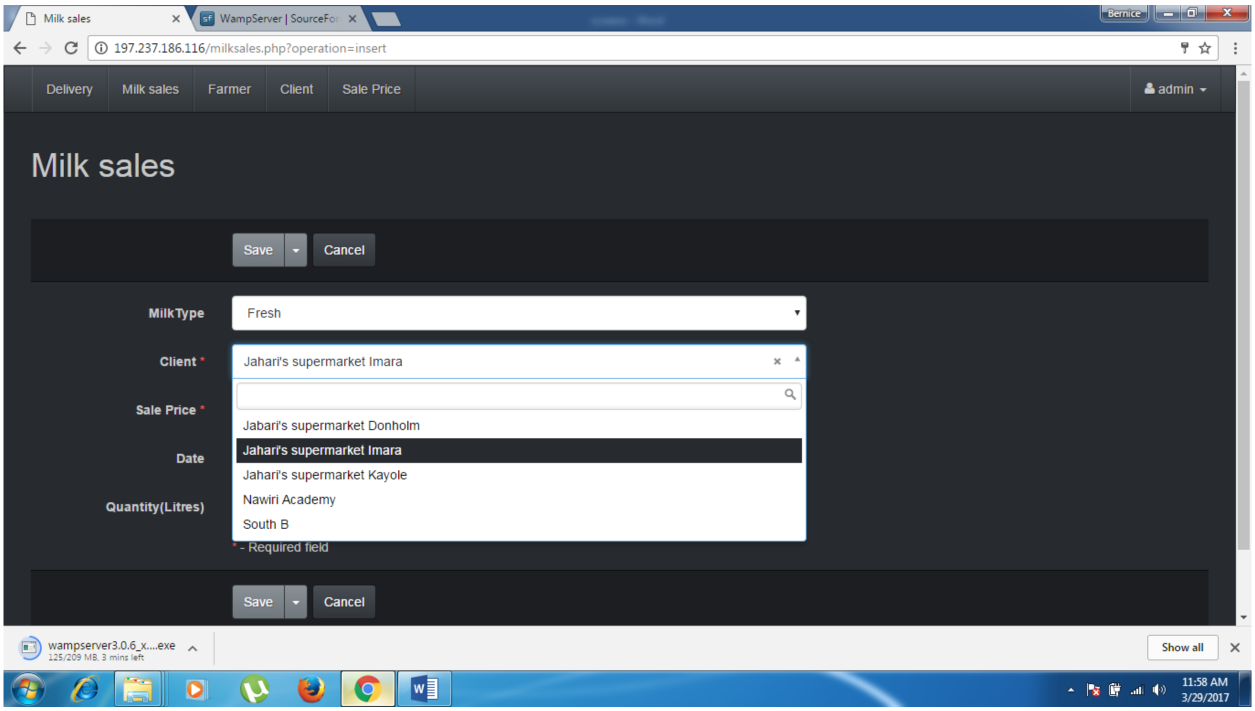

Figure 5.17 Test for select entry fields from database.

The fetch function is also used to display the tabular reports from the database the function is used for most of the modules in the system e.g. Figure 5.18 shows delivery records test report.

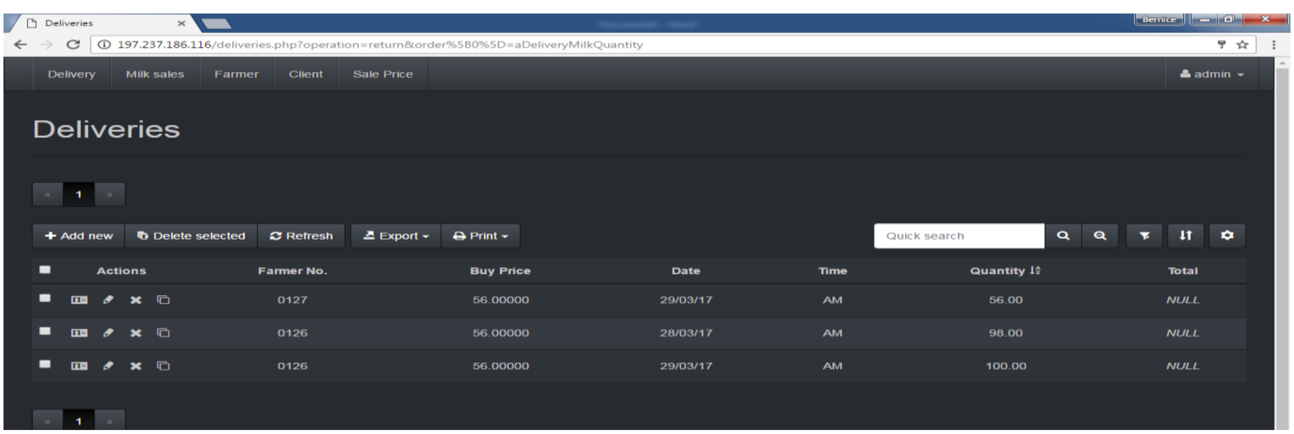

Figure 5.18 Delivery entry record display test.

The system allows for individual records to be displayed by fetching the data from the database the user can browse through the individual records. This type of record display shows more elaborate details of the individual record as compared to the tabular display. Figure 5.19 shows an example of the display showing an individual delivery entry.

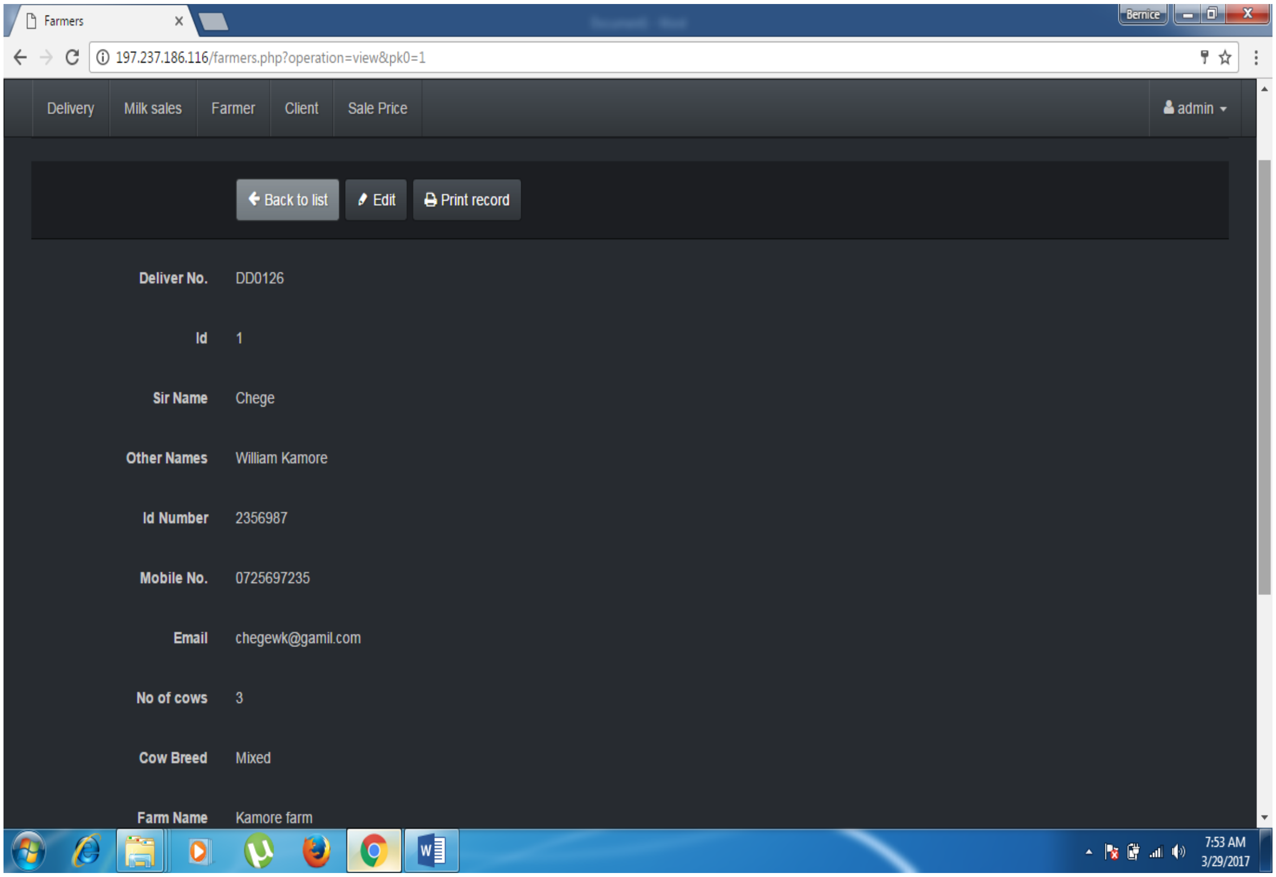

Figure 5.19 Single record display test.

The SMS module is another unit tested, this because it is a part of the reporting unit dependent on the delivery module. Each time a delivery is made it triggers a function in the database which signals the SMS server to send messages to the farmer delivering the milk. The Figure 5.20 shows a test case for the SMS delivering system as displayed on an android smartphone.

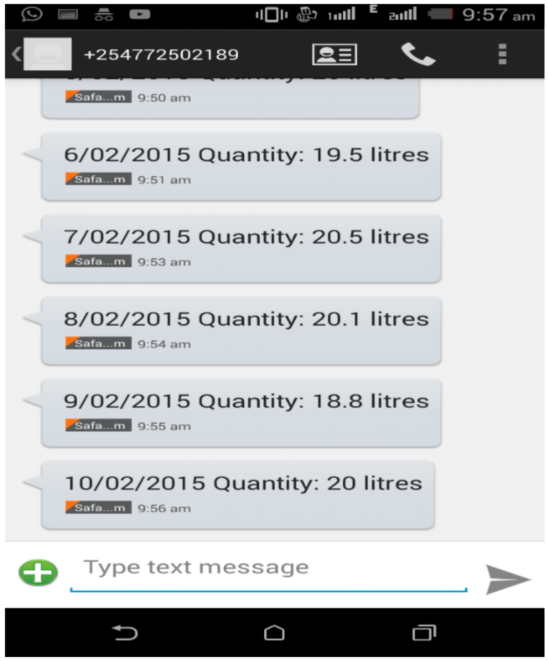

Figure 5.20 Delivery report messaging test cases shown on the mobile phone.

5.3.2. Integration Testing

Integration testing involves combining the units and then testing if the units work together as a system. The test performed is the bottom up integration testing which involves unit testing as already done in section 5.3.1, then followed by tests of progressive higher level combinations of units called modules or builds.

5.3.3. System Testing

This is the next level in the testing and tests the system as a whole. Once all the components are integrated, the application as a whole is tested rigorously to see that it meets Quality Standards. System Testing is the first step in the Software Development Life Cycle, where the application is tested as a whole. The application is tested thoroughly to verify that it meets the functional and technical specifications. The application is tested in an environment which is very close to the production environment where the application will be deployed. System Testing enables us to test, verify and validate both the business requirements as well as the Applications Architecture. The system has been put to test in a dairy milk collection company called Dunmore Dairy located in Muranga County.

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5.3.4. Acceptance Testing

This test will gauge whether the application meets the intended specifications and satisfies the client's requirements. A set of Test Cases that will be used to test the application. More ideas will be shared about the application and more tests can be performed on it to gauge its accuracy and the reasons why the project was initiated. Acceptance tests are not only intended to point out simple spelling mistakes, cosmetic errors or Interface gaps, but also to point out any bugs in the application that will result in system crashers or major errors in the application. By performing acceptance tests on an application the developer will deduce how the application will perform in production. A questionnaire handed to the test users of the system to receive feedback on the use of the system and the appeal of the interface to the users.

Chapter 6: Discussion

6.1 Introduction

In this Chapter, the main findings with regard to the research questions and test are summarized and conclusions based on the findings presented. The system development process based on the waterfall model used in the thesis also present test findings for the system. Furthermore, the strengths and limitations of this thesis are considered. This Chapter concludes with recommendations for the dairy farmers on the milk record keeping so as to build a strong knowledge base on dairy farming.

6.2 Findings with Regards to Research Questions

In Chapter 1 of this thesis document the research objectives and questions are highlighted. The document from Chapters two to five has solved the objectives highlighted. This chapter will try to answer the questions based on the findings of the document.

6.2.1 Information Needed for Milk Recording

In the dairy farm there is a lot of information requiring to be collected, stored and analyzed. Milk data is a major part of the dairy business and therefore it is very important to collect the information. The information available about milk includes the quantity (in litres or Kilograms), quality (which includes the butter fat content), source (the production farm or the individual cow) and the price (price per litre). This research thesis requires collection of milk data which is most suitable for analysis thereby we concentrate on the quantity and the price. This ensures that there is enough information for production analysis and financial analysis of the information.

6.2.2 Challenges Facing Milk Recording

The dairy farming industry has many challenges including recording data like milk delivery recording. Milk is the main product of the dairy farms and thus the major focus of the industry. In Chapter 1 of the thesis document we discuss the importance of milk recording and some of the challenges facing the collection of milk data. In chapter 3, the questionnaire reveals the current methods of data collection, the availability of technology and the technological awareness of the dairy population. The finding shows that mobile phone is the most commonly available technology which can be used for data collection. The knowledge of mobile phone use among the population has steadily grown and thus making the technology worth exploiting for data collection. This document has concluded in creating an application for recording of the milk deliveries which is accessible via the mobile phone. This research finding shows that using m-agriculture for recording is by far the most efficient method.

6.2.3 The Architectures, Models and Frameworks Used for Milk Recording

There are many architectures, models and frameworks as discussed in Chapter 2., which are used in different aspects and applications of the M-agriculture concept. The architectures such as the cloud based architectures and the general mobile based architectures have all been instrumental in the development of this system. The system has made use of various technologies used by the different models and architectures and has come up with a more efficient and less complex version of an integration of the models, architectures and frameworks. The system has made use of the mobile platform which as discussed in Chapter 2 has grown significantly in Kenya and is widely used throughout the country. This shows that the resultant application is viable and can be of great use to the general population. The acceptance test results emphasize on the ease of use of the system and the general acceptance of the end users of the system.

6.2.4 System Development

The architecture utilizes the cloud based technology which ensures that the database is not limited to the mobile phone storage which is very minimal. The database configuration as described in Chapter 4 shows that the database is configured centrally. The server side programming is done using PHP coding and the database is MySQL, which are both open source software. The use of the open source software for coding has minimized the cost of coding.

6.2.5 System Testing

The unit and system testing were performed by the developer satisfactorily to ensure that the system functionalities work as intended, as shown in Chapter 5. The various functions and classes performing different tasks were verified to be working as intended. The units were integrated and tested ensuring that the system works well as per the requirements. User acceptance test is carried out to ensure that the users are comfortable with the use of the system. From the test results shown in Figure 6.1, 6.2 and 6.3 displaying an analysis graph for user interface acceptance with an above average feedback for the software according to the user survey.

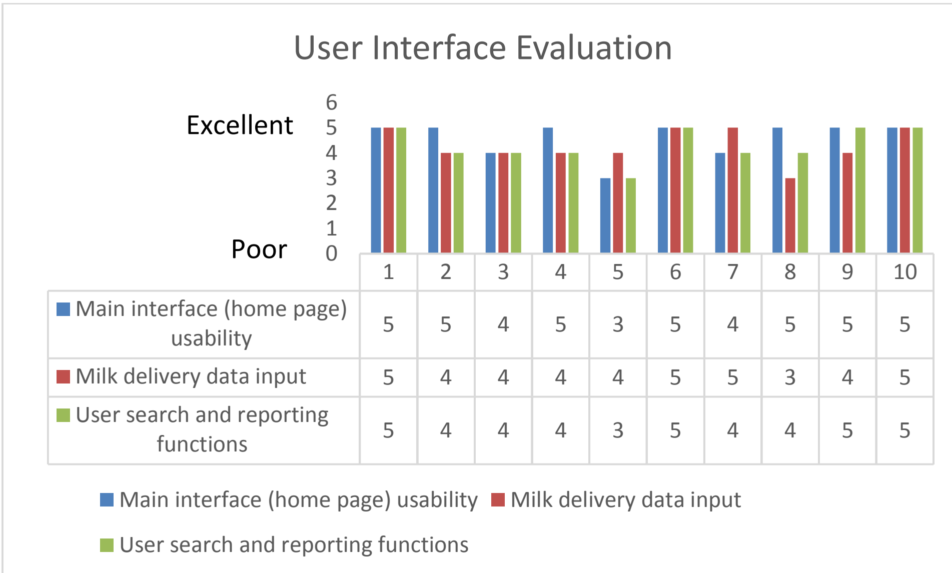

Figure 6.1 User Interface Evaluation Test.

After developing the system and testing by the developer, the first prototype of the system is given to be tested in the actual designated market. A small dairy company receiving and distributing milk from Muranga county was given the software to test and give feedback on the various usability areas as the acceptance test. Questionnaires were issued to ten of the users and feedback from nine recorded. A sample of the questionnaire can be viewed in the Appendix B showing the usability questions as given to the users. Figure 6.1 shows the graphical representation of the feedback results for the first section of questionnaire rating the User Interface Evaluation with 0 as Poor and 5 as Excellent. The average results for Main interface usability, Milk delivery data input and Search and reporting functions are all above 4 on the graph. This shows that the feedback is above average rating for the User Interface Evaluation.

The second section of the questionnaire covers the System Usability as viewed by the test users. Figure 6.2 shows the graphical representation of the results as given by the test users. The system was being rated on efficiency of recording page, accessibility of pages and the page navigation. The average rating of the system usability as shown by the collected results displayed in Figure 6.2 shows that the general view by the users is above 4. This shows that the feedback is above average according to the test users.

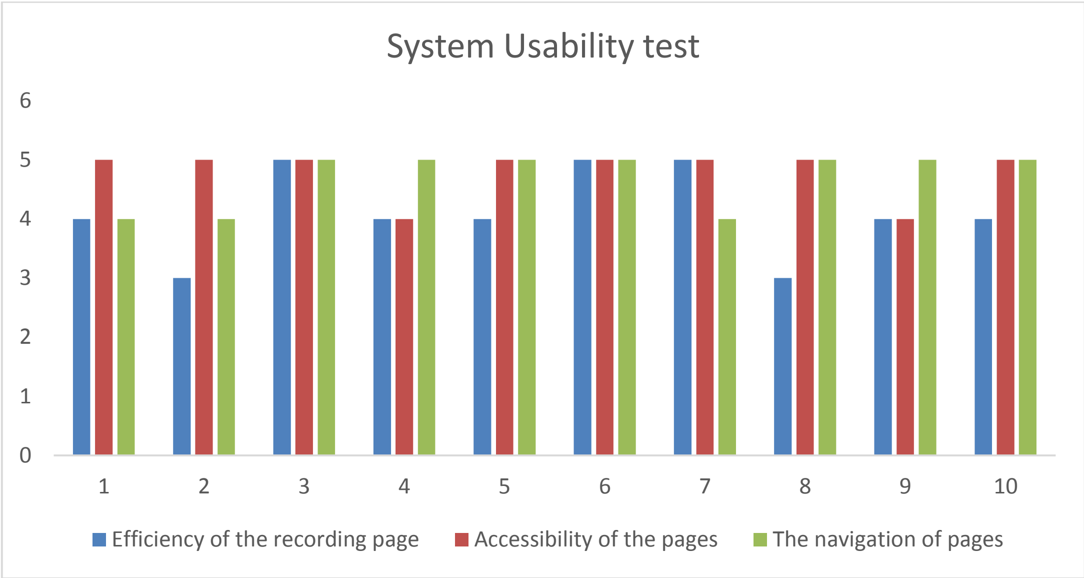

Figure 6.2 System usability test results.

The last section of the acceptance test questionnaire tests the System Accuracy. The users were asked to confirm the accuracy of the entered information, then to test the accuracy of the search function and the error reporting function. The Figure 6.3 below shows the graphical representation of the results of the survey.

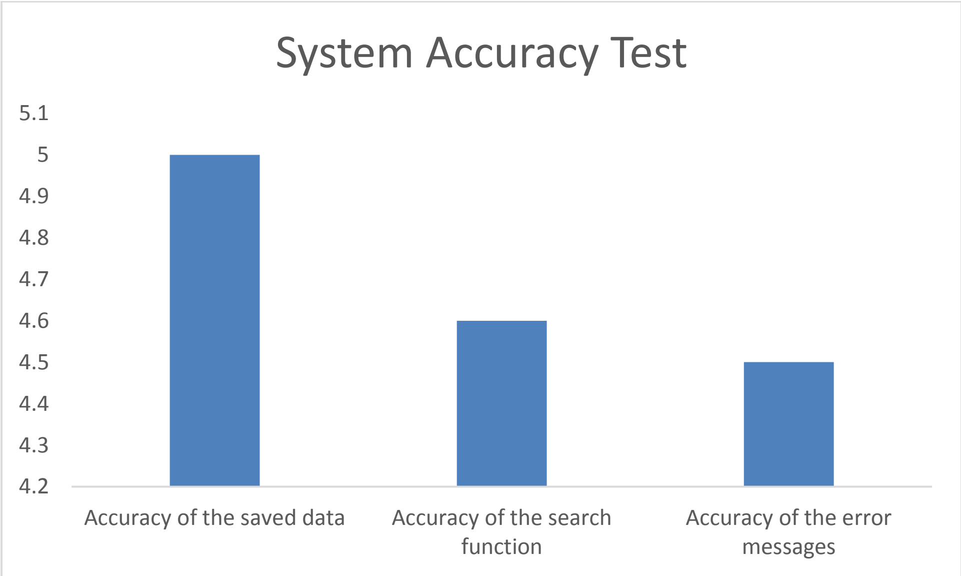

Figure 6.3 Test results for the system accuracy survey.

6.3 Strengths and Limitations

The system has a number of advantages listed below: -

i. This software requires basic input of data meaning that the system is easy for basic use by everyone. The main technology which is the mobile based technology is widely available and still growing as described in Chapter 2. Availability of the mobile phones means that the users are already conversant with the use and thus the system is easy to use.
ii. Since most of the aspects and the infrastructure of the technology are already available due to other popular applications using the same technology, the setup of the system is relatively easy and less costly. Most of the users are already mobile phone owners and therefore the system will have very minimal cost to the end users.
iii. The training requirement for the system is reduced due to the popularity of the mobile technologies in the Kenyan market. Most of the target users already use mobile phone apps such as Mpesa from Safaricom therefore the training is already made easier.
iv. The milk delivery data is already available but collected in mostly manual ways as described in Chapter 2 of the paper. The M-agriculture Recording system for milk producers utilizes the cloud technology making it more reliable, accessible and efficient than the other systems as described in Chapter 2.
v. Due to the use of cloud technology, data storage is abundant and in case of need to expand, the expansion is relatively easy and no user interruptions.

The system also has limitations which are listed below: -

i. The system is limited to areas with access to internet which can be assessed by the mobile phones. This scenario is not widely spread because telecommunication companies in Kenya have ensured that internet and mobile phone infrastructure is spread in most areas.
ii. The other limitation is the educational level of some of the targeted population which makes us doubt their tech savviness. In Chapter 3 the survey shows that that is not much of a concern because most of the target population are well conversant with the use of the mobile phone due to prior use of other mobile apps.

Chapter 7: Conclusion and Recommendations

7.1 Introduction.

In this chapter we look into the conclusion of the research which includes the need for collecting the data, the development of the system and the recommendations of the system which also include suggestions for system use and future research.

7.2 Need for Milk Data Collection.

Information collected in regards to milk production is very important to the farmer and to the dairy industry. Management of milk in the dairy ensures adequate growth and development of the industry. As much as information is important to the management, collection is the tricky part. In Kenya farmers are distributed throughout the Counties and therefore manually cumulating the information is costly and difficult. Technology offers a faster simpler and cheaper way of collecting the information. This thesis project has shown the need for the collection of information and has developed a system to try and solve the information problem within the dairy industry.

7.3 System Development.

After the conceptual model was developed, data was collected including the system specifications and requirements from Chapter 2 to 3. In chapter 4 the design architecture and the UML diagrams were drawn giving directions to how the system is to be implemented. The coding for the client and server side application was done using PHP and the database MySQL. The SMS server is done using the Ozeki message server for the receiving and sending of SMS reports. The system was then tested by the developer and an acceptance testing done by users.

7.4 Mobile Technology Usability Among Dairy Farmers.

In Chapter 3 of this research a survey was carried out to inquire on the technologies the farmers use to collect their data for milk production. The survey also showed if the farmers own and are able to use mobile phones and smartphones. The feedback showed that although the mobile device is not used to collect data most of the farmers own mobile phone and are able to use them fairly well. This shows that the use of the mobile phone as data collection tools is actually possible and can be considered as a viable option.

7.5 Conclusion

The dairy industry is an important part of the Kenyan economy and a majority of the population, therefore collection of information for the analysis of the sector and the improvement is of great importance to the industry and the individuals. The mobile phone is one of the fastest growing technology and has proved to be important for data collection in other systems, therefore using the technology to improve the dairy sector of Kenya is an excellent way forward. This research has combined different technologies to come up with an effective, easy to use way of collecting information for the dairy sector.

Making use of internet technology, which can be accessed via mobile phones ensures that the system can be accessed anywhere with internet present. The system provides real-time access to the reports and the analysis of the data from anywhere as long as there is internet connectivity. Due to the use of internet application the system is not limited to only mobile phones but can also be used in other devices that have internet connectivity including laptops, tablets and desktop computers.

Collecting data requires a lot of storage spaces which is not feasible when using mobile storage, therefore the use of the cloud based storage structure ensures that there is enough space. This software utilizes the cloud architecture in developing the server side configuration to ensure that there is enough space for the information and also the provision for future expansion.

This Thesis document in Chapter 2 has covered the various architectures, models and frameworks used by other systems. These includes m-agriculture models, mobile based architectures and cloud based architectures. In the final section of the chapter there is the conceptual model for the M-agriculture recording system which is used for the development of the system.

7.6 Recommendations

i. The system can be used to curate milk production data for individual farmer s. The farmer can use the information for management of his/her own personal dairy business. This can help the farmer to improve production.

ii. The dairy institutions collecting milk from farmers can use the system to record milk from farmers and to curate the collected records. The institutions can use the records to monitor its productivity and the productivity of its farmers.

iii. Since the data is stored in a centralized database dairy institutions can use the data to estimate area milk productivity. This information can be very useful in monitoring and spotting of problems within the dairy industry.

iv. This research has shown that the available technology can be used to solve problems in any sectors of the economy. Therefore, sectors which have a lot of data that require storage and analysis such as the dairy sector and even the agricultural sector as a whole, should look to technological solutions. Technology can offer simple and cost effective solutions to problems which seem to be persistent and difficult to solve.

v. The research also shows how mobile based technologies have been embraced and adopted by the majority of the population which means that there is an opportunity for developers to use this to help solve many problems technologically. The system developed in this research offers a simple solution to the dairy farmers and the institutions which provide delivery services. Therefore, is highly recommendable for the dairy sectors to adopt such solutions.

7.7 Suggestions for Future Research

The dairy sector has many different sections that have useful information this research has looked at a possible solution for collecting milk delivery information. Other information such as livestock health, feeding and breeding are also very important to the dairy sector. Further research can be put to try and solve the data collection problem in those areas.

This solution gives a simple way of data collection and thus should not be limited to the dairy sector. The architecture should be introduced in other related fields and modifications can be done to adopt the system. This is an area that can also be put into further research.

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Appendices

Appendix A: Questionnaire

Uasin Gishu Dairy Farmer's Survey

You are invited to participate in a survey for M-agriculture Recording system for milk producers. In this survey, approximately 99 dairy farmers will be asked to complete a survey that asks questions about milk production management. It will take approximately 3 minutes to complete the questionnaire.

Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions.

Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact Richard Limo at +254723055106 or by email at limoh3@gmail.com.

SECTION ONE - Personal Profile

1. **Please indicate your age bracket?** *Mark only one oval.*

- Below 20 Years
- 20-35 years
- 35-50 years
- 50-65 years
- Above 65

2. **What is your education level?** *Mark only one oval.*

- Primary level
- Secondary level
- Tertiary level
- Other: ....

3. **Which part of Uasin Gishu county do you farm?** Mark only one oval.

- Wareng
- Eldoret East
- Eldoret West
- Eldoret North

SECTION TWO – Milk Recording

4. Do you keep milk production records? *Mark only one oval.*

- ⬭ Yes
- ⬭ No

5. If yes, how do you record your milk production data? *Mark only one oval.*

- ⬭ Paper
- ⬭ Laptop/ Desktop
- ⬭ Computer Tablet
- ⬭ Mobile phone
- ⬭ Other: ....

6. How do you rate the usefulness of your recording method? *Mark only one oval.*

	1	2	3	4	5	
Very Inefficient	⬭	⬭	⬭	⬭	⬭	Very efficient

7. **Where do you sale your milk?** *Mark only one oval.*

- ⬭ Local neighborhood (milk vendors, homes, schools etc.)
- ⬭ Dairy institutions (SACCOs, KCC, Brookside, etc.)
- ⬭ Other: ....

SECTION THREE – Mobile Technology

8. Do you own a mobile phone? *Mark only one oval.*

- ◯ Yes
- ◯ No

9. If yes, what type of mobile phone? *Mark only one oval.*

- ◯ Basic mobile phone (no internet connection)
- ◯ Smartphone (internet connected)

10. Would you use a mobile based application as a milk recording tool? *Mark only one oval.*

- ◯ Yes
- ◯ No

Appendix B: Questionnaire

System User Acceptance Test

You are invited to participate in a Test for M-agriculture Recording system for milk producers. In this Test, approximately 10 users will be asked to complete a test that asks questions about the system. Answer the questions as accurately as possible to get the best feedback.

Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is very important for us to learn your opinions.

Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact Richard Limo at +254723055106 or by email at limoh3@gmail.com.

SECTION ONE – User Interface Evaluation

11. Main interface (home page) usability rating? *Mark only one oval.*

- Excellent
- Above average
- Average
- Below average
- Poor

12. Performing milk delivery data input? *Mark only one oval*

- Excellent
- Above average
- Average
- Below average
- Poor

13. User search and reporting functions? Mark only one oval.

- Excellent
- Above average
- Average
- Below average
- Poor

SECTION TWO – System Usability test

14. How do you rate the efficiency of the recording page? *Mark only one oval.*

	1	2	3	4	5	
Very Inefficient	⬭	⬭	⬭	⬭	⬭	Very efficient

***15.* How do you rate the accessibility of the pages?** *Mark only one oval.*

	1	2	3	4	5	
Very Inefficient	⬭	⬭	⬭	⬭	⬭	Very efficient

***16.* How do you rate the navigation of pages?** *Mark only one oval.*

	1	2	3	4	5	
Very Inefficient	⬭	⬭	⬭	⬭	⬭	Very efficient

SECTION THREE – System Accuracy Test

***17.* How do you rate the accuracy of the saved data?** *Mark only one oval.*

	1	2	3	4	5	
Very Inaccurate	⬭	⬭	⬭	⬭	⬭	Very accurate

***18.* How do you rate the accuracy of the search function?** *Mark only one oval.*

	1	2	3	4	5	
Very Inaccurate	⬭	⬭	⬭	⬭	⬭	Very accurate

***19.* How do you rate the accuracy of the error messages?** *Mark only one oval.*

	1	2	3	4	5	
Very Inaccurate	⬭	⬭	⬭	⬭	⬭	Very accurate

Appendix C: Search Function Source Code

```
protected function CreateGridSearchControl (Grid $grid)

      {

 $grid->UseFilter = true;

 $grid->SearchControl = new SimpleSearch ('farmersssearch', $this->dataset,

 array ('FarmerId', 'FarmerSirName', 'FarmerOtherNames', 'FarmerNatIdNumber', 'DeliverId', 'FarmerMobileNo', 'FarmerEmail', 'CowNo', 'CowBreed', 'FarmName', 'FarmCounty', 'FarmLocation', 'OtherDetails'),

  array($this->RenderText ('Farmer Id'), $this->RenderText ('Sir Name'), $this->RenderText ('Other Names'), $this->RenderText ('National Id'), $this->RenderText ('Customer Code'), $this->RenderText ('Mobile Number'), $this->RenderText ('Email Address'), $this->RenderText('Cows'), $this->RenderText('Breeds'), $this->RenderText ('Farm Name'), $this->RenderText('County'), $this->RenderText('Location'), $this->RenderText ('Other Details')),

  array ('=' => $this->GetLocalizerCaptions()->GetMessageString('equals'),'<>' => $this->GetLocalizerCaptions()->GetMessageString('doesNotEquals'), '<' => $this->GetLocalizerCaptions()->GetMessageString('isLessThan'),'<=' => $this->GetLocalizerCaptions()->GetMessageString('isLessThanOrEqualsTo'), '>' => $this->GetLocalizerCaptions()->GetMessageString('isGreaterThan'), '>=' => $this->GetLocalizerCaptions()->GetMessageString('isGreaterThanOrEqualsTo'),

                'ILIKE' => $this->GetLocalizerCaptions()->GetMessageString('Like'),

                'STARTS' => $this->GetLocalizerCaptions()->GetMessageString('StartsWith'),

                'ENDS' => $this->GetLocalizerCaptions()->GetMessageString('EndsWith'),

                'CONTAINS' => $this->GetLocalizerCaptions()->GetMessageString('Contains')

                ), $this->GetLocalizerCaptions (), $this, 'CONTAINS'

            );
```