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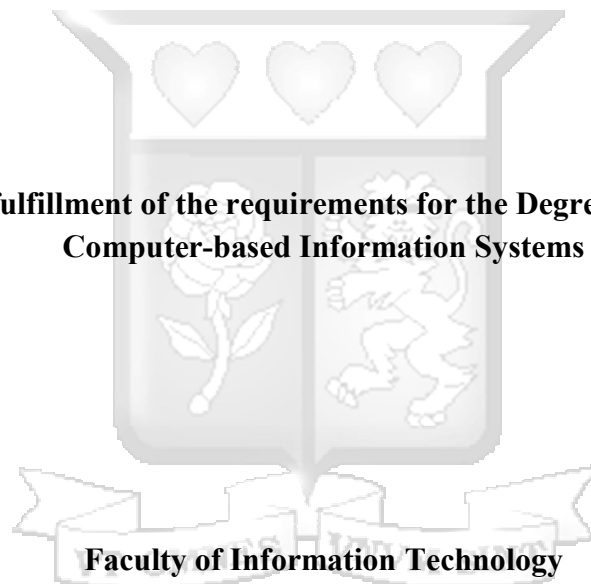
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**Mobile Based Expert System Model for Animal Health Monitoring: Cows Disease Monitoring
in Kenya**

PETER MURIU

078277

**Submitted in partial fulfillment of the requirements for the Degree of Masters of Science in
Computer-based Information Systems**



Strathmore University

Nairobi, Kenya

June, 2016

Declaration

I declare that this work 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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Muriu, P. K.

June 2016

Approval

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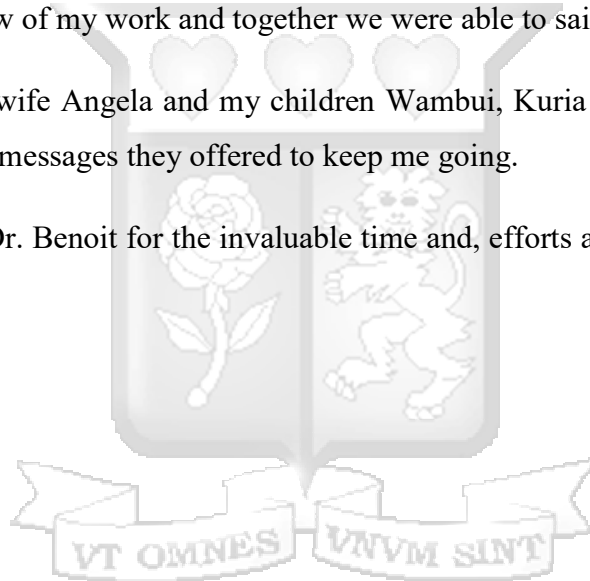
My sincere gratitude goes to the Almighty God for giving me the strength to keep working even when I didn't have the motivation to keep going on.

I wish to thank my supervisor Dr. Joseph Orero who through his advice and direction I was able to come up with quality work. My gratitude goes to Prof. Ateya who provided valuable insights through the class presentations, he also offered guidance, encouragement and corrected me through my presentations.

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Finally, I wish to thank Dr. Benoit for the invaluable time and, efforts and advice offered throughout the journey.



Dedication

This research is dedicated to my beloved Mother, Alice Wambui.

For the endless love, support and encouragement.

You have successfully made me into the person I have become.

You are a true inspiration.



Abstract

A host of diseases affect livestock in Kenya. These diseases as well as pests cause heavy losses to livestock farmers through deaths, reduced productivity and loss of markets for products. The research aimed at gaining deeper insights into the challenges faced by livestock farmers in Kenya, to understand the methods used for animal health monitoring and disease prediction and to establish the data and information requirements for animal health management at a farm. This study further proposed a mobile based expert system model for animal health monitoring.

Mobile uptake in Kenya coupled with significant strides made in mobile telecommunication infrastructure bring new potential to animal health management. The ubiquitous nature and pervasiveness of mobiles enable the use of information and communication technology everywhere, by everyone, and at all times. Using mobile technology, the model automates the process of managing animal health at a farm including recording farm, farmers' and animal details, predicting animal disease and monitoring of animal health right at the farms. It provides a collaborative platform between a farmer and a veterinary expert. The health of the affected cow is then monitored to recovery.

The model was tested through simulation of various modules. Of the 29 participants that took part in this exercise, 69 percent were satisfied that the model fulfilled the intended functions of animal health monitoring. 76 percent of the respondents also found the model easy to use. The model was therefore successful in management of farm, farmers and animal records as well as continuous monitoring of animal health.



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Abbreviations/Acronyms

3G	- Third generation set of technologies
AgGDP	- Agriculture Gross Domestic Product
AU-IBAR	- African Union Interafrican Bureau for Animal Resources
BoP	- Base of the Pyramid
CA	- Communications Authority of Kenya
CCK	- Communications Commission of Kenya
CDMA	- Code Division Multiple Access
CRBT	- Caller Ring Back Tone
DNS	- domain name system
EDGE	- Enhanced Data rates for GSM Evolution
EMPRES-i	- Emergency Prevention System Global Animal Disease Information System
ERM	- Entity-Relationship Model
EW	- Early warning
FAO	- Food and Agricultural Organization
FMD	- Foot-And-Mouth Disease
GDP	- Gross Domestic Product
GLEWS	- Global Early Warning System
GOARN	- Global Outbreak Alert and Response Network
GoK	- Government Of Kenya

GPRS	- General Packet Radio Service
GSM	- Global System for Mobile Communication
KENIC	- Kenya Network Information Centre
KNBS	- Kenya National Bureau of Statistics
LTE	- Long-Term Evolution
M-VAS	- Mobile Value-Added Services
NGO	- Non-Governmental Organizations
OIE	- World Organization for Animal Health
RVF	- Rift Valley fever
PRS	- Premium Rate Services
RDBMS	- Relation Database Management System
SARS	- Severe Acute Respiratory Syndrome
SDLC	- Software Development Life Cycle
SMS	- Short Message Service
TAD	- Transboundary Animal Diseases
USSD	- Unstructured Supplementary Service Data
WAHID	- World Animal Health Information Database
WAHIS	- World Animal Health Information System
WHO	- World Health Organization
WiMAX	- Worldwide Interoperability for Microwave Access



Definition of Terms

Agile Development	Development methodologies that employ short iterative cycles, and rely on tacit knowledge within a team as opposed to documentation (Awad, 2005).
Avian Influenza	A severe, often fatal flu virus of birds, especially poultry, that is transmissible from them to humans (Peiris, de Jong, & Guan, 2007).
Bulk SMS	Is the dissemination of large numbers of SMS messages for delivery to mobile phone terminals (Push Mobile Media, 2014)
Caller Ring Back Tone (CRBT)	Is an audible indication that is heard by the originator of a telephone call while the destination being called is ringing (Push Mobile Media, 2014).
Code Division Multiple Access (CDMA)	Is a channel access method used by various radio communication technologies where several transmitters can send information simultaneously over a single communication channel (Lammle, 2015).
Contagious Diseases	Is a subset category of transmissible diseases that can be transmitted from person to another (Monroe County Government, n.d)
Disease	a disorder of structure or function in a human, animal, or plant, especially one that produces specific signs or symptoms or that affects a specific location and is not simply a direct result of physical injury (Oxford University Press, 2016)
Domestication	Process by which wild plants or animals become adapted to humans and the environment they provide (Price, 2002).
Early warning (EW)	is “the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to

take action to avoid or reduce their risk and prepare for effective response” (Grasso, Singh, & Pathak, 1012).

Enhanced Data rates for GSM Evolution (EDGE) a digital mobile phone technology that allows improved data transmission rates as a backward-compatible extension of GSM (Lammle, 2015).

Foot-And-Mouth Disease Foot and mouth disease is a highly contagious viral infectious disease of cattle, sheep, goats and pigs. It can also affect wild animals, especially buffalo, which act as a significant hosts and in which the disease is generally much milder than in cattle (Infonet-Biovision, n.d).

General Packet Radio Service (GPRS) is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM) (Lammle, 2015).

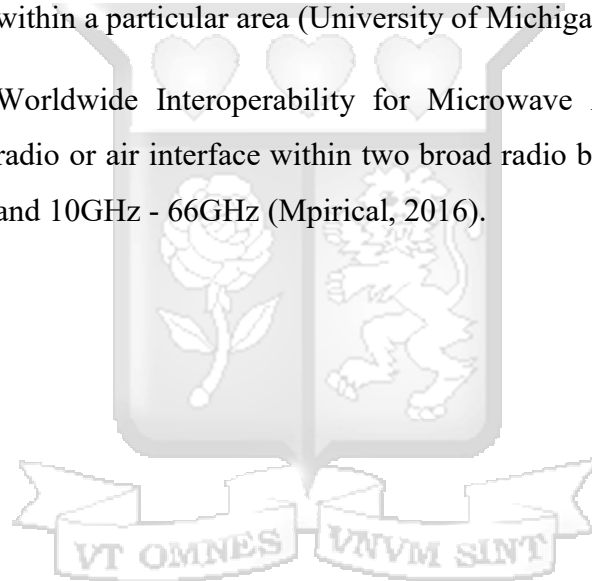
Infectious Diseases Are disorders caused by organisms — such as bacteria, viruses, fungi or parasites (Dalgety, Sraper, & Sang, 2002).

Kenya Vision 2030 Is the country's development programme covering the period 2008 to 2030 and was launched on 10 June 2008 by President Mwai Kibaki (Kenya Vision 2030, 2007).

Long-Term Evolution (LTE) Is a 4G wireless broadband technology developed by the Third Generation Partnership Project (3GPP), an industry trade group (Lammle, 2015).

Mobile Computing ability to use the technology to wirelessly connect to and use centrally located information and/or application software through the application of small, portable, and wireless computing and communication devices (Barnatt, 2013).

Software Development Life Cycle (SDLC)	Is a term used in systems engineering, information systems and software engineering to describe a process for planning, creating, testing, and deploying an information system (Rosenblatt, 2013)..
Unstructured Supplementary Service Data (USSD)	Is a protocol used by GSM cellular telephones to communicate with the service provider's computers (Push Mobile Media, 2014).
Wi-Fi	A facility allowing computers, smartphones, or other devices to connect to the Internet or communicate with one another wirelessly within a particular area (University of Michigan, 2015).
WiMAX	Worldwide Interoperability for Microwave Access (WiMAX) is radio or air interface within two broad radio bands 2GHz to 11GHz and 10GHz - 66GHz (Mpirical, 2016).



Chapter 1. Introduction

1.1 Background of Study

Agriculture is essential to the economy of Kenya (United Nations Economic Commission for Africa, 2013) contributing 27.3 percent of the total Gross Domestic Product (GDP) (Kenya National Bureau of Statistics, 2015). The country is highly dependent on agriculture as a source of food, industrial input, employment and foreign exchange. The agricultural sector accounts for 65 percent of the export earnings and provides livelihood (employment, income, and food security needs) for more than 75 percent of the Kenyan population (Government of Kenya, 2015). Performance of this sector is highly correlated with performance of the economy. Recognizing this factor, the Government of Kenya through the Vision 2030, set the goal for agriculture sector to achieve innovative, commercially oriented and competitive agriculture by the year 2030 (Kenya Vision 2030, 2007)

Livestock is one of the key subsectors of the agriculture sector and contributes 17 per cent of the Agriculture Gross Domestic Product (AgGDP), 7 per cent of exports and provides 50 per cent of the agricultural labour (Government of Kenya, 2010). Many Kenyans rely on this subsector for food products (meat, milk, eggs, honey); non-food-industrial products (wool, hair, silk, hides, skins, furs, wax, feathers, bones, horns); cash needs and a source of employment and recreation.

Kenya mobile uptake stands at 36.1 million mobile subscriptions (Communications Authority of Kenya (CA), 2015) against a population of 43 million people (Kenya National Bureau of Statistics, 2015). This translate to a mobile penetration of 83.9 per cent. According to CA (2015) this is attributed to increased demand for mobile data services, m-commerce, m-banking services and other emerging mobile services.

Significant strides have been made in mobile telecommunication infrastructure, mobile handset technology and mobile computing bringing new potential to animal health monitoring and management. Mobile ubiquitous nature and pervasiveness transcend physical distance when

accessing or manipulating information while also enabling use of information and communication technology everywhere, by everyone, and at all times.

This study sought to develop a mobile based model that will help farmers maintain animal health records at a farm including recording farm and farmers' details, recording animal details, help in predicting presence or occurrence of animal disease; prescription administration and monitoring animals' health status right at the farms.

For each individual animal in a farm, records are kept right from birth to death in a central database. By recording health characteristics, the model aims at helping veterinary experts in predicting and detecting diseases in an animal; generating necessary information required by stakeholders to take appropriate action on the affected animal and to monitor the animal health status to recovery. Through a collaborative platform, the model provides human to human interaction between a farmer and a veterinary expert.

1.2 Problem Statement

The continuously increasing risk of animal disease and spread across countries and continents, due to the increase of movements of humans, animals and animal products as a consequence of globalization, increasing free trade and interdependency is a major concern to many countries (African Union Interafrican Bureau for Animal Resources, 2013). The advent of highly contagious disease outbreaks such as avian influenza, severe acute respiratory syndrome (SARS), West Nile virus, and monkey pox (Yang, Yang, Zhou, & Zhao, 2008) around the world has had tremendous societal and economic implications.

As diseases and pests cause heavy losses through deaths, reduced productivity and loss of markets for products (Government of Kenya, 2010), there is need to take appropriate measures to prevent, control and eradicate diseases in livestock. One of the most important measures is to predict and diagnose animal diseases early to allow for relevant interventions to mitigate or minimize the risks associated with animal diseases.

There lacks a mobile based model to predict possible occurrence of animal disease and to track the health of the animal to recovery. A diagnostic model helps to estimate the probability or

risk of presence of a specific disease or condition. (Collins, Reitsma, Altman, & Moons, 2015). With a mobile based model, a farmer captures data using handheld devices and the data stored in a central database can help veterinary experts to predict animal disease. Early detection and prediction of disease can help in ensuring that relevant interventions are put in place to improve on animal health and facilitate awareness and preparedness of stakeholders. It will also facilitate proactive control measures aimed at reducing the risk posed by animal disease outbreaks.

1.3 Research Objectives

The overall objective of this research was to develop a model to capture animal records, to predict occurrence of animal diseases and to monitor animal health to recovery. Specific objectives include:

- i. To investigate the core challenges faced in this sector with regards to occurrence of animal diseases in Kenya
- ii. To review architecture designs of existing animal health monitoring and disease prediction tools
- iii. To establish data and information requirements to be handled by the proposed model
- iv. To develop a model for disease prediction and animal health monitoring
- v. To validate the new model

1.4 Research Questions

- i. What are the challenges faced in this sector with regards to occurrence of animal diseases in Kenya?
- ii. What architecture designs are used in existing animal health monitoring and disease prediction tools?
- iii. What data and information requirements is to be handled by the proposed model?
- iv. How can model be designed to predict disease and monitor animal health?
- v. How will the new model be validating and tested?

1.5 Justification

Throughout the life of an animal, there are potential risks which may affect the health of the animal. One of this risk is the increase of movements of humans, animals and animal products and therefor increasing opportunity of disease introduction and spread. Another risk is the inability for farmers to track animal health and keep important records regarding the animals that would otherwise aid in taking proactive measures at the early stages of infection. The increase in human to animal interconnectedness leading to animal-to-human and human-to-human interactions elevate the risk of accidental or deliberate introduction of disease causing agents.

There is need to monitor the health of animals and to proactively predict disease occurrence, hence the model to predict foot-and-mouth disease (FMD). Focus on FMD was educated by the fact that it is highly contagious, prevalent and often has huge societal and economic impact. The disease is used to test model with different data and different parameters.

This study will be beneficial to the farmers, agricultural extension officers, health care offices and other stakeholder.

1.6 Scope and Limitations

Scope is limited to monitoring animal health and predicting animal disease, particularly foot-and-mouth disease that affects cattle. Area will be limited to Kenya.

1.7 Limitations

1.7.1 Data Limitations

There is a limitation where both primary and secondary research techniques may not be able to offer the necessary information needed to fulfil the research objectives. The researcher may hence be forced to make up or scale down the scope of the research as suitable while remaining relevant to the research.

1.7.2 Time Limitations

While carrying out this project, the researcher has a full time Job at a fast paced international banking institution. Coupled with other courses being undertaken, the researcher may

luck sufficient time to effectively finishing the study project. That notwithstanding, needs to ensure that adequate time is apportioned for all project associated undertakings as well as for any course related activities. This will mitigate any risks that the quality of the project and the successful completion of the project in not compromised.

1.8 Ethics in Research

Information confidentiality has been observed in this study. The data collected will be used for academic purposes only and will be treated with strict confidentiality. Personally identifiable information will not be collected and responses are not traced back to the respondents.



Chapter 2. Literature review

2.1 Introduction

An empirical framework, aimed at understanding the concept and investigating the research problem, is presented. This section comprises of five sections. The first section discusses the agriculture sector and livestock industry in Kenya. The second section looks at management of animals and animal health. The third section reviews mobile technology. The fourth section discusses expert systems. The fifth and final section reviews related work that has been done in this field.

2.2 Agriculture sector and livestock industry in Kenya

2.2.1 History of Animals and Human Interdependency

A look at some history on domestication of animals and how human interdependency has developed over time has been done to appreciate the importance of animals and animal well-being. Domestication refers to “Process by which wild plants or animals become adapted to humans and the environment they provide” (Price, 2002). Domestication of plants and animals significantly transformed Earth’s biosphere, affecting human population size and altering human evolution (Larson & Fuller, 2004). From hunting and gathering, man was now able to supplement his diet through animal and plant products while also discovering many other uses for both plants and animals. Price (2002) outlines in the Table 2.1 a number of reasons why populations of animals are bred in captivity and thus potentially subjected to the process of domestication.

Table 2.1 Some Objectives of Breeding Animals in Captivity

(Adapted from (Price, 2002)) p 4

- | |
|--|
| <ol style="list-style-type: none">1. Domestication<ol style="list-style-type: none">a. Animal productsb. Companionshipc. Scientific studyd. Recreational uses2. Conservation<ol style="list-style-type: none">a. Release in natureb. Preservation of speciesc. Germplasm resources3. Public display<ol style="list-style-type: none">a. Educationb. Pleasure |
|--|

There is a continued dependency on domesticated animals in various ways: economically, domesticated animals provided man with food, clothing, labour and transportation; man also uses domesticated animals to fulfil social need such as sports, companionship, providing security, religious worships among others; and most recent contribution in human health through the use of animals in biomedical research and space travel.

2.2.2 Agriculture Sector in Kenya

Agriculture is essential to the economy of Kenya (United Nations Economic Commission for Africa, 2013) contributing 27.3 percent of the total Gross Domestic Product (GDP) (Kenya National Bureau of Statistics, 2015). The country is highly dependent on agriculture as a source both employment and of foreign exchange. The agricultural sector accounts for 65 percent of the export earnings and provides livelihood (employment, income, and food security needs) for more than 75 percent of the Kenyan population (Government of Kenya, 2015).

Performance of this sector is highly correlated with performance of Kenya's economy. Recognizing this factor, the Government of Kenya through the Vision 2030, set the goal for

Agriculture sector to achieve innovative and commercially oriented and competitive agriculture by the year 2030 (Kenya Vision 2030, 2007)

2.2.3 Livestock Industry in Kenya

Livestock is a subsector of agriculture consisting beef, dairy, sheep, goats, camel, poultry, piggery and emerging livestock subsectors. This subsector contributes 17 per cent of the Agriculture Gross Domestic Product (AgGDP), 7 per cent of exports and provides 50 per cent of the agricultural labour (Government of Kenya, 2010). Many Kenyans rely on this subsector for food products (meat, milk, eggs, honey); non-food-industrial products (wool, hair, silk, hides, skins, furs, wax, feathers, bones, horns); cash needs and a source of employment.

2.3 Management of animals and animal health

Among the many challenges faced by stakeholders, a few are discussed here including livestock welfare, health of animal products, livestock diseases and disease outbreaks.

2.3.1 Livestock Welfare

World over, the safe utilization of animal products and livestock production in general is affected by animal diseases and veterinary public-health problems (Food and Agriculture Organization (FAO), 2002). Farmers must ensure wellbeing of their animals to minimize production losses. The consequences are dire and may include food insecurity, loss of livelihoods, increased poverty, restriction of marketing opportunities, disincentives to investment and public-health risks. From an economic perspective, the United Kingdom Farm Animal Welfare Committee (2011) argues that the welfare of animals and that of humans are closely linked as shown in Figure 2.1.

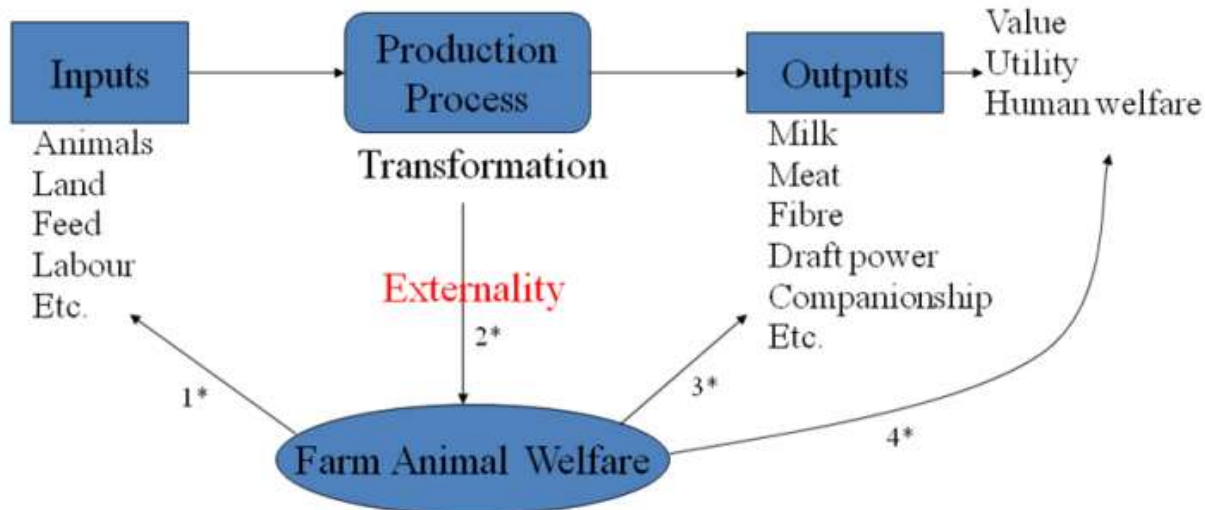


Figure 2.1: The place of farm animal welfare in an economics framework
(The Farm Animal Welfare Committee (FAWC), 2011)

2.3.2 Health of animal products

The gap between the haves and have-nots has continued to expand and with it comes challenges of managing diseases that affect livestock. Social inequality and poverty can result in human infections (e.g. gastrointestinal anthrax) from the eating of dead animals or uninspected meat. Lack of political will particularly not reporting or misreporting occurrence of infectious disease for economic and political and reasons (e.g. SARS in China) pose challenges to the fight on livestock diseases. (Lashley, 2006).

Considerable burden as a result of livestock diseases is placed on individuals and health care worldwide. Diseases in general, exact a greater toll on the population from the elderly, young children to the infants.

2.3.3 Livestock Diseases

Diseases pose significant challenges to livestock farmers in Kenya. These diseases as well as pests cause heavy losses through deaths, reduced productivity and loss of markets for products (Government of Kenya, 2010). African Union Interafrican Bureau for Animal Resources (2013) argues that globalization, increasing free trade and interdependency among nations increases

movements of humans, animals and animal products. Consequently, this increases risk of animal disease introduction and spread across countries and continents.

A host of disease affect livestock. Foot-and-mouth disease (FMD) highly contagious and infectious viral diseases. (Pendell, Leatherman, Schroeder, & Alward, 2007). FMD affects cloven-hoofed animals and greatly reduces animal productivity and may also result to death. Besides productivity effects, an FMD outbreak also leads to market effects because importing countries usually react by imposing import bans on any country experiencing such disease. Thus an FMD outbreak can have large economic costs for affected farmers and also for the whole food chain (Gohin, Cordier, Krebs, & Rault, 2013).

FMD exhibits the following characteristics (Herenda, Chambers, Ettriqui, Seneviratna, & da Silva, 2000): Anorexia and fever of up to 41°C; Blisters inside the mouth that lead to excessive secretion of stringy or foamy saliva and to drooling; loss in weight, animal condition and growth rate; Productivity(Milk) yield drops dramatically in milking animals

Other characteristics include: Cattle stamp their feet; Vesicles develop on the tongue, interdigital cleft of the feet.; Vesicles on the teats and udder; Lesions on the mammary gland and feet; Cattle may lose one or both horns of the foot

2.3.4 Disease Outbreaks

Animal disease outbreaks pose significant threat to both humans and animals. In the recent past, a number of these outbreak such as avian influenza, severe acute respiratory syndrome (SARS), West Nile virus, and monkey pox (Yang, Yang, Zhou, & Zhao, 2008) have occurred presenting tremendous societal and economic implications. While some of these outbreaks have not occurred in Kenya, continuous monitoring and surveillance is necessary. In a country like Kenya with human wild life conflicts, the spread of infectious diseases among and between wild and livestock (Horan, Fenichel, Wolf, & Gramig, 2010) has also become a major threat to farmers.

The Figure 2.2 illustrates how Multi-disciplinary public private partnerships can help in control of disease outbreaks (Mackey, Liang, & Liang, 2012)

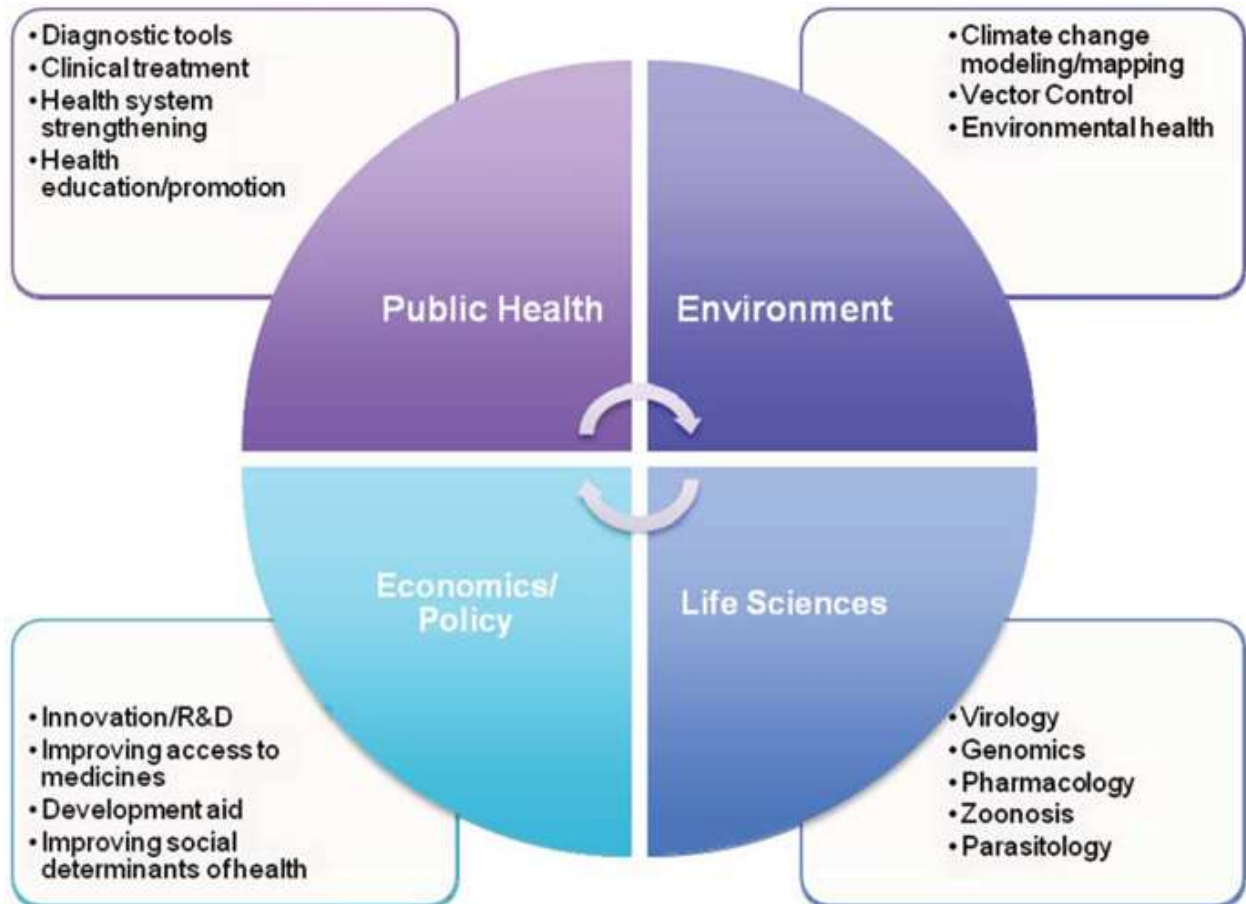


Figure 2.2: Multi-disciplinary public private partnerships for emerging and re-emerging neglected tropical diseases

2.4 Mobile Technology

2.4.1 Mobile Phone

The mobile phone is a definitive feature of modern society. It is a device that is used for communication; it is an aesthetic object, it is a tool used to perform business transactions and an icon of culture. It has become central to a wide range of activities, transforming family and friendships, work and leisure, the media and communication. It is becoming increasingly acceptable to have and use mobile phones and other mobile devices in social situations, work place, sporting, and schools as well as many other facets of life. We have moved into an era where phone numbers refer to people instead of places and a mobile phone is a constant companion that

accompanies a person throughout their daily life and allows them the convenience of easy communication and access to information (Paullet, Pinchot, & Rota, 2010).

2.4.2 Mobile Subscription in Kenya

Kenya’s mobile market has grown significantly over the years since the inception of mobile telephone service in 1992. During the initial years, the cost of owning a mobile phone remained very high with a mobile handset costing as much as Kshs 250,000. Until the enactment of Kenya Communications Act in 1998 and the introduction of competition in the mobile industry, this service was limited to the privileged few members of the society and only attracted less than 20,000 subscribers between 1993-1999 (Communications Commission of Kenya(CCK), 2008a). Statistics indicate that the subscription soar to the current 36.1 million representing 83.9 percent mobile penetration (Communications Authority of Kenya (CA), 2015) as shown in the Figure 2.3.

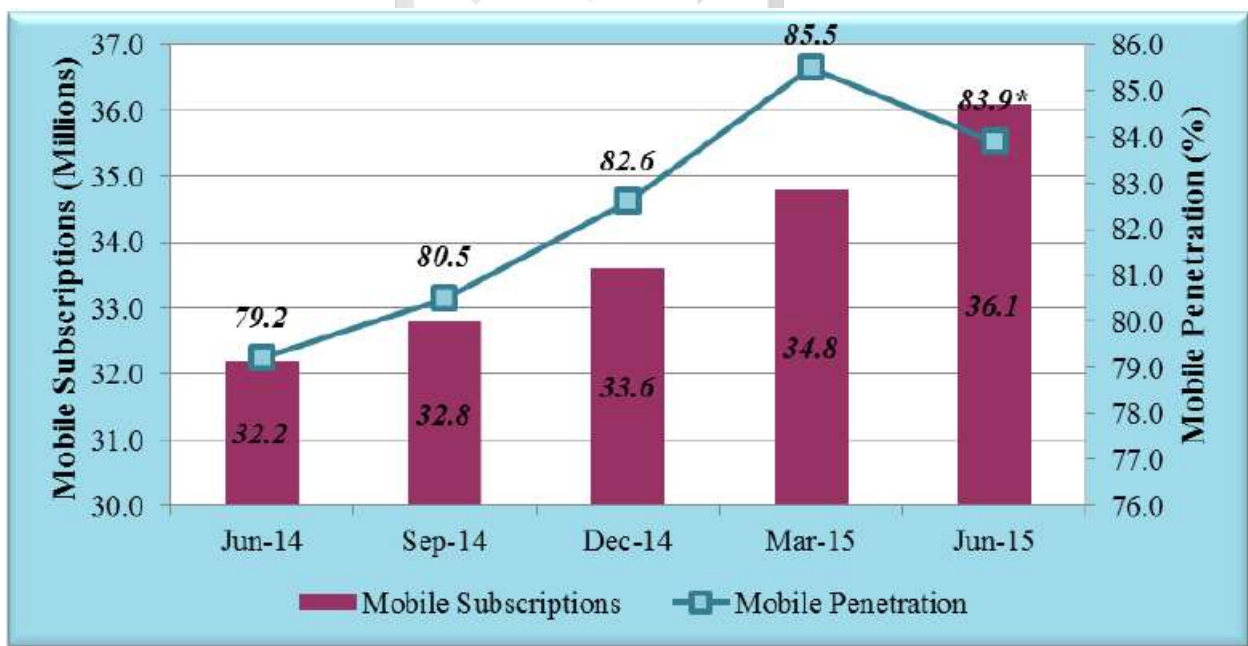


Figure 2.3: Mobile Subscription

2.4.3 Mobile Phone Usage

Mobile phone usage has also seen tremendous and unprecedented growth. As subscription and usage increases, reliance on mobile phone is becoming prevalent. More and more Kenyans

depend on their mobile phones to perform activities outside the traditional voice services offered by mobile network operators. A wide range of mobile value-added services (M-VAS) products have been introduced transforming the way mobile phones are used (Deloitte, 2011). There are a number of M-VAS products used in Kenya including premium rate services (PRS), caller ring back tone (CRBT), bulk SMS, short codes, mobile money, music on demand, unstructured supplementary service data (USSD) among others.

As usage increases, handset makers continue to improve on designs and features while ensuring affordability and quality. More brands with more superior features continue to be introduced to the market increasing competition and reducing the cost of owning a mobile phone. With the cost of mobile phones decreasing steadily, what was once considered a luxury good is now more commonly considered a necessity by many Kenyans, including those at the economic base of the pyramid (BoP) (iHub Research and Research Solutions Africa, 2012).

2.4.4 Mobile Technology

Wireless technologies are increasingly being used in a variety of ways. The major wireless advantages are communications to mobile subscribers, the opportunity for reducing infrastructure costs in fixed systems, the ability to rapidly deploy new systems, and the implementation of communications for sparsely populated areas and global users. (Technology Task Group 3 (TTG-3), 2000). The most common wireless phone technologies are Global System for Mobile Communication (GSM) with 73 percent of world market and Code Division Multiple Access (CDMA) with 14 percent of the worldwide market (Communications Commission of Kenya(CCK), 2008b). Other popular wireless technologies include General Packet Radio Service (GPRS); Enhanced Data rates for GSM Evolution (EDGE); Third generation (3G) set of technologies; Bluetooth technology; Worldwide Interoperability for Microwave Access (WiMAX); Wi-Fi; Long-Term Evolution (LTE)

Users now expect more from their Mobile and providers of technology. They are looking for more portable devices that offer faster data connections and mobility that is not only seamless but also flawless. They also expect devices with multiple functionalities, products that networked and combined services. (Scripp Business Insights, 2010).

2.4.5 Mobile Devices

Barnatt (2013) classifies Mobile computing devices based on use as: “mobile computers or laptops; ultra-books; netbook; tablet computers; E-book readers; smartphones; media players and mobile games consoles; and ambient computing devices”. The choice of device to be used is determined by the nature of the nature of work activity to be performed. This presents options to famers on the different mobile computing devices they wish to use based on their different circumstances.

Indeed, mobile technologies bring new potential to farmers across the country. Its ubiquitous nature (Danijel & Karsten, 2004) provide farmers with the ability of accessing or manipulating information from their farms. Its pervasiveness enables them to use information and communication technology everywhere and at all times. While a wide range of mobile technology usage exists, emphasis is focused on how mobile technology can contributes to farmers particularly in managing animal records, monitoring the health of animals and predicting diseases.

2.5 Expert Systems

2.5.1 Introduction

Jackson (1990) defines expert systems (also known as knowledge-based systems) as “a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice”. Giarratano & Riley (2005) also define expert system as “a computer system that emulate the decision ability of a human expert.” That is to say that an expert system is intended to act like human being in all aspects. Expert systems are capable of offering solutions to specific problems in a given domain or are able to give advice, both in a way and at a level comparable to that of experts in the field (Lucas & van der Gaag, 1991)

2.5.1 Building blocks of Expert Systems

Expert systems are organized in three distinct levels including Knowledge base, working memory and inference engine as shown in the Figure 2.4 (Badiru & Cheung, 2002):

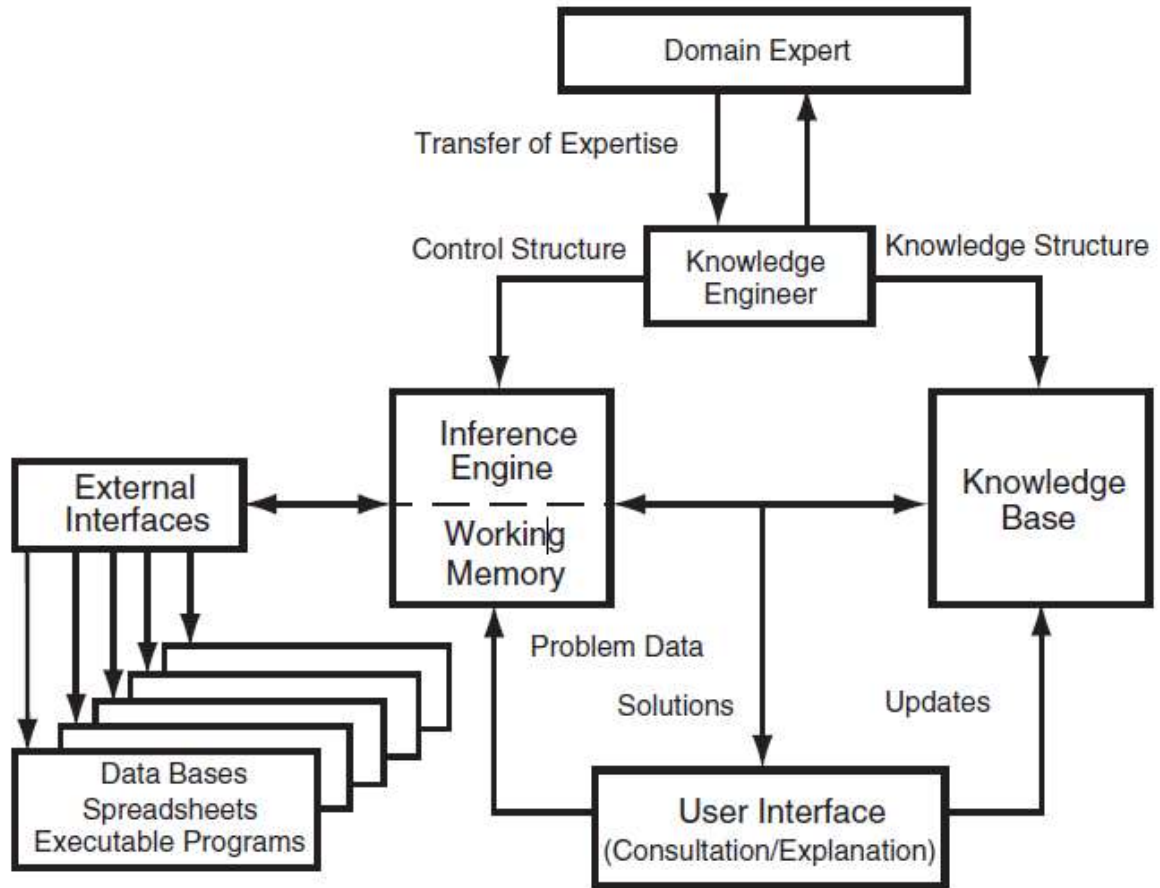


Figure 2.4: Integration of expert systems components

2.5.2 Knowledge base

Problem solving rules and procedures are held in the Knowledge base that also holds facts and intrinsic data relevant to the problem domain. The model, in the knowledge database, should capture details about disease characteristics. This will be used in the “if...then” analysis. Some of the characteristics for foot and mouth disease include:

- i. Anorexia and fever of up to 41°C
- ii. Blisters inside the mouth that lead to excessive secretion of stringy or foamy saliva and to drooling
- iii. loss in weight, animal condition and growth rate

- iv. Productivity(Milk) yield drops dramatically in milking animals

Other characteristics include

- v. Cattle stamp their feet
 - i. Vesicles develop on the tongue, interdental cleft of the feet.
 - ii. Vesicles on the teats and udder
 - iii. Lesions on the mammary gland and feet
 - iv. Cattle may lose one or both horns of the foot

2.5.3 Rule base

Rule base contain rules for reasoning. They relate information or facts in the IF (antecedent) part with to some action in the THEN (consequence) part. Rules may have multiple antecedent joined by keyword AND (conjunction), OR (disjunction) or a combination of both. Below is an example of the “if...then” analysis for the above characteristics:

- R1. If anorexia and fever (temperature) \geq to 41°C Then A
- R2. If Blisters exists inside the mouth and excessive secretion of stringy or foamy saliva and drooling then B
- R3. If there is loss in weight or the is loss in animal condition and growth rate the C
- R4. If production (Milk) yield drops dramatically then D

A rule is triggered if all the conditions are satisfied and then the consequents are fired.

2.5.4 Inference Engine

An inference engine consists of algorithms for manipulating the knowledge represented in the knowledge base (Lucas & van der Gaag, 1991). The inference engine uses either forward chaining or backward chaining for problem solving and conflict-resolution. Forward chaining is

reasoning from facts to the conclusions resulting from those facts (Giarratano & Riley, 2005). Since the model is driven by data to arrive at certain conclusion, forward chaining is described.

Using a mobile user interface farmers enter disease symptoms and characteristics (facts). The inference engine interrogates the knowledge base and links the facts provided to perform some reasoning in order to arrive at a solution or diagnosis. To aid farmers, a series of questions are provided, the response of which form the basis of prediction.

2.5.5 Working Memory

Working memory refers to task-specific data for the problem under consideration (Badiru & Cheung, 2002). It consists of accumulated facts or data. Using the working memory, the model is expected to store all the matches and use them in the prediction process. From the above example of “if...then” analysis, outcomes in Table 2.2 may be expected in the working memory:

Table 2.2 Outcomes of if-then Analysis

Conditions				Outcome	Deduction	Prescription
A	B	C	D	1	Foot and Mouth present	Administer FMB Medication
A	B	C		2	Foot and Mouth present	Administer FMB Medication
A	B			3	Possible Foot and Mouth present	Further review by veterinarian
A		C	D	4	Possible Foot and Mouth present	Further review by veterinarian
A		C		5	Possible Foot and Mouth present	Further review by veterinarian
A			D	6	Possible Foot and Mouth present	Further review by veterinarian
A				7	Possible Foot and Mouth developing	Monitor animal closely
	B	C	D	8	Foot and Mouth present	Administer FMB Medication
	B	C		9	Possible Foot and Mouth present	Further review by veterinarian
	B		D	10	Possible Foot and Mouth present	Further review by veterinarian
	B			11	Possible Foot and Mouth developing	Monitor animal closely
		C	D	12	Possible Foot and Mouth present	Further review by veterinarian

		C		13	Possible Foot and Mouth developing	Monitor animal closely
			D	14	Possible Foot and Mouth developing	Monitor animal closely

Outcomes 1, 2 and 8 predict “Foot and Mouth present” and prescribes “Administer FMB drugs”

Outcomes 3, 4, 5, 6, 9, 10 and 12 predict “Possible Foot and Mouth present” and prescribes “Further review by veterinarian”

Outcomes 7, 11, 13 and 14 predict “Possible Foot and Mouth developing” and prescribes “Monitor animal closely”

2.6 Related Work

This section looks at work done in disease surveillance, disease prediction and early warning systems, and describes some of the applications systems developed and used in these areas. The section further describes work done on animal health management and disease prediction system.

2.6.1 Disease surveillance and early warning systems

Through disease surveillance, disease prediction and early warning systems, the risk of disease outbreaks can be minimized. Disease Surveillance is essential for farmers to identify animal diseases, foodborne pathogens and foodborne diseases, as well as risk factors, to help reduce their impact on animal and human health and environmental contamination (Balogh , Halliday, & Lubroth, 2013).

Early detection of disease outbreaks is also critical in minimizing mortality and morbidity levels through timely intervention and implementation of control and disease prevention measures (Kshirsagar, Savalia, Kalyani, Kumar, & Nayak, 2013). Early warning (EW) is “the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response” (Grasso, Singh, & Pathak, 1012)

Significant work has been carried out in the area of disease surveillance and early warning systems by international organizations including World Organization for Animal Health (OIE), Food and Agriculture Organization (FAO), World Health Organization (WHO) and African Union Interafrican Bureau for Animal Resources (AU-IBAR). The information and data gathered by this organization over time is crucial in determining future occurrence of a disease outbreak based on historical and past occurrences.

2.6.1.1 World Animal Health Information Database (WAHID) Interface

World Organization for Animal Health (OIE) developed World Animal Health Information Database (WAHID) Interface that provides access to all data held within OIE's new World Animal Health Information System (WAHIS). It replaces and significantly extends the former web interface named Handistatus II System (World Organisation for Animal Health (OIE), 2013).

According to OIE, WAHIS provides a comprehensive range of information ranging from “immediate notifications and follow-up reports submitted by Country / Territory Members notifying exceptional epidemiological events current in their territory; six-monthly reports stating the health status of OIE-listed diseases in each Country / Territory; annual reports providing health information and information on the veterinary staff, laboratories and vaccines among other reports.”

Kenya is among member countries that submit information to WAHID. The information submitted on disease outbreaks in Kenya overtime will provides reference data to the disease prediction model and aid in determining occurrence of a disease outbreak based on historical and past occurrences.

2.6.1.2 Emergency Prevention System for Animal Health (EMPRES-i).

Food and Agriculture Organization (FAO) has implemented EMPRES-i (Food and Agriculture Organization (FAO), 2015). According to FAO (2012), EMPRES-i is a global information system designed to facilitate sharing and analysis of country, regional and global disease information. This platform promotes monitoring early warning and response to

transboundary animal diseases (TADs) including emergent zoonoses, as well as monitoring and supporting their progressive eradication and control.

EMPRES-i aims to consolidate disease events worldwide using information that EMPRES receives from different official and unofficial sources: reports from country or regional projects, reports resulting from field missions, partners such as cooperating institutions, Non-Governmental Organizations (NGOs), government Ministries of Agriculture and Health, FAO in-country representations or other United Nations parties, public domains, the media and web-based health surveillance systems.

For verification purposes, EMPRES-i uses both official and unofficial sources of information. This way, a good level of awareness on TADs and zoonoses is maintained. This information is used to generate and disseminate early warning messages, but it is also fed into the EMPRES-i and disposed in a structured and digested format to the public (Food and Agriculture Organization (FAO), 2012).

Unlike WAHID that rely on official submission of data, EMPRES-I also incorporates unofficial sources making it more comprehensive. The information submitted on disease outbreaks in Kenya and that incorporated from unofficial sources overtime will provides reference data to the animal health monitoring and disease prediction model and aid in determining occurrence of a disease outbreak based on historical and past occurrences.

2.6.1.3 Global Outbreak Alert and Response Network (GOARN)

World Health Organization (WHO) also has developed and implemented a system called Global Outbreak Alert and Response Network (GOARN) (World Health Organization (WHO), 2015a). According to WHO (2015a), The Global Outbreak Alert and Response Network (GOARN) is a technical collaboration of existing institutions and networks who pool human and technical resources for the rapid identification, confirmation and response to outbreaks of international importance.

The Network provides an operational framework to link this expertise and skill to keep the international community constantly alert to the threat of outbreaks and ready to respond. The

Global Outbreak Alert and Response Network contributes towards global health security by combating the international spread of outbreaks, ensuring that appropriate technical assistance reaches affected states rapidly and contributing to long-term epidemic preparedness and capacity building (World Health Organization (WHO), 2015a).

GOARN presents collaboration advantage and the ability to pool human and technical resources. Farmers and outreach officials using GOARN will have an added advantage in that they can supplement the results of prediction provided by the animal health monitoring and disease prediction model and are able to take appropriate action timely.

2.6.1.4 Global early warning and response system (GLEWS+)

Another early warning system is the Global early warning and response system (GLEWS+) that was developed and implemented through combined efforts from the three organizations OIE, FAO and WHO (Food and Agriculture Organization (FAO), World Organization for Animal Health (OIE) & World Health Organization (WHO), 2011). According to FAO, OIE and WHO (2011), the goal of GLEWS+ is to “inform prevention and control measures, through the rapid detection and risk assessment of health threats and events of potential concern at the human-animal-ecosystems interface.” GLEWS+ also seek to improve data sharing and risk assessment for animal disease threats of the three sister organizations (FAO, OIE and WHO) for the benefit of the international community (World Health Organization (WHO), 2015b).

These systems are based on early warning. Early warning is based on the concept that dealing with a disease epidemic in its early stages is easier and more economical than having to deal with it once it is widespread. They deal with early warning of outbreaks and also have the capacity to predict spread of the outbreak to new areas. This is an essential pre-requisite for the effective containment and control of epidemic animal diseases, including zoonoses (Food and Agriculture Organization (FAO), World Organization for Animal Health (OIE) & World Health Organization (WHO), n.d.). They also depend on reports from member organizations on disease outbreaks upon which information is analysed, enriched and disseminated back to member organizations as illustrated in the Figure 2.5 (Food and Agriculture Organization (FAO), World Organization for Animal Health (OIE) & World Health Organization (WHO), 2011).

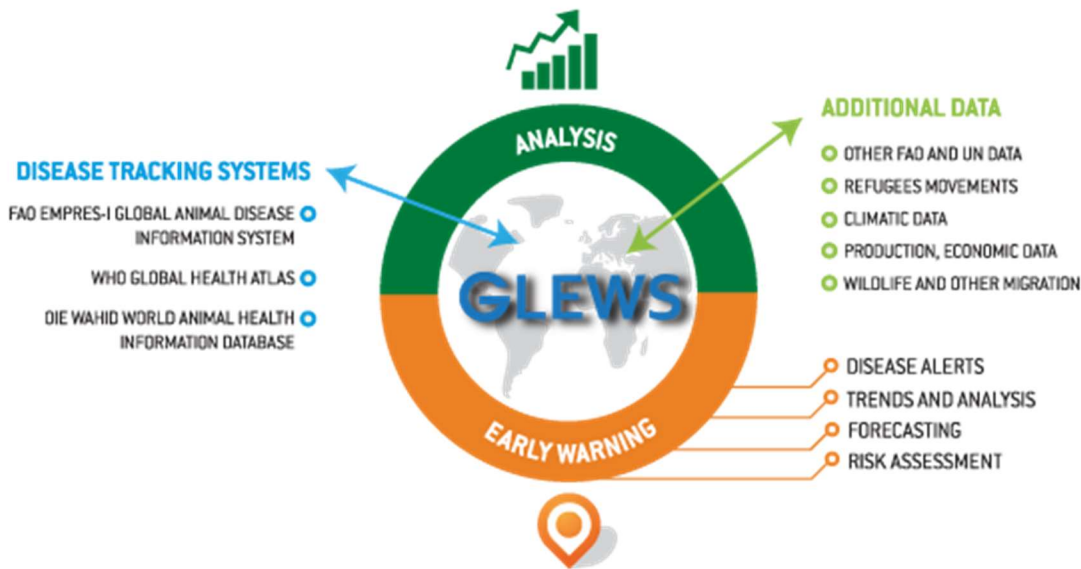


Figure 2.5: About Global Early Warning System (GLEWS)

GLEWS+, unlike WAHID, EMPRES-i GOARN, was developed and implemented through combined efforts of the three organizations making it more comprehensive compared to the other three. Enrich data from GLEWS+ will go a long way in determining the likelihood of disease occurrence in a certain area.

2.6.2 Animal Health Monitoring and Disease Prediction Systems

Accurate recording of all animal health events is important for timely identification of disease outbreaks. It also helps in identification of recurrently affected animals for culling and make effective to manage sick animals. Data and information recorded is also useful to health officials and can be used in design of preventative programs (DairyNZ, 2015).

Monitoring this information allows any increasing levels of disease in animals to be identified early and managed, which is particularly important for larger livestock herds where small and subtle changes can quickly lead to significant effects (DairyNZ, 2015). Disease predictions on the other hand are developed to help in estimating the probability or risk that a specific disease or condition is present or that a specific event will occur in the future, to inform their decision making (Collins, Reitsma, Altman, & Moons, 2015).

Animal Health Monitoring and Disease Prediction Systems offer various functionality including i) Design features: registration of animal, farm and farmers' details; ii) recording animal health details such as disease/condition, treatment/dose type and treatment date; iii) ability to capture disease symptoms characteristics, perform diagnosing and provide diagnostic advice or suitable treatment; iv) provide other optional functionality such as a knowledge base to provide tips and advice to farmers; animal calculators and animal calendar that can track important animal past, current and future events; market/auction prices; collaborative platform that can link farmers with other farmers and buyers of farm produce.

2.6.2.1 Modisar

Modisar, developed by Modisar Net (2015), is a desktop application that helps farmers to track their farm records, cattle herds, farm costs and sales. In addition, Modisar sends advice to farmers on animal vaccinations, feed and nutrition also, they receive instructions on finance via text messages. Modisar is a desktop application which run both on and offline. Does not require active internet connection Farmers can work off their desktops and once internet is available, they can synchronize data to the Modisar Azure Cloud servers. By synchronizing, Farmers will have a backup of their data in the cloud and are can access this from Modisar Farm Management web Application (Biztech Africa, 2014).

The proposed animal health monitoring and disease prediction model is mobile based providing farmers with the ability to record and access information from anywhere and at any time. The animal health monitoring and disease prediction model implements the functionality allowing farmers to track their farm records and cattle herds. Other features such as management of farm costs and sales and farming advice will be included in future implementations of the model.

2.6.2.2 VetAfrica

Developed by Cojengo (2013), VetAfrica mobile application allows farmers to record animal data and receive diagnostic advice and guidance about suitable treatment. VetAfrica is designed to be a decision support system for proficient farmers, animal health workers and veterinary professionals.

VetAfrica is only available in windows store and therefor is unavailable to millions of android users.

2.6.2.3 Mobile Cattle Tracker

Mobile Cattle Tracker, developed by University Of Nebraska–Lincoln (2013), allows the farmer to enter animal related events electronically as they happen. Production data like birth and health records; weights and measurements; and management activities need to be entered real time, so they can be available for review when animals are gathered and worked.

The app isn't a recordkeeping program, but a way to collect data. After data is collected, it can be emailed as an Excel file attachment. The app allows producers to keep records from year to year and can be started at any time during the production year.

2.6.2.4 M-Farm

M-Farm is developed by M-Farm (2015) and offers real-time market prices for crops, matching Kenyan farmers with buyers. As a transparency tool for Kenyan farmers, the app allows them to simply SMS the number 3535 to get information about the retail price of their products, buy their farm inputs directly from manufacturers at favourable prices, and find buyers for their produce. The application allows remote farmers to plug into market updates and as a result, keep up with the competition

2.6.2.5 MedAfrica

The MedAfrica application was developed by MedAfrica (2012) and helps users diagnose symptoms and providing directories of doctors and hospitals with the aim to revolutionize how people in developing areas, particularly on the African continent, access and use health information.

MedAfrica platform brings basic information about health and medicine to all phones — not just smartphones — and enabling people to use that information on their own. However, it's currently providing functionality for human diseases.

2.6.2.1 iCow

iCow, developed by Green Dreams Technology (2015), is an SMS (text message) and voice-based mobile phone application for small-scale dairy farmers in Kenya. iCow provides farmers with valuable tips on gestation (cows' estrus cycle), cow breeding, animal nutrition, milk production and fodder management. iCow hosts a number of functionalities that farmers can subscribe to including: Mashauri-Farmer Tips, Kalenda (Livestock Calendar) and Vetinari.

Upon subscription to iCow's Mashauri-Farmer Tips, farmers receive SMS tips at a small fee. Subscription of a Cow, Calf, and Heifer to Kalenda (Livestock Calendar) farmers receive customized tips on registered livestock again at a fee. The Vetinari helps farmers to find and locate the nearest Vet or AI (Artificial Inseminator). No subscription is required to use Vetinari as Farmers simply need to insert their location and thereafter receive SMS's with contacts of the nearest veterinarian or Artificial Inseminator (AI) at a fee.

iCow is currently available in English and Kiswahili and designed to run on both low-end and high-end mobile phones. The animal health monitoring and disease prediction model will implement Livestock Calendar and Vet or AI directory and provide information to farmers at no fee. Unlike SMS based implementation of iCow, animal health monitoring and disease prediction model will provide real-time access to information via GSM, 3G or LTE network. The farmer is presented with an interface to constantly monitor the cow's health.

2.7 Conceptual Framework

Adopted from Makhubele (2012), conceptual framework in Figure 2.6 links the research objectives and problem statement with the reviewed literature:

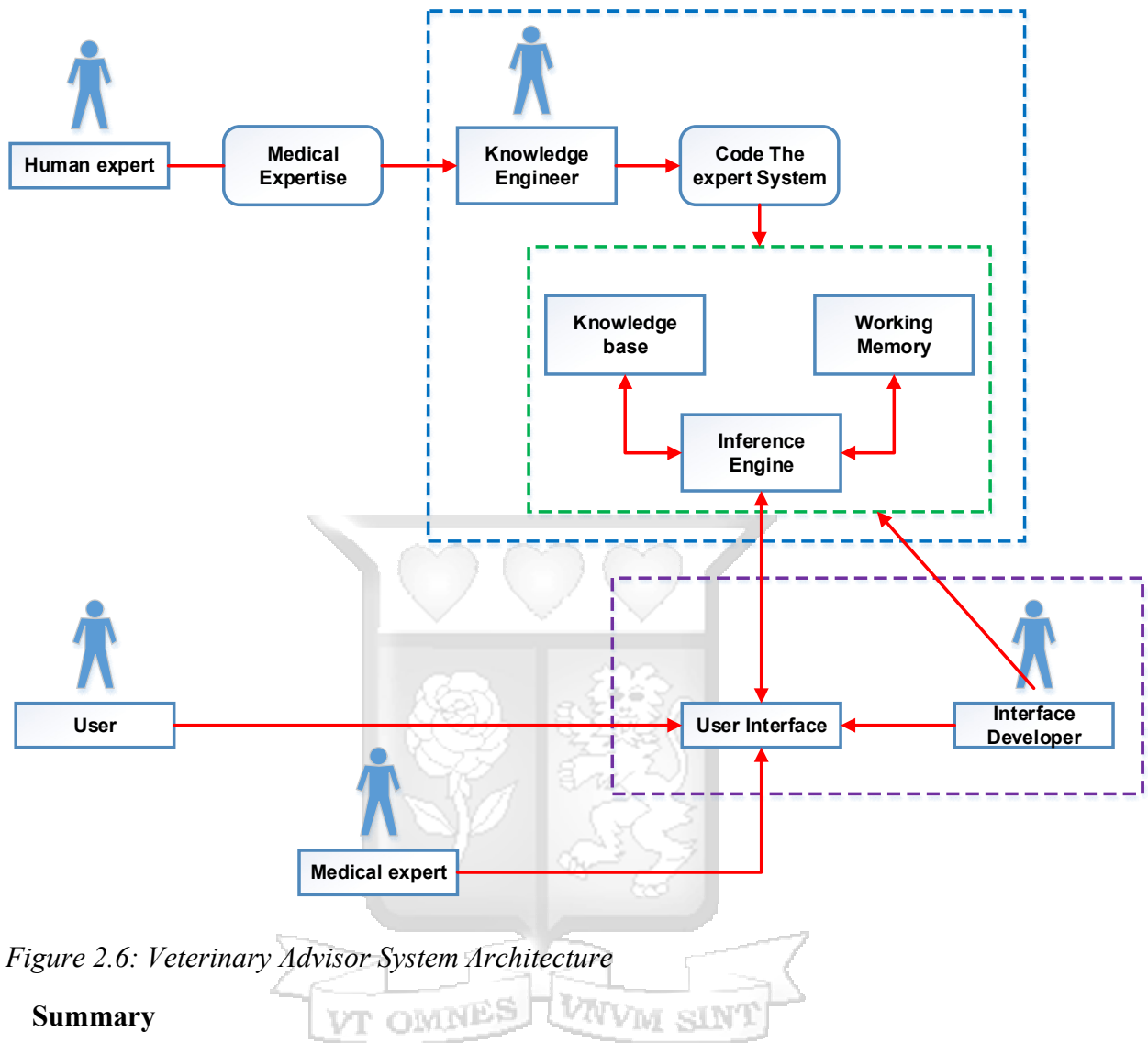


Figure 2.6: Veterinary Advisor System Architecture

2.8 Summary

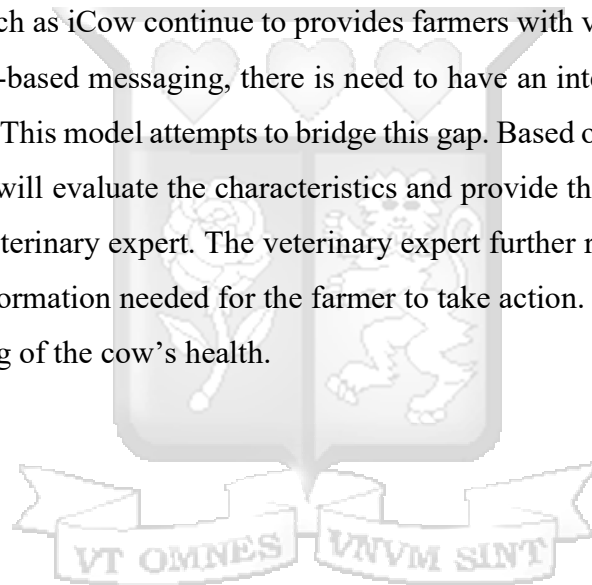
Livestock contribute greatly to the wellbeing of farmers. Research has shown that the animals and plants has affected the course and evolution of man. Animals, therefore has been central to the survival of man having contributed economically, socially and even religiously. It is imperative for man to maintain the health and well-being of the animals. More so with advent of new technologies that have continue to reshape the society.

The world is becoming a global village. Globalization and free trade between nations is creating borderless environment where humans, animals and goods flow freely. Animal disease outbreaks, in such a stage, has far reaching consequences as it may affect all aspects of human life.

Relevant technologies exist that can help in to characterize and predict occurrence of animal diseases in advance. This is very important as relevant interventions can therefore be put in place to mitigate or minimize the risks of animal diseases.

A mobile based expert system model for animal health monitoring and disease prediction is proposed. Upon animal registration, a stakeholder logs in, searches and selects the affected animal and then responds to a series of questions whose response form the basis of prediction. In either the presence or absence of a disease, the stakeholder is provided with relevant information that is sufficient to educate on the next course of action. These information is also disseminated to veterinary officers who reviews it and provides relevant details to farmer for action.

While systems such as iCow continue to provides farmers with valuable tips through SMS (text message) and voice-based messaging, there is need to have an interactive platform that add more value to the farmer. This model attempts to bridge this gap. Based on characteristics provided by the farmer the model will evaluate the characteristics and provide the farmer with preliminary advice and also alert a veterinary expert. The veterinary expert further reviews the characteristics and provides relevant information needed for the farmer to take action. Further, the model allows for continuous monitoring of the cow's health.



Chapter 3. Research Methodology

3.1 Introduction

A research methodology is an approach and a set of supporting methods and guidelines to be used as a framework for doing design research (Blessing & Chakrabarti, 2009). This chapter deals with the research methodology adopted in the study. It lays emphasis on research design, population and sample of the study, data collection method, research procedures and data analysis method.

Investigation into the state of information systems usage in animal health monitoring and disease prediction has been carried out with the aim of gaining an insight of the extent into which information technology has been utilized in animal health management and disease prediction. The investigation also aimed at establishing how information systems have been used to overcome challenges associated with disease prediction and more so, how these technologies address information requirements for an animal health monitoring and disease prediction model.

3.2 The Research Design

Research design is the conceptual structure within which research is conducted; it constitutes the blueprint for the collection, measurement and analysis of data. As such the design includes an outline of what the researcher will do from writing the hypothesis and its operational implications to the final analysis of data (Kothari, 2004). Research design therefore will attempt to answer fundamental issues on research including: what data the researcher is planning to gather; how the researcher plans to gather this data; from whom the researcher plan to get this data; how the researcher will analyse the data in order to make inferences from it.

The technique employed in this study is applied research design. Applied research was adopted for this research as the study seek to find a solution to everyday problems faced by livestock farmers. The research attempts to address practical questions rather than theoretical questions (Beins & McCarthy, 2012). Key findings of the research will be used for development of animal health monitoring and disease prediction. It is envisaged that using the proposed model, farmers will keep animal records and monitor animal health, through its lifetime, right at the farm.

The research plan of this study was two phased. Qualitative and quantitative studies were carried out in the first phase to investigate the core challenges faced by farmers with regards to occurrence of animal diseases, to review architecture designs of existing animal health monitoring and disease prediction models and to establish data and information requirements to be handled by the proposed model. During the second phase the research developed the architecture of a mobile based animal health monitoring and disease prediction model and validated it.

3.3 Population and Sampling

Mugenda and Mugenda (2003) defines population as an entire group of individuals, events or objects having a common observable characteristics and a sample as a smaller group obtained from the accessible population. Sampling is the process of selecting a number of individuals for a study in such a way that the individuals selected represent the large group from which they were selected, the population (Mugenda & Mugenda, 2003).

Purposeful sampling strategy is adopted. Purposive or purposeful is a non-probability sampling strategy in which the researcher sampling selects participants who are considered to be typical of the wider population (Singh, 2007). It is a non-probabilistic sampling technique that allows a researcher to use cases that have required information with respect to the objectives of the study (Mugenda & Mugenda, 2003). This strategy has been adopted to target stakeholders within Kenya who have required information to meet the objectives of this study. This is mainly due to practical reasons related to logistical issues and accessibility to some stakeholders.

3.4 Data Collection Methods

Data refers to all the information a researcher gathers for the study (Mugenda & Mugenda, 2003). Data may be classified as either primary or secondary data. Primary data refers to information obtained first-hand by the researcher on the variable of interest for the specific purpose of study while secondary data refers to information gathered from sources that already exist (Sekaran & Bougie, 2009).

Primary data collection methods and tools used included questionnaires as they are easy to analyse, administer and information collected is standardized with a degree of anonymity; and

interviews as they offer the opportunity to gather comprehensive data and also offers avenue for clarifications (Munambo, 2011). Secondary data on the other hand was gathered from journals, newspaper articles and other existing literature. These are easily accessible, readily available and economic (Munambo, 2011).

3.5 Data Analysis

Once data had been gathered and assembled, automated computer analysis tools were used to perform data analysis. More specifically, Microsoft Excel and SPSS tools was used. Unlike other quantitative analysis software, SPSS provides a window user interface which makes the software very user-friendly. Researchers can use simple menus, pop-up boxes and dialogue boxes to perform complex analyses without writing even a single line of syntax. It is an integrated software which also provides a spreadsheet-like utility function for entering data and browsing the working data file (Singh, 2007).

3.6 System Design and Development Methodology

Development of the model adhered to the agile method of Software Development Life Cycle (SDLC) process. SDLC is structured analysis method that uses a series of phases, called the systems development life cycle to plan, analyse, design, implement, and support an information system (Rosenblatt, 2013). Agile process follows the software development life cycle which includes requirements gathering, analysis, design, coding, testing and delivers partially implemented software and waits for the customer feedback. In the whole process, customer satisfaction is at highest priority with faster development time. (Sharma, Sarkar, & Gupta, 2012)

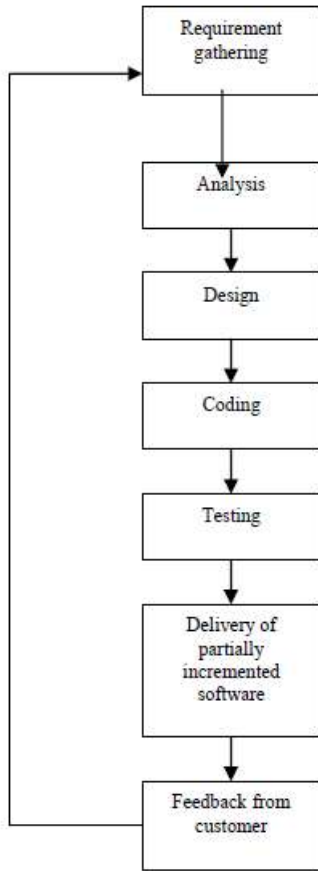


Figure 3.1: Phases of Agile Process

3.6.1 Requirement Gathering

This was a fact finding process of the project where requirements of the mobile based animal health monitoring and disease prediction model was established. The agile process allowed for an interactive process where requirement discovery took place throughout the design and development process. The process involved interviews with subject matter experts as well as gathering of information through a pre-written series of question in form of an online questionnaire as shown in appendix 2.

Based on the analysis performed on the survey responses and interviews of subject matter experts, a number of functional requirements and non-functional requirements were identified.

Functional requirements:

- i. The model to allow for new user registration and ability to allow these users to log into the system.
- ii. The model to allow for registration of farms and store data into the database.
- iii. The model to allow for registration of animals in a farm and store data into the database.
- iv. The model to have a functionality to setup system parameters and static maintenances necessary for its smooth running.
- v. The model to provide a functionality for capturing animal behavior and characteristics. Farmers to be presented with a functionality to search and select a specific animal and to be allowed to capture symptoms, animal behavior and characteristics through a series of predefined questions.
- vi. The model to provide an advisory module to provide farmers with preliminary advice and to alert veterinary experts on affected animals.
- vii. A disease prediction functionality should exist to allow the veterinary expert review animal symptoms, behavior and characteristics and predict disease.
- viii. A prescription functionality should exist to allow the specialist prescribe or give instructions that govern the plan of care for the affected animal including the preparation and administration of drugs.
- ix. The system should allow for monitoring, tracking and updating of conditions for affected animals to recovery.
- x. There should have a functionality to provide reports and queries.

Non-Functional requirements

- i. Usability: The system should be easy to use, easy to learn, user friendly and devoid of errors

- ii. Reliability: The system should be dependable and should function as stated in these requirements
- iii. Performance: The system should respond in timely manner.
- iv. Scalability: The system should be parameterized to accommodate addition functionalities in future.
- v. Availability: System should be available for use at all times, particularly during the day when most users are active.
- vi. Security: System should have segregation of functions and data such that details of one farmer are not viewed by a different farmer.
- vii. Data Integrity: The system should maintain data integrity and ensure users access and manipulate only the data they are allowed to. There should be programming data integrity check as well as database data integrity checks.
- viii. Interoperability: The system should accept data on animal resources from organizations such as AU-IBAR, FAO, OIE and WHO.

3.6.2 Analysis

This phase was used to review and analyse the validity of the requirements. A study of possibility of incorporating the requirements in the model to be development was also done. Key requirements included: registration of users, farms and animals; recording of animal behaviour and characteristics; prediction of presence or absence of disease, provision of relevant advice to the farmer and disseminating the details to veterinary expert; provision of interface for veterinary expert to review animal records and characteristics, enter diagnosis and prescription thereof; dissemination of diagnosis and prescription details to the farmer.

3.6.3 Design

This phase was used to prepare the system and software design based on requirement specifications. Testing and validation strategy was also derived in this phase. This is discussed in Chapter 6 in greater details.

3.6.4 Coding

It is in this phase where the actual code was produced.

3.6.5 Testing

In this phase, the developed code was tested against the requirements to ensure that the model was solving the needs identified and gathered during the requirements phase. This is discussed in chapter 7 in greater details.

3.6.6 Delivery and Deployment

After successful testing during the testing phase the model was delivered and deployed to the stakeholders for use. This is discussed in chapter 7 in greater details.

3.6.7 Feedback from users

Users recommended some minor changes that were analysed and implemented. Bugs were also fixed as soon as they were reported or identified. The model was re-deployed for use. It is expected that as the model is subjected to more use, problems and additional requirements may come up and these will need to be analysed and solved from time to time.

3.7 Model Design Schedule

As described in section 3.6, development of the model adhered to the agile method of SDLC process. The various systems development life cycles took varying timeframes to accomplish. The system design and development process took a total period of four months to complete, starting January 2016 and ending April 2016. The duration taken in each cycle is indicated in the project schedule shown in Figure 3.2 below.

	Task Name	% Complete	Duration	Start	Finish	Predec	Resource Names
0	Project Plan	0%	87 days	Fri 1/11/16	Tue 5/3/16		
1	Initiation	0%	1 day	Fri 1/1/16	Mon 1/4/16		
2	Topic Selection and approval	0%	1 day	Fri 1/1/16	Mon 1/4/16		Faculty/Supervisor/Peter Muriu
3							
4	Requirement Gathering	0%	16 days	Mon 1/4/16	Tue 1/26/16	1	
5	Gather business requirements (BR)	0%	4 days	Mon 1/4/16	Fri 1/8/16		Peter Muriu
6	Functional requirements (FR) definition	0%	4 days	Fri 1/8/16	Thu 1/14/16	5	Peter Muriu
7	Review & Approval of BR & FR with Supervisor	0%	1 day	Thu 1/14/16	Fri 1/15/16	6	Faculty/Supervisor
8							
9	Analysis	0%	7 days	Fri 1/15/16	Tue 1/26/16	7	
10	Review and analyse validity of requirements	0%	5 days	Fri 1/15/16	Fri 1/22/16		Peter Muriu
11	Review & Approval of BR & FR with Supervisor	0%	2 days	Fri 1/22/16	Tue 1/26/16	10	Faculty/Supervisor
12							
13	Design	0%	11 days	Tue 1/26/16	Wed 2/10/16		
14	System Architecture and Design documentation	0%	5 days	Tue 1/26/16	Tue 2/2/16	11	Peter Muriu
15	Confirm Tech Specs, Create Arch Diagrams & other artifacts (may require multiple occurrences covering more complex systems)	0%	5 days	Tue 2/2/16	Tue 2/9/16	14	Peter Muriu
16	Review	0%	1 day	Tue 2/9/16	Wed 2/10/16	15	Faculty/Supervisor
17							
18	Construction	0%	38 days	Wed 2/10/16	Mon 4/4/16		
19	Build Baseline Code	0%	30 days	Wed 2/10/16	Wed 3/23/16	16	Peter Muriu
20	Unit Testing	0%	3 days	Wed 3/23/16	Mon 3/28/16	19	Peter Muriu
21	System Integration Testing(SIT) tasks	0%	3 days	Mon 3/28/16	Thu 3/31/16	20	Peter Muriu
22	Installation documentation and planning	0%	1 day	Thu 3/31/16	Fri 4/1/16	21	Peter Muriu
23	UAT Environment Preparation	0%	1 day	Fri 4/1/16	Mon 4/4/16	22	Peter Muriu
24							
25	Validation	0%	9 days	Mon 4/4/16	Fri 4/15/16		
26	User Acceptance Testing	0%	3 days	Mon 4/4/16	Thu 4/7/16	23	Peter Muriu
27	Usability Testing	0%	3 days	Thu 4/7/16	Tue 4/12/16	26	Peter Muriu
28	UAT & Implementation Review	0%	3 days	Tue 4/12/16	Fri 4/15/16	27	Peter Muriu
29							
30	Implementation	0%	4 days	Fri 4/15/16	Thu 4/21/16		
31	Production Environment Preparation	0%	2 days	Fri 4/15/16	Tue 4/19/16	28	Peter Muriu
32	Release Notes / Technology Handoff Document	0%	1 day	Tue 4/19/16	Wed 4/20/16	31	Peter Muriu
33	Deployment to production	0%	1 day	Wed 4/20/16	Thu 4/21/16	32	Peter Muriu
34							
35	Post Implementation	0%	8 days	Thu 4/21/16	Tue 5/3/16		
36	Ensure closure of project issues	0%	7 days	Thu 4/21/16	Mon 5/2/16	33	Peter Muriu
37	Submit Project Documentation	0%	1 day	Mon 5/2/16	Tue 5/3/16	36	Peter Muriu

Figure 3.2 Project Schedule

The project schedule was key to the success of this research as it guided the control and execution of the project right from the start. To clearly show the project activities along the timeline, the Gantt chart in Figure 3.3 was developed.

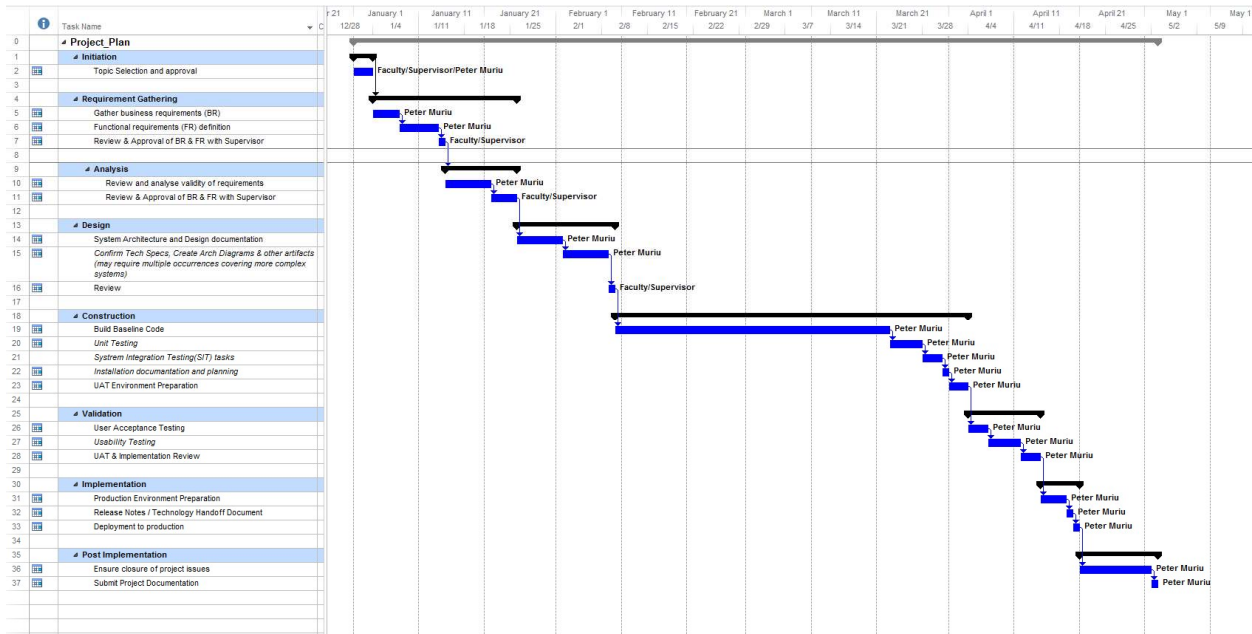


Figure 3.3 Gantt Chart

3.8 Research Quality

Kirk and Miller (1986) identify three types of reliability referred to in quantitative research, which relate to: (1) the degree to which a measurement, given repeatedly, remains the same (2) the stability of a measurement over time; and (3) the similarity of measurements within a given time period. This study adheres to the three types of reliability.

3.9 Ethical Considerations

The ethical considerations taken into account include conflict of interest, consent from participants, confidentiality of data provided and plagiarism.

Chapter 4. Data analysis and Results

4.1 Introduction

The aim of this chapter is to present the results of the online survey carried out. While undertaking the survey the objective was to gain deeper insights into the challenges faced in livestock farmers in Kenya, to understand the methods used for animal health monitoring and disease prediction and to establish the data and information requirements for a farm.

The online survey was subdivided into four main sections: Section A was aimed at getting information concerning the general profile of the respondents. The target respondents were narrowed down to small scale farmers across the various counties. This served to ensure that the information provided was accurate and unbiased.

Section B aimed to find out challenges faced by the respondents in the livestock sector including the main production constraints and methods used in the health management and treatment of the livestock.

Section C, sort to find out the methods used by respondents to these challenges and more so how they manage animal health monitoring and disease prediction. Further, respondents were requested to specify how they communicate with veterinary experts and the state extent to which mobile phones and the Internet aids in this communication.

Section D of the online survey identified the data and information requirements for a farm. The questions in these section sought to establish the kind of livestock respondents keep in their farms, the number of animals kept and the main methods used to identify these animals. Further, respondents were requested to specify the types or farm records they keep and how these records were kept.

4.2 General Profile of the Respondents

4.2.1 Dependency on livestock

Man continue to depend on livestock for wellbeing. 77.3.9 percent of responded use animal products at least on a daily basis with 40.9 percent using animal products daily and 36.4 using animal products multiple times a day.

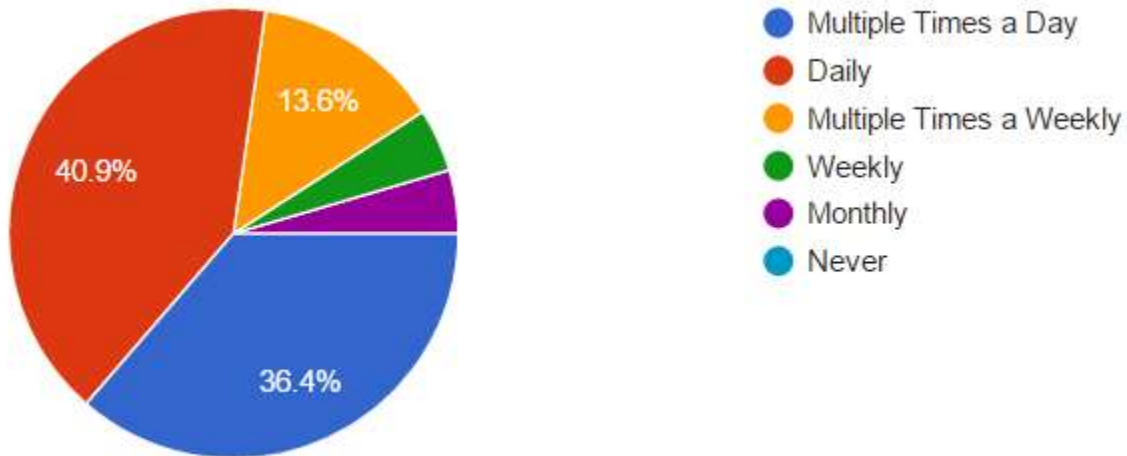


Figure 4.1: Frequency of use of animal products

4.2.2 Farming methods

Most farmers practice mixed farming method where they keep livestock and produce crops. The ratio of farmers practicing mixed farming stood at 63.3 per cent against 13.6 and 22.7 for purely livestock farming and crop production respectively. The type of farming method is important as it determines the degree into which a respondent depends produce coming from either livestock, crops or both. A respondent practising mixed farming is likely going to subsidise his dependency on animal products with those product resulting from crop production. They are also likely to supplement animal feed with products or by-product crop production. The type of farming method is important as it determines the risk of exposure to disease pathogens and also determines risks of spread of disease outbreaks.

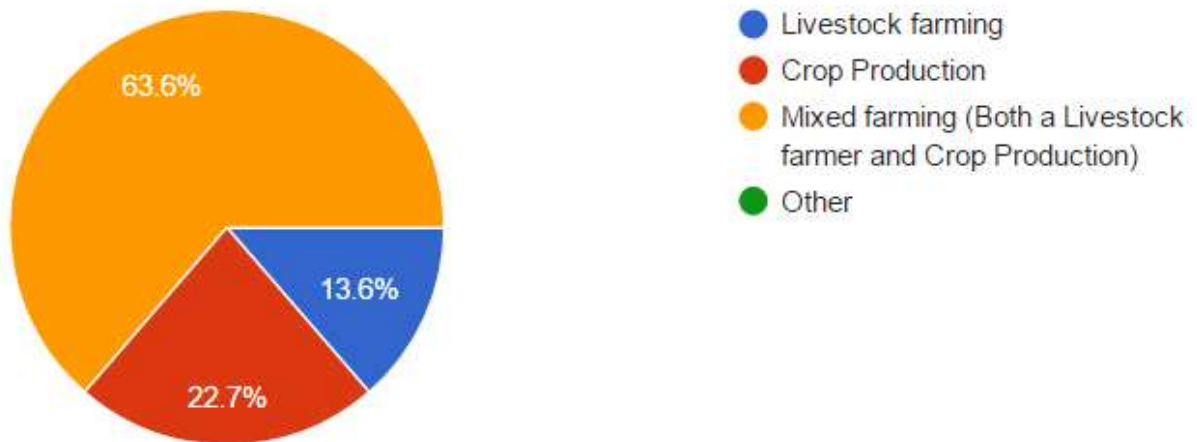


Figure 4.2: Adopted farming methods

4.2.3 Farming experience and farm size

The experience of the farmer varied disparately with most respondents falling between one to five years at 36.4 percent and at 27.3 percent were the most experienced farmers with over 20 years' experience. Experienced respondents are like to react differently to unusual animal behaviour or characteristics and are also likely to make the right decisions compared to inexperienced ones.

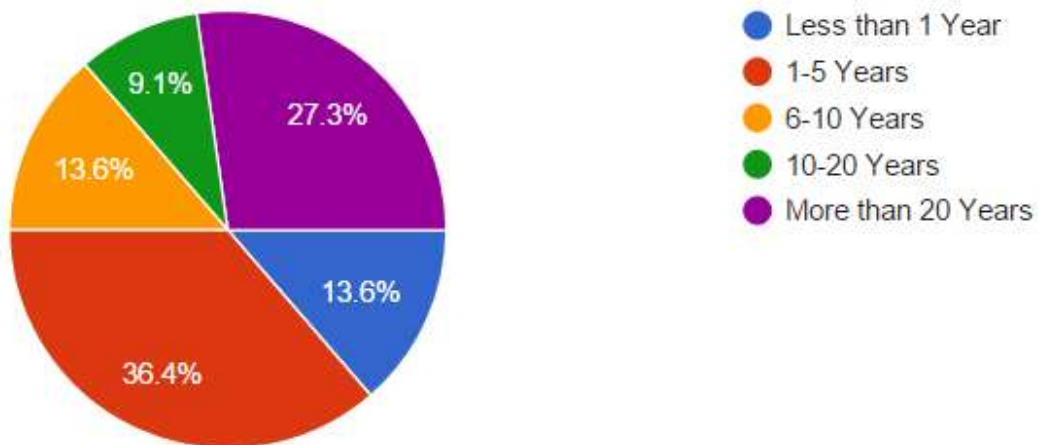


Figure 4.3: Farming experience

Majority of respondents own small parcels of land with 50 per cent owning one to five acres, 18 per cent with less than one acre and 13.6 percent 6-10 acres. Despite the land constraints, most respondents practice mixed farming at 59.1 percent, free-lance at 22.7 per cent and only 13.6 per cent practice zero grazing.

4.2.4 Farming motivation

The major motivation of respondents is income generation. 68.2 per cent cited income generating as the main driver followed by consumption at 50 per cent and hobby at 18.2 per cent.

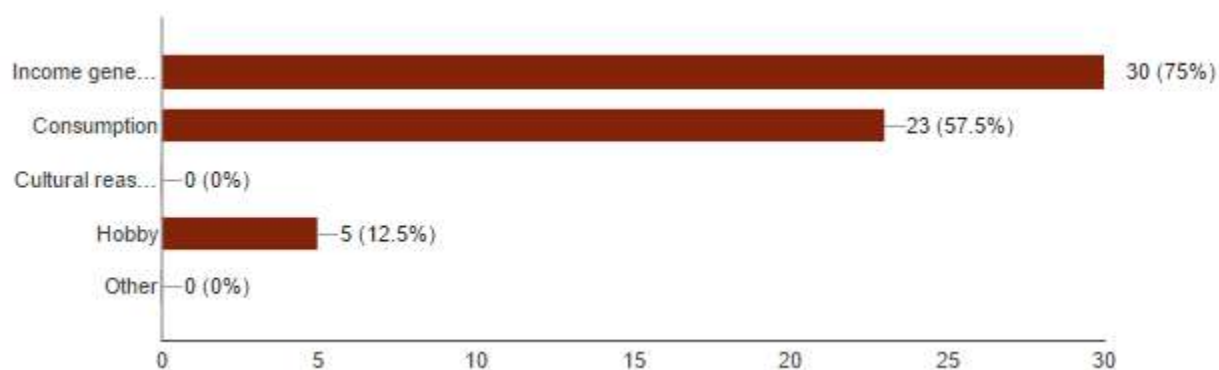


Figure 4.4: Farmers motivation for farming

4.3 Challenges faced by livestock farmers

4.3.1 Main production constraints

According to the respondents, diseases (63.6 per cent) caused the greatest production constraints followed by inadequate veterinary services (36.4 percent). The lack of feed and lack of water both stood at 31.8 percent.

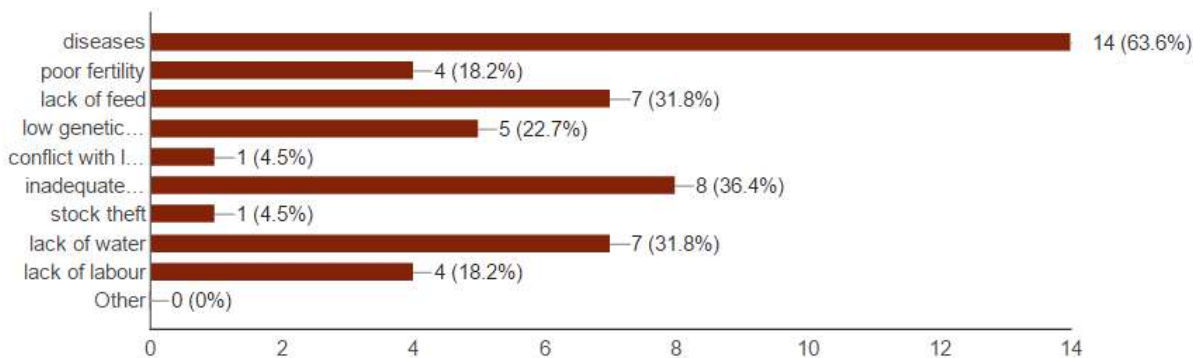


Figure 4.5: Main production constraints

4.3.1 Main source of advice on health management and treatment of the livestock

Private veterinarians (63.6 percent) was the main source of advice on health management and treatment of the livestock while the government extension officers command only 31.8 percent.

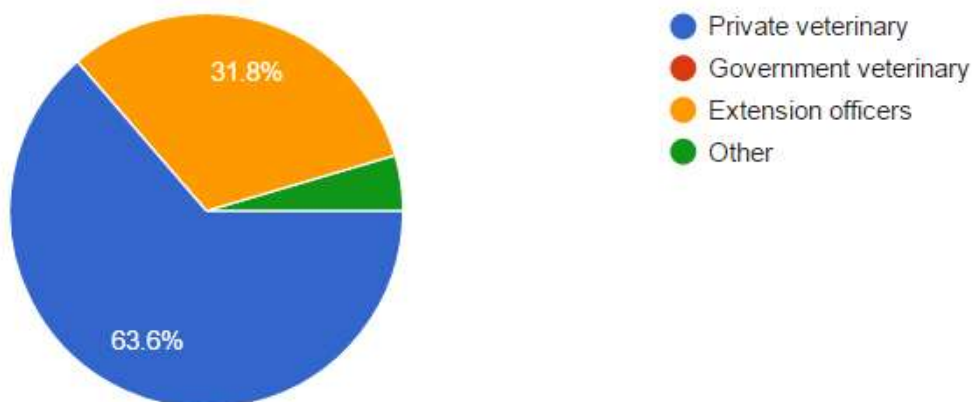


Figure 4.6: Main source of advice on health management and treatment of the livestock

4.4 Animal health monitoring and disease prediction

4.4.1 Communication with health experts

Phone calls (50 per cent) and face to face (45 per cent) communication were the main methods farmers used to relay or communicate behaviour and characteristics of sick animals to the veterinary officer. On the other hand, the veterinary officer was cited as having to communicate

advise and prescription details to the farmer through face to face (77.3 per cent) and only 18.2 percent done through the phone.

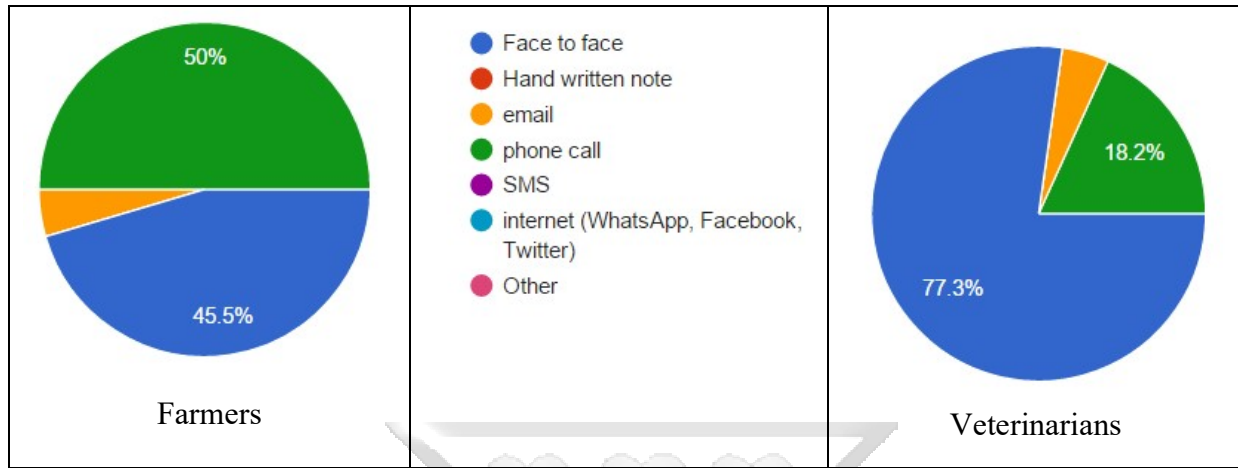


Figure 4.7: Modes of communication with veterinary experts

4.4.2 Mobile phones and internet access

68.2 per cent of respondents use smartphones while those using ordinary phones stood at 27.3 per cent. Internet (63.6 per cent) to most respondents is accessed through GSM (Internet on your mobile phone/ data bundles), 13.6 percent access internet through Wi-Fi or wireless hotspots and 22.7 per cent have no internet access

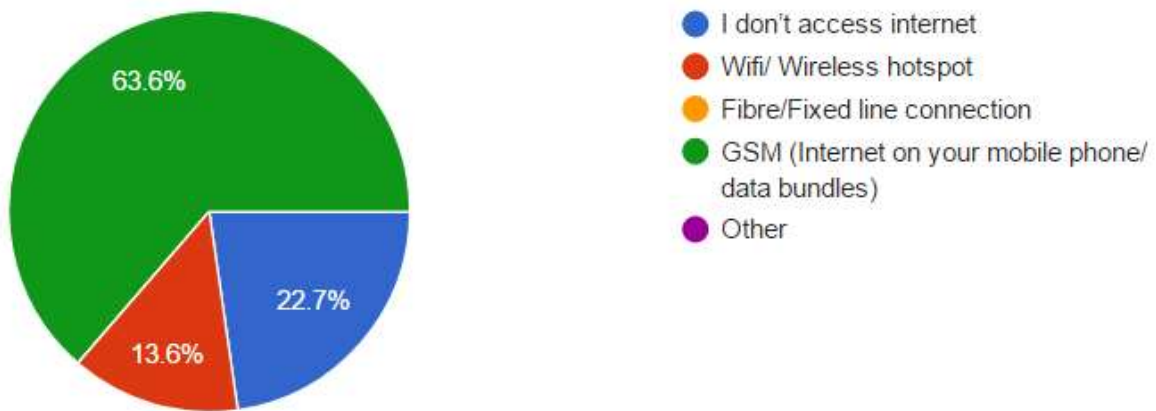


Figure 4.8: Methods of Internet access

4.5 Data and information requirements

4.5.1 Livestock kept in farms

Majority of respondents kept cattle with the highest respondents keeping less than 5 heads of cattle. Of the respondents who kept chicken, majority of them kept more than 20 chicken. Sheep goats and pigs had least respondents keeping them.

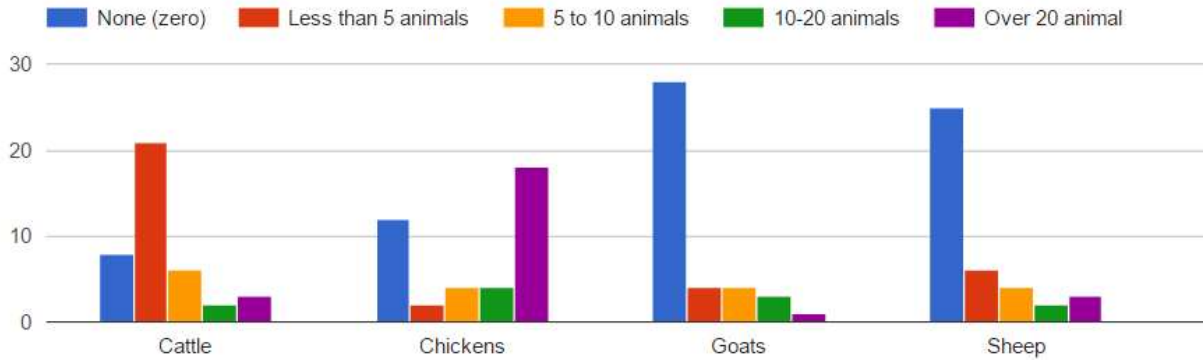


Figure 4.9: Livestock kept in farms

The method of identifying animals is important for the purpose of record keeping. 44.7 percent of respondents cited tagging as their main method of identifying animals. A further 28.9 percent of the respondents use nicknames to identify their animals.

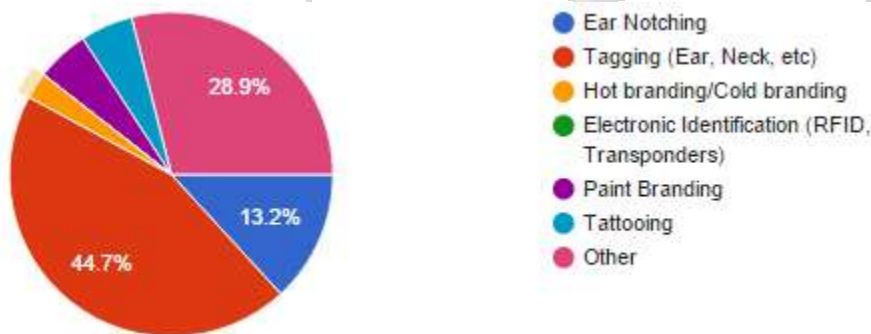


Figure 4.10: Modes of communication with veterinary experts

4.5.2 Type of records kept farms

In order to identify the main records kept in farm, respondents were asked to rank a predefined list of record types. Respondents ranked production records at the top followed by vaccination records, deworming records, treatment records, dipping/spraying records, disease occurrence and other records in that order.

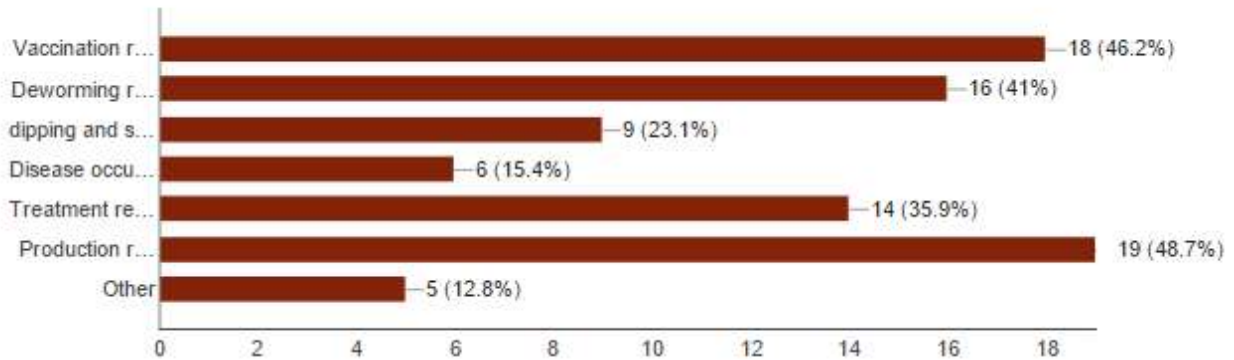


Figure 4.11: Types of records kept

4.5.3 Record keeping methods

In order to establish the records keeping methods employed, respondents were asked to rank a predefined list of record keeping methods. Handwritten records, such as a ledger or notebook was ranked highest by respondents. At least 25 per cent of the respondents kept no records at all.

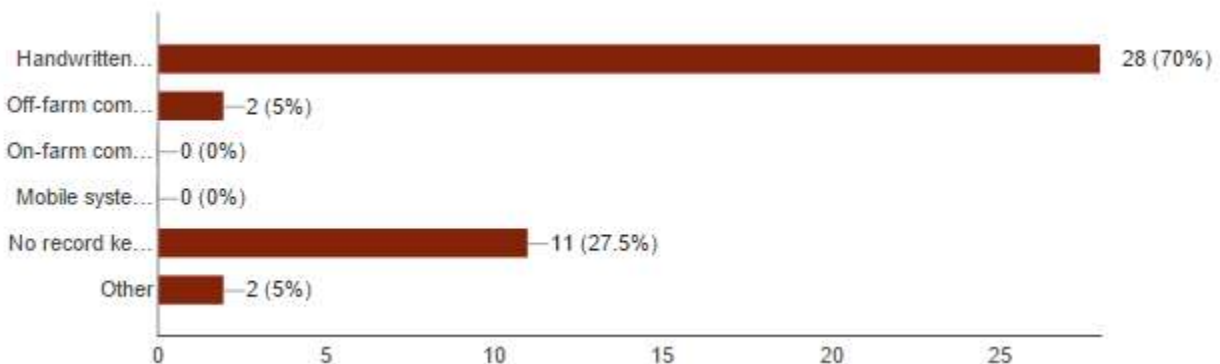


Figure 4.12: Record keeping methods

4.6 Discussion of Results

4.6.1 Introduction

This study shows that significant number of people use animal products at least on a daily basis. To fulfil demand for animal products, farmers should employ safe and cost effective farming methods. This will enable optimum utilization of the decreasing parcels of land available to provide feed for the animals and fulfil the single largest cited motivation, income generation. With majority of respondents having one to five years of experience, there is need for a reliable model that can assist with management and monitoring of animal health.

4.6.2 Threats to farmers

Animal diseases (63.6 per cent) and by inadequate veterinary services (36.4 percent) paused the greatest production constraints to farmers. With this model, farmers can easily document animal characteristics and receive immediate advice right at the farm. The model also disseminates these characteristics to the veterinary officers who also can conveniently review and provide advice to the farmers from anywhere they are and at any time. With the main source of advice on health management and treatment of the animals, coming from private veterinarians (63.6 percent), there appear to be a ready pool of beneficiaries for the model.

4.6.3 Automation Animal health monitoring

Phone calls (50 per cent) and face to face (45 per cent) were the main communication methods between farmers and veterinary officers. Trying to explain characteristics of a sick animal over the phone can be expensive, not clear, prone to distractions and forgetfulness and may also be prone to language barriers. Using this model, the farmers are only requested to document characteristics as they see them. By doing so, electronic records are created, analysed and advise provided to the farmer immediately. The same records also become available to the veterinarian for review and response.

The model brings significant potential to the 68.2 per cent of respondents using smartphones with internet (63.6 per cent) through GSM (Internet on your mobile phone/ data

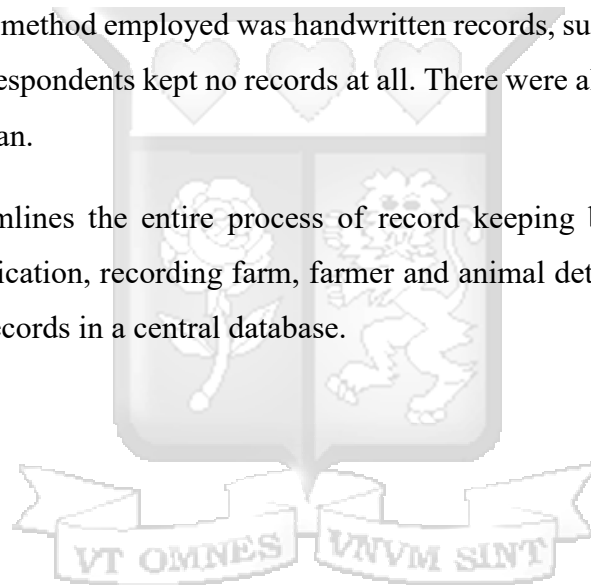
bundles). Additionally, the health of the animal is continuously monitored to the full recovery of the animal.

4.6.4 Record Keeping

Majority of respondents kept cattle with the highest respondents keeping less than 5 heads of cattle. These animals require some form of identifying animals for the purpose of record keeping. While majority, 73.6 percent of respondents, cited tagging and nicknames as their main method of identifying animals, there is need for all the to identify their animals.

Respondent identified the main records kept in farm as production records, vaccination records, deworming records, treatment records, dipping/spraying records and disease occurrence. The main record keeping method employed was handwritten records, such as a ledger or notebook while 25 per cent of the respondents kept no records at all. There were also farmers whose records are kept by the veterinarian.

The model streamlines the entire process of record keeping by allowing for a proper method of animal identification, recording farm, farmer and animal details and most importantly maintain animal health records in a central database.



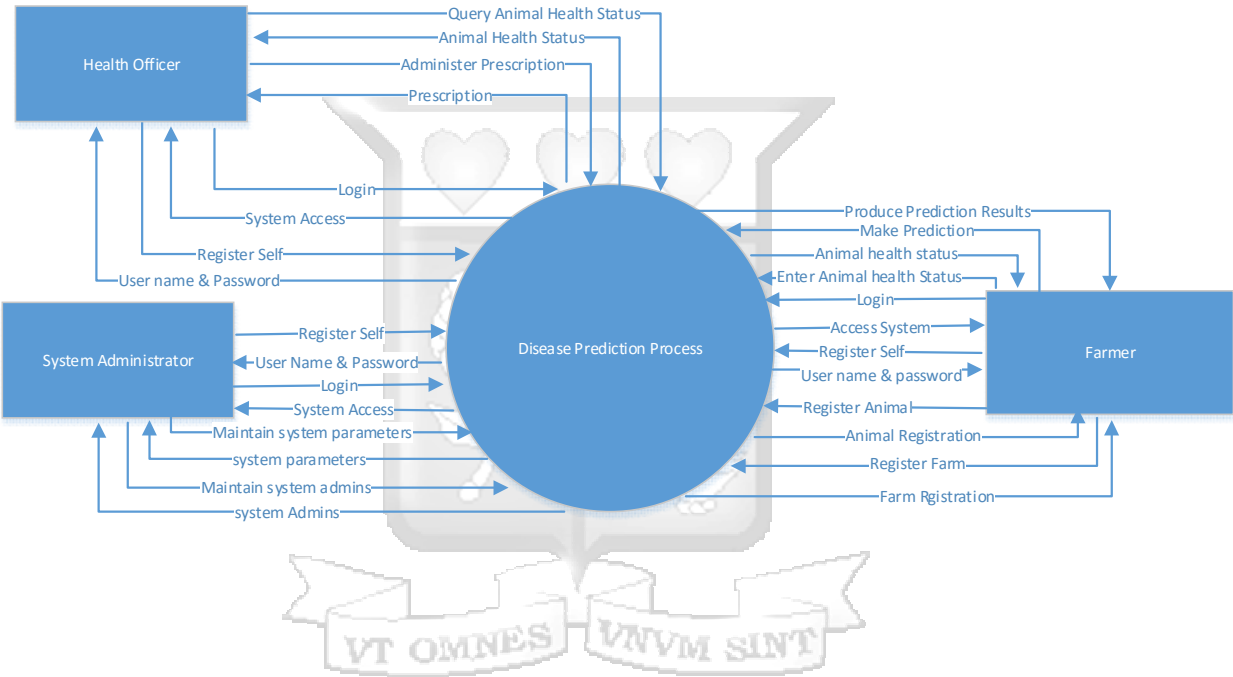
Chapter 5. System Design and Architecture

5.1 Introduction

This section focus on systems design, software modelling and architecture of the model.

5.2 Software Design

5.2.1 Context diagram



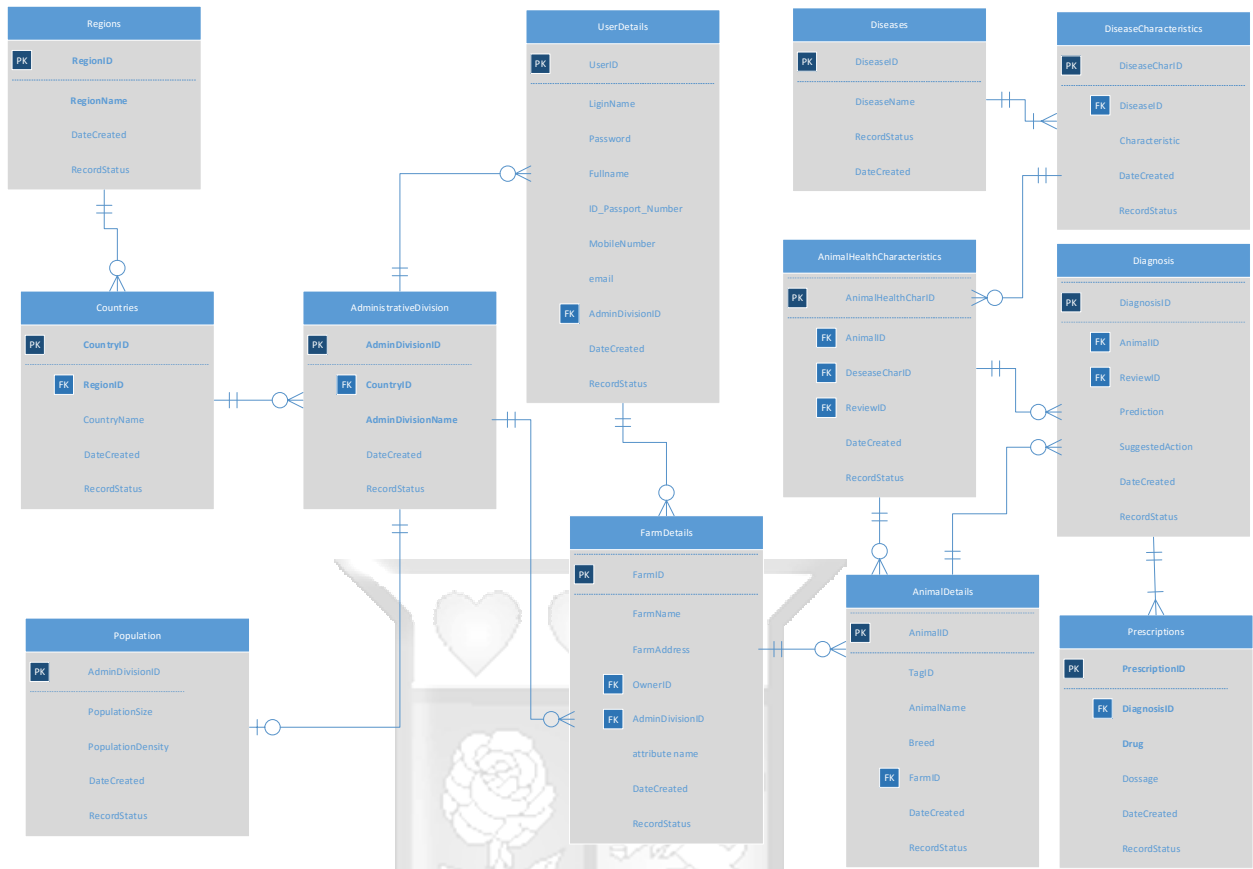


Figure 5.1: Animal health monitoring and disease prediction model Conceptual Data Model

5.2.4 Logical designs

Logical database design was created based upon the conceptual data model using normalization principles. To allow for insert, modify, and delete rows without errors or inconsistencies, a well-structured relation was created that contains a minimum amount of redundancy. Relations in this design are shown in the Table 5.1:

Table 5.1 Animal Health Monitoring And Disease Prediction Model Logical Database
Design: Relations

Regions (<u>RegionID</u> , RegionName, DateCreated, RecordStatus)
Countries (<u>CountryID</u> , <u>RegionID</u> , CountryName, DateCreated, RecordStatus)
Admindivision (<u>AdminDivisionID</u> , <u>CountryID</u> , AdministrativeDivisionsName, DateCreated, RecordStatus)
Population (<u>AdminDivisionID</u> , PopulationSize, PopulationDensity, DateCreated, RecordStatus)
Userdetails (<u>UserID</u> , LoginName, Password, FullName, ID_Passport_Number, MobileNumber, Email, <u>AdminDivisionID</u> , DateCreated, RecordStatus)
Farmdetails (<u>FarmID</u> , FarmName, FarmAddress, <u>UserID</u> , <u>AdminDivisionID</u> , DateCreated, RecordStatus)
Animaldetails (<u>AnimalID</u> , TagID, AnimalName, Breed, FarmID, DateCreated, RecordStatus)
Diseasedetails (<u>DiseaseID</u> , DiseaseName, DateCreated, RecordStatus)
Diseasecharacteristics (<u>DiseaseCharID</u> , <u>DiseaseID</u> , RulebaseID, Characteristic, DateCreated, RecordStatus)
Animalhealthcharacteristics (<u>AnimalHealthCharID</u> , <u>AnimalID</u> , <u>ReviewID</u> , <u>DiseaseCharID</u> , DateCreated, RecordStatus)
Diagnosis (<u>DiagnosisID</u> , <u>AnimalID</u> , <u>ReviewID</u> , Prediction, SuggestedAction, DateCreated, RecordStatus)
Prescription (<u>PrescriptionID</u> , <u>DiagnosisID</u> , Drug, Dosage, DateCreated, RecordStatus)

Further, the Figure 5.2 captures these relations graphically:

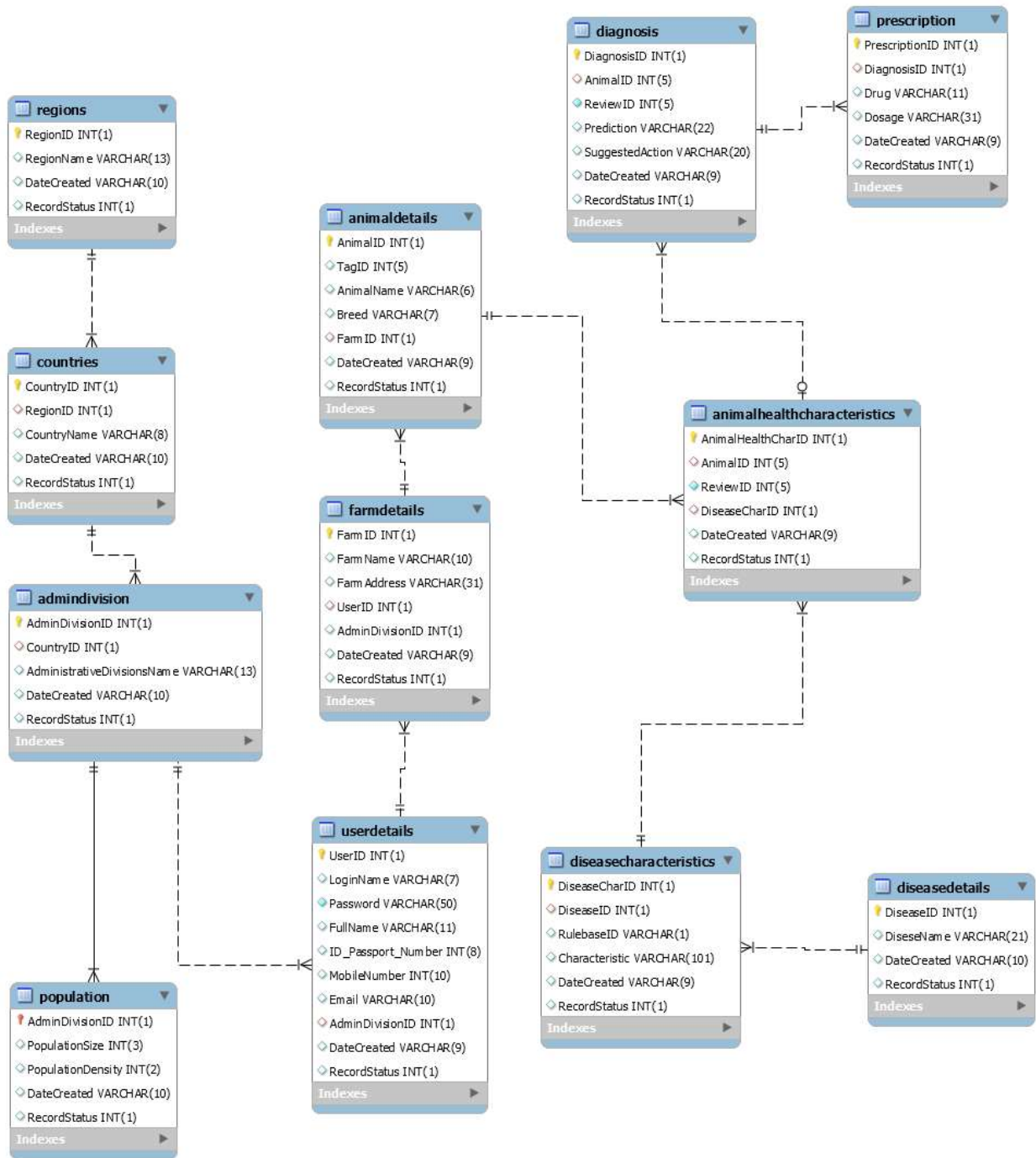


Figure 5.2: Animal health monitoring and disease prediction model Logical Database Design

and internal are easily identified and interactions among the requirements and the actors is well modelled.

Several main use cases were identified as described in the Table 5.2.



Table 5.2 System Use Cases

Use Case	Actor	Description
1. Register Self	All	Register oneself into the system.
2. Login	All	Login to the system
3. Maintain system parameters	System Administrator	Maintain static data and system parameters such as rules and knowledgebase entries for expert system, of disease characteristics and geospatial information
4. Register farm details	Farmer	Register information relating to the farm where animals are reared
5. Register animal	Farmer	Register animals reared in the farm
6. Record behaviour and characteristics	Farmer	Provide answers to a series of questions whose input is used by the system to predict presence of animal disease.
7. Predict/ Diagnose disease	Health officer	Review animal records, behaviour and characteristics and provide diagnosis
8. Produce prescription/ advice	Health officer/Extension Officer	Prescribe drugs and provide advice to the farmer
9. Monitor animal health	Farmer	Provide answers to a series of questions to describe and characterize animal health.
10. Query animal health	Farmer/Health officer/Extension Officer	Perform ad-hoc queries on status of animal health

5.3.2 Sequence Diagram

The sequence diagram in Figure 5.4 models the collaboration of objects in the animal health monitoring and disease prediction model and shows how processes operate with one another based

on a time sequence to perform predictions. The sequence diagram is useful to demonstrate and communicate how the system works by showing how various objects and modules interact with each other.

5.3.2.1 System Administrator Sequence Diagram

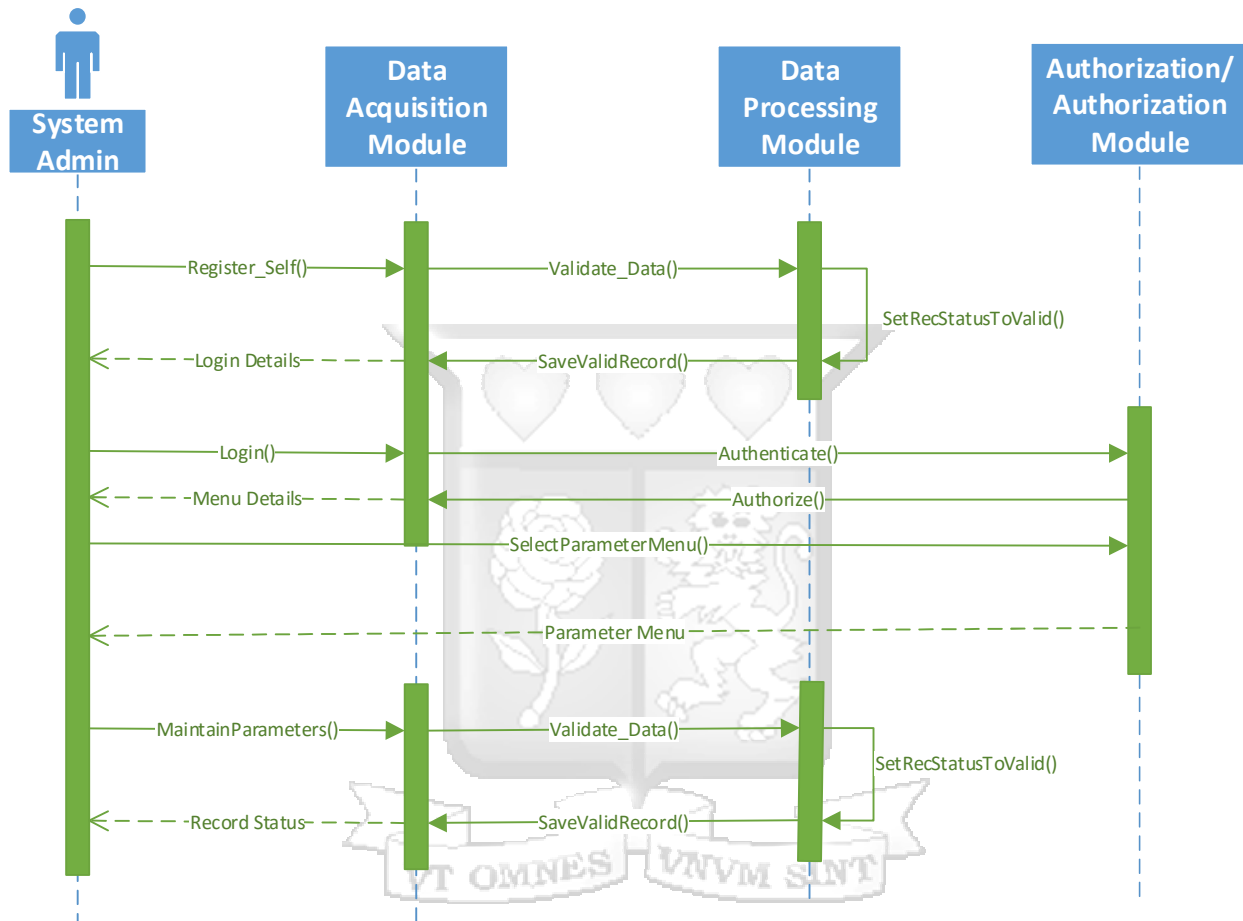


Figure 5.4: Animal health monitoring and disease prediction model sequence diagram for the system administrator

5.3.2.2 Farmer Sequence Diagram

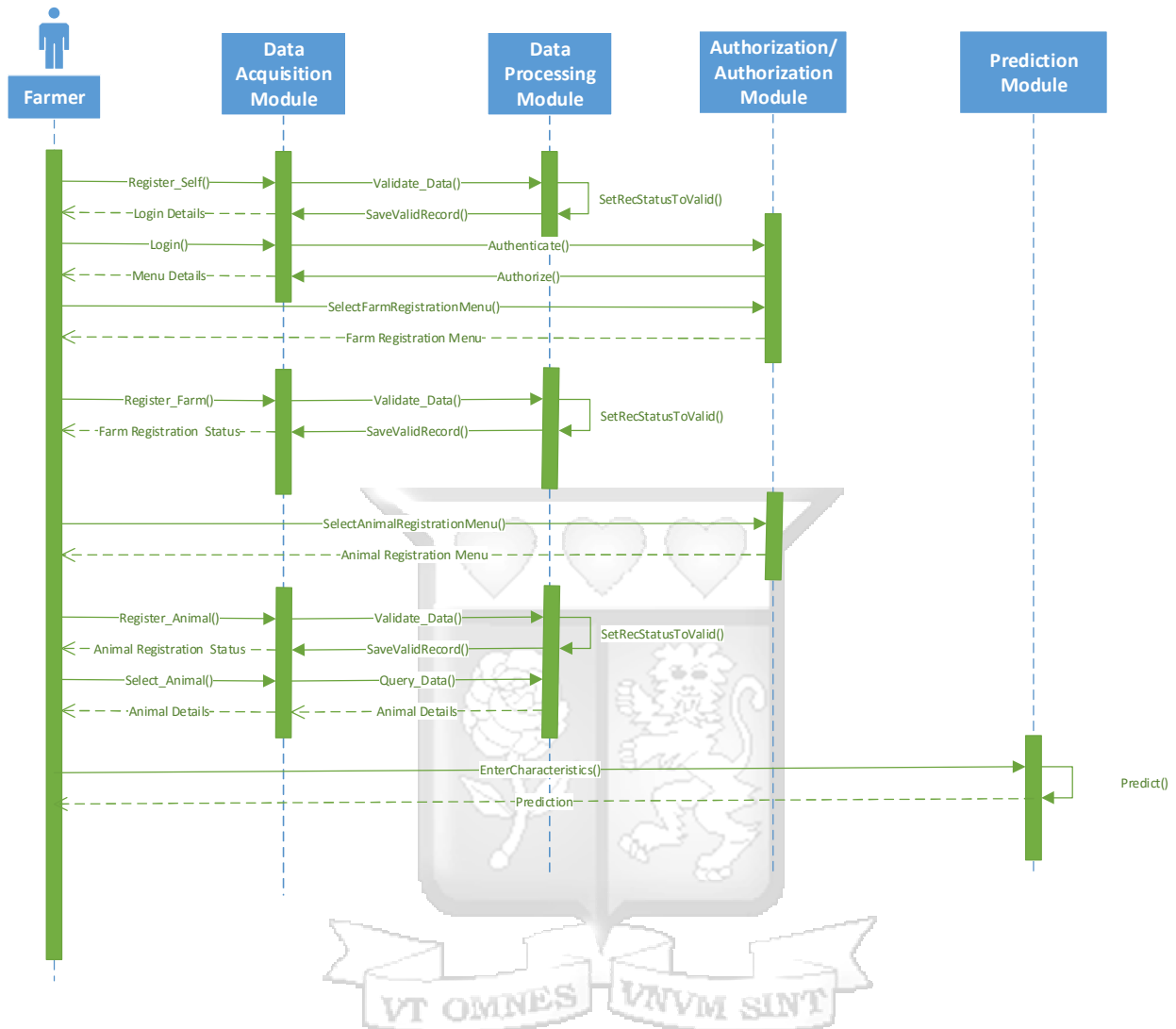


Figure 5.5: Animal health monitoring and disease prediction model sequence diagram for the farmer

5.3.2.3 Health Officer Sequence Diagram

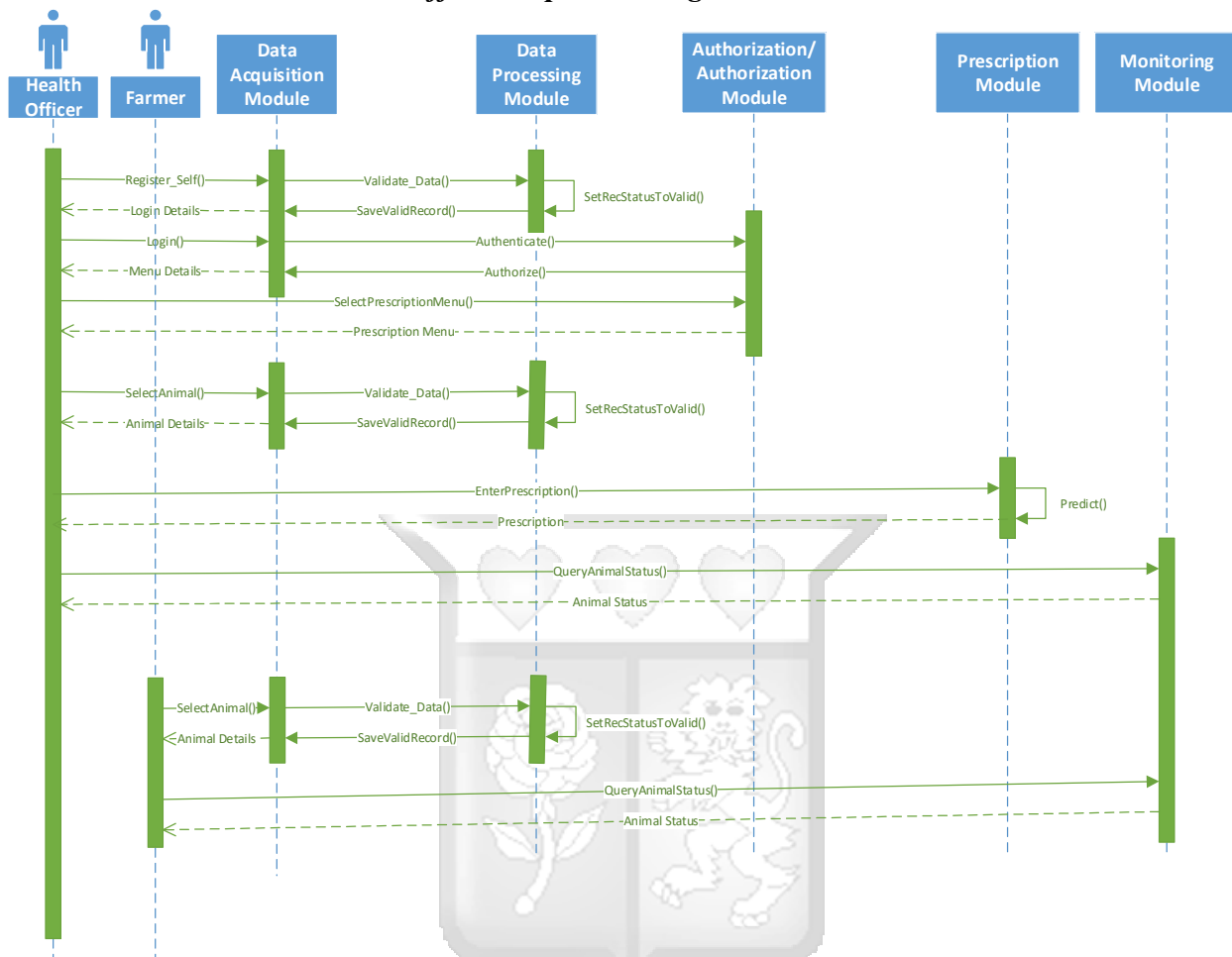


Figure 5.6: Animal health monitoring and disease prediction model sequence diagram for the health officer

The system administrator should have administrative privileges to perform system configurations by providing values to system parameters. At registration, the administrator will be requested to provide a user name and password in addition to others personal and geospatial details. With username and password, the newly created administrator will login to the system and perform several functions including updating system parameters and static maintenances.

For a farmer, the system should allow the farmer to register as a user in the system. At registration, the farmer will be requested to provide a user name and password in addition to others personal and geospatial details. With username and password, a farmer will login to the system

and perform data entry for farm and animal registration. Having registered the farm and the animals, the farmer should access the “record behaviour and characteristics” module, select the animal in question and answer as series of questions regarding the animal health condition, behaviour and its symptoms. Based on the responses, the system should perform preliminary review and provide advice to the farmer. In addition to this, the system should provide relevant details that will aid the farmer’s next course of action. The farmer is also able to update the health status of the animal in the monitoring module. This status can also be interrogated by the farmer or health office as and when required.

For an extension officer, veterinary officer and other stakeholders, the system should allow the stakeholder to register as a user in the system. At registration, the stakeholder will be requested to provide a user name and password in addition to others personal and geospatial details. With username and password, a stakeholder will login to the system and perform several functions including reviewing status of animals, updating details on animal condition as required and perform prescription if needed.

The system should provide management information system (MIS) reports as per the needs of all the stakeholders

5.4 System Architecture

To implement the animal health monitoring and disease prediction model, the research recommended the general architecture shown in the Figure 5.7. The model uses mobile technology and internet to deliver functionality.

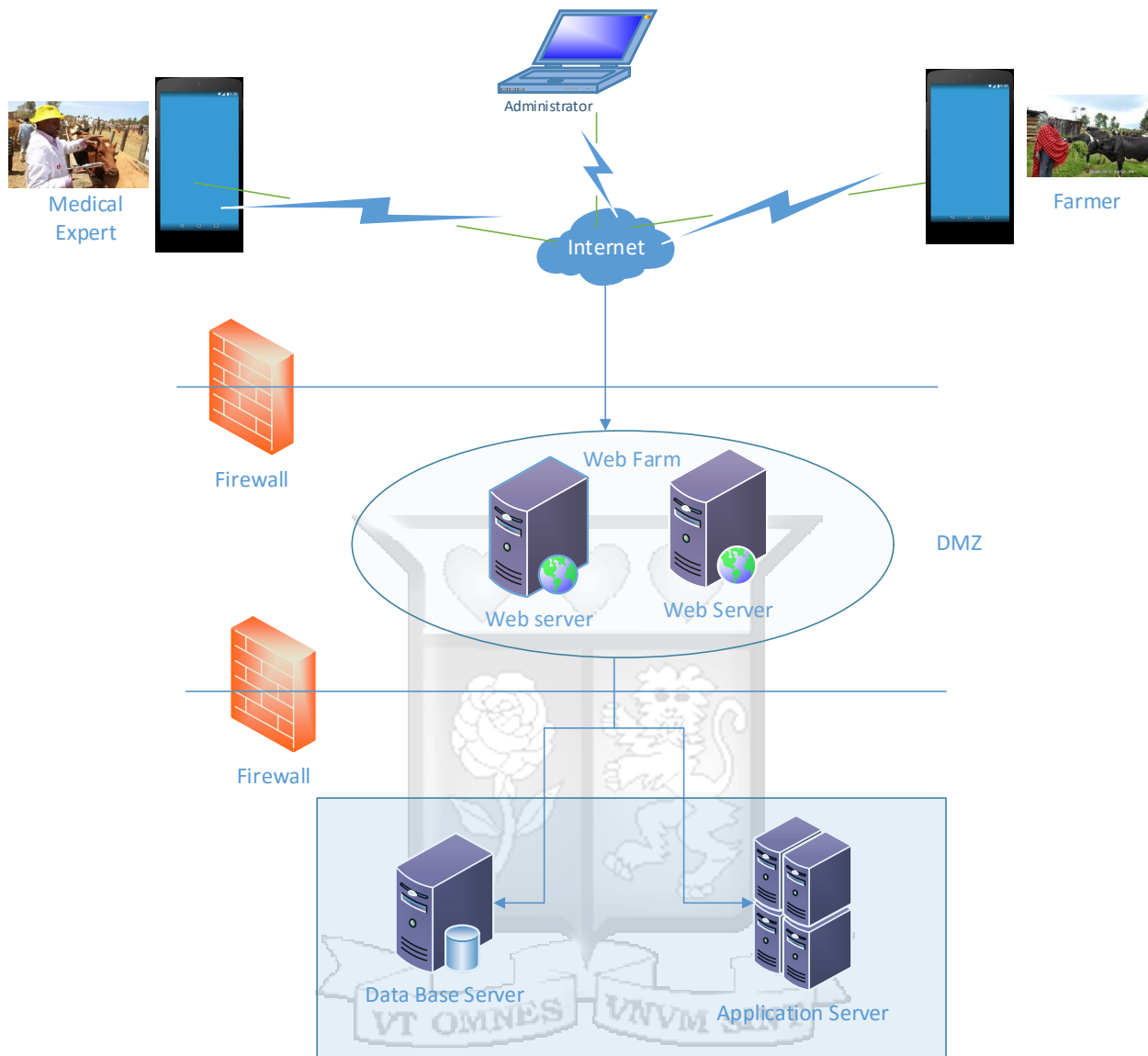


Figure 5.7: General architecture for the animal health monitoring and disease prediction model

Below is a description of the elements contained in the Figure 5.7.

Clients: This is the end-user who makes use of the animal health monitoring and disease prediction model.

Internet: The medium through which the animal health monitoring and disease prediction model is accessed.

Firewalls: Contain security rules to provide protection over the internet. It also does analysis of incoming and outgoing HTTP traffic and protect against application layer attacks aimed at the web servers

DMZ: Demilitarized zone (DMZ) is a host or network segment located in a "neutral zone" between the Internet and private network. It prevents outside users from gaining direct access to an organization's internal network while not exposing a web, email or DNS server directly to the Internet.

Web Farm: This is a group of computers acting as servers and housed together in a single location to provide web hosting services using multiple servers.

Webserver: A server hosting the website.

Database server: Server hosting the application database.

Application server: Server hosting the application

5.5 Domain Registration

A domain name is an easy and memorable name for an internet computer. The domain name leads to a unique Internet Protocol (IP) number which acts as a routing address on the Internet. The domain name system (DNS) translates Internet names into IP numbers which transmit information across the Internet network. A domain, Muriu.me.ke was registered with Kenya Network Information Centre (Kenic) a non-profit organization aimed at managing and operating the .KE.

5.6 Security Design

Security is key in any system implementation. Use of strong passwords, implementation of firewall and firewall rules, use of secure socket layer certificates are some of the considerations that have been put in place to provide adequate security.

Chapter 6. System implementation and Testing

6.1 Overview

Implementation of the animal health monitoring and disease prediction model involved construction of new system and delivery of that system into a production environment where users could access it for day-to-day operations. Construction of the user and system interfaces, application programs and database was done to fulfil the design requirements. A host of tools were used to accomplish this including Java Development Kit (JDK), Eclipse, Android Development Tools (ADT), Android SDK (software development kit), Apache Tomcat, MySQL data base engine, MySQL workbench, ADOdb, Apache web server among others.

Upon successful building and functionality testing, the animal health monitoring and disease prediction model was released for installation. Direct installation was used as this was new tool and no previous version existed in the implementation environment.

6.2 Physical designs

MySQL Relation Database Management System (RDBMS) was used to perform the implementation of the animal health monitoring and disease prediction model database. MySQL is an inexpensive (freeware) RDBMS is easy to use while providing a host of benefits including being secure, powerful and scalable. Its speed and its small size make ideal for Web site and mobile based database solutions.

The Figure 6.1 shows database installation:

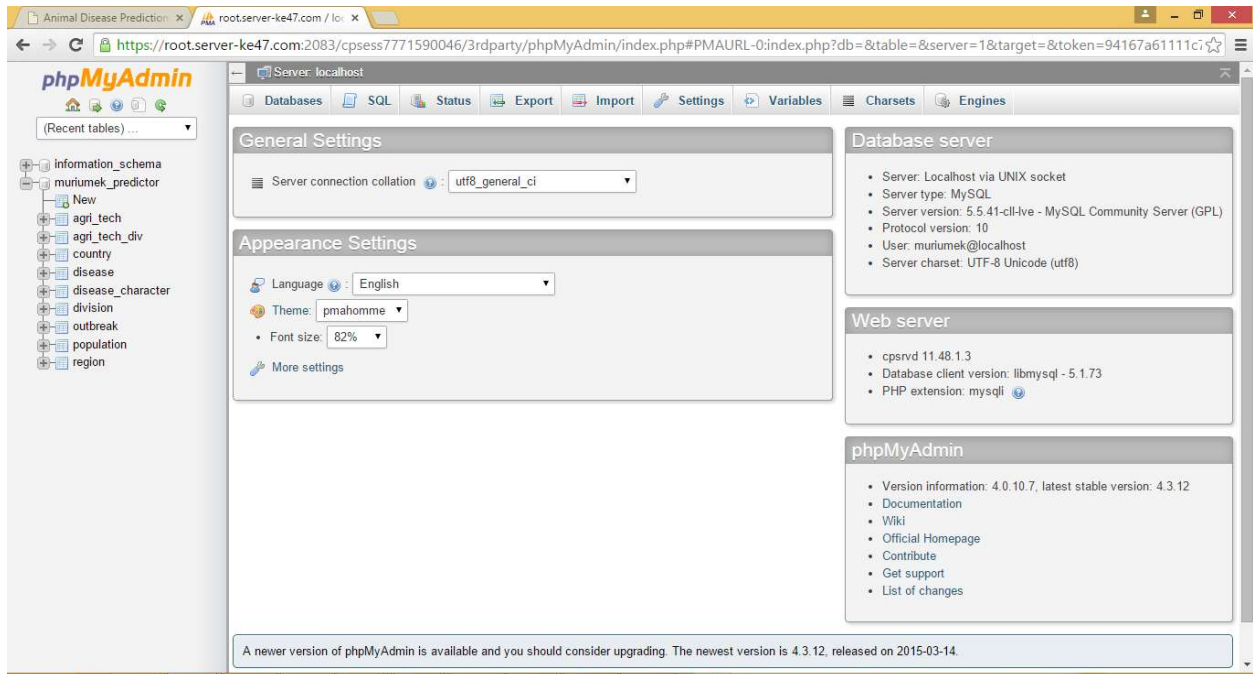


Figure 6.1: Animal health monitoring and disease prediction model Logical Database Design

The Figure 6.2 shows Web server installation:

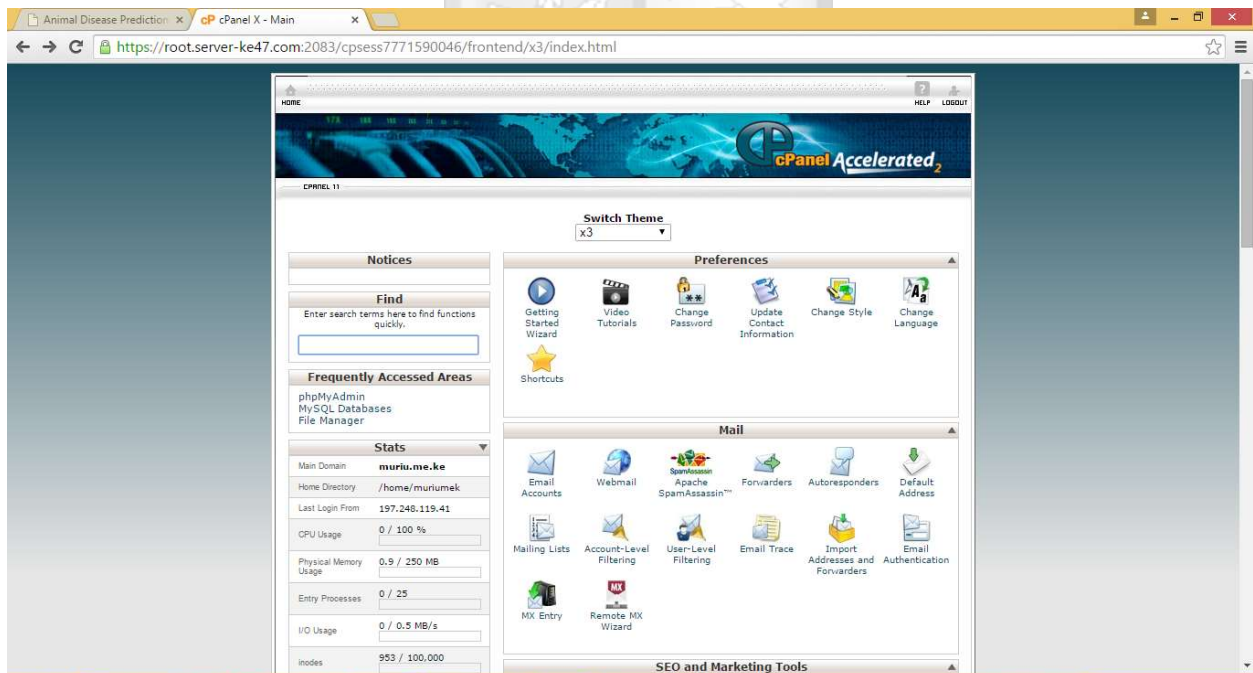


Figure 6.2: Web server installation

6.3 Sample Screen Shots

The Figure 6.2 highlights the animal health monitoring and disease prediction model application on the phone:

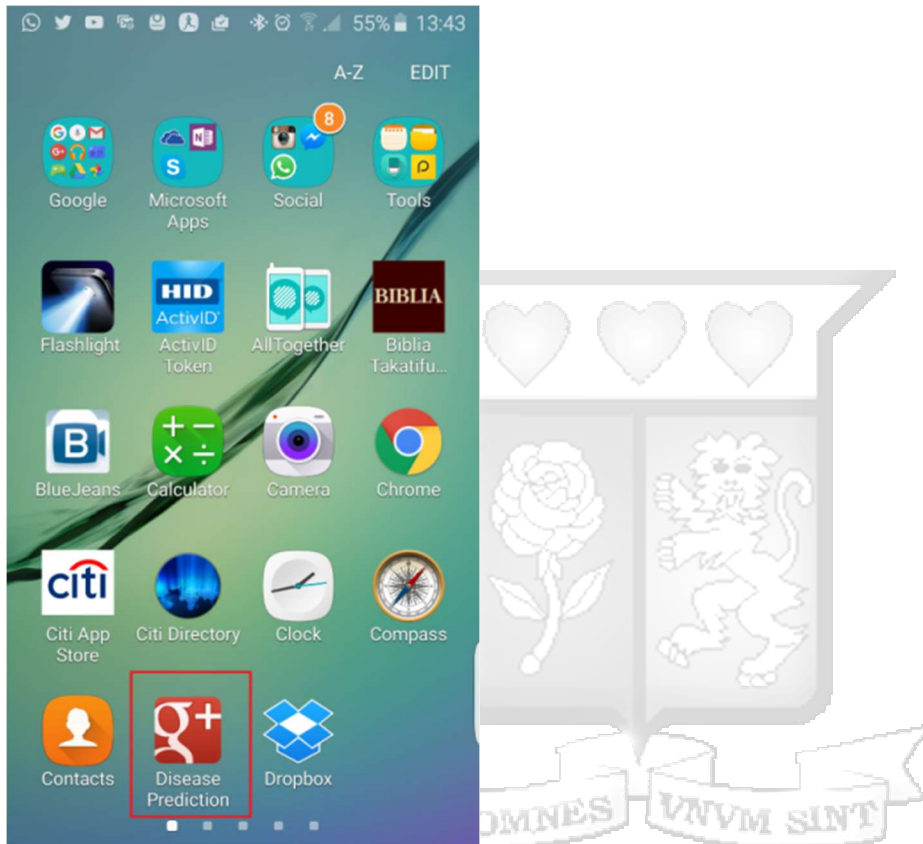
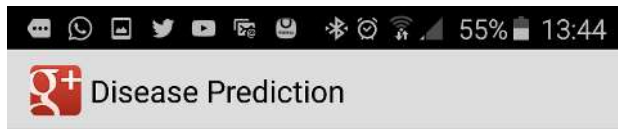


Figure 6.3: Animal health monitoring and disease prediction model application

The Figure 6.4 shows the animal health monitoring and disease prediction model “log in Screen”:



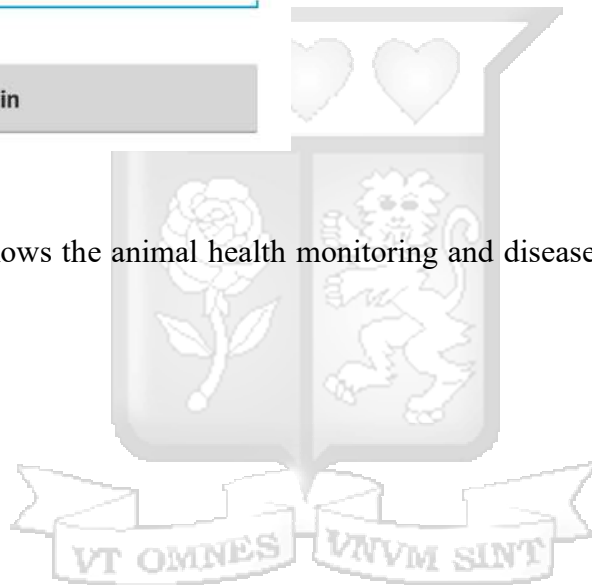
pvkuria

.....

Sign in

Figure 6.4: log in Screen

The Figure 6.5 shows the animal health monitoring and disease prediction model “home Screen”:



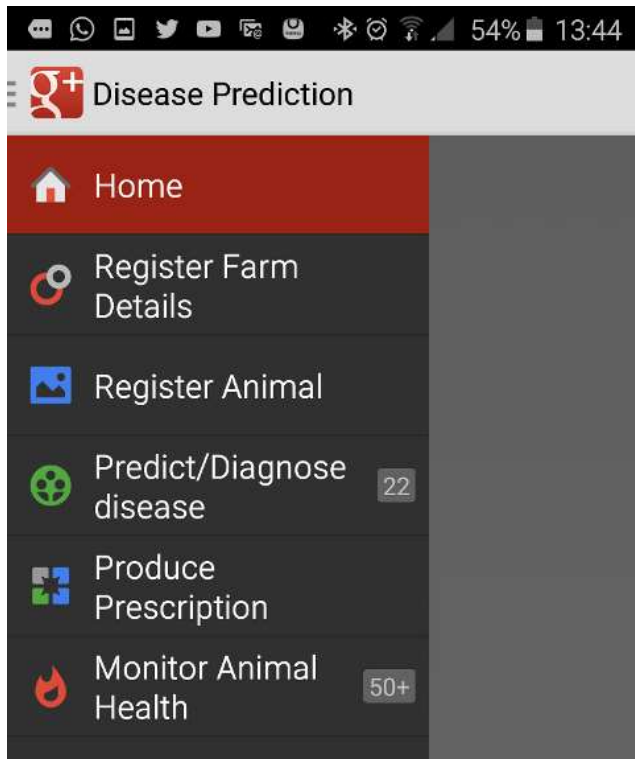


Figure 6.5: Home Screen

The Figure 6.6 shows the animal health monitoring and disease prediction mode “farm registration screen”:

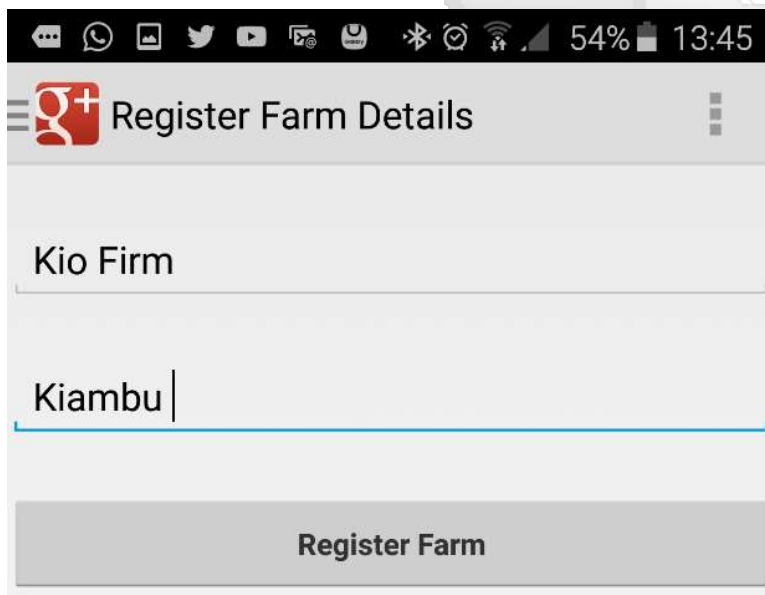


Figure 6.6: farm registration screen

The Figure 6.7 shows the animal health monitoring and disease prediction model “animal registration screen”:

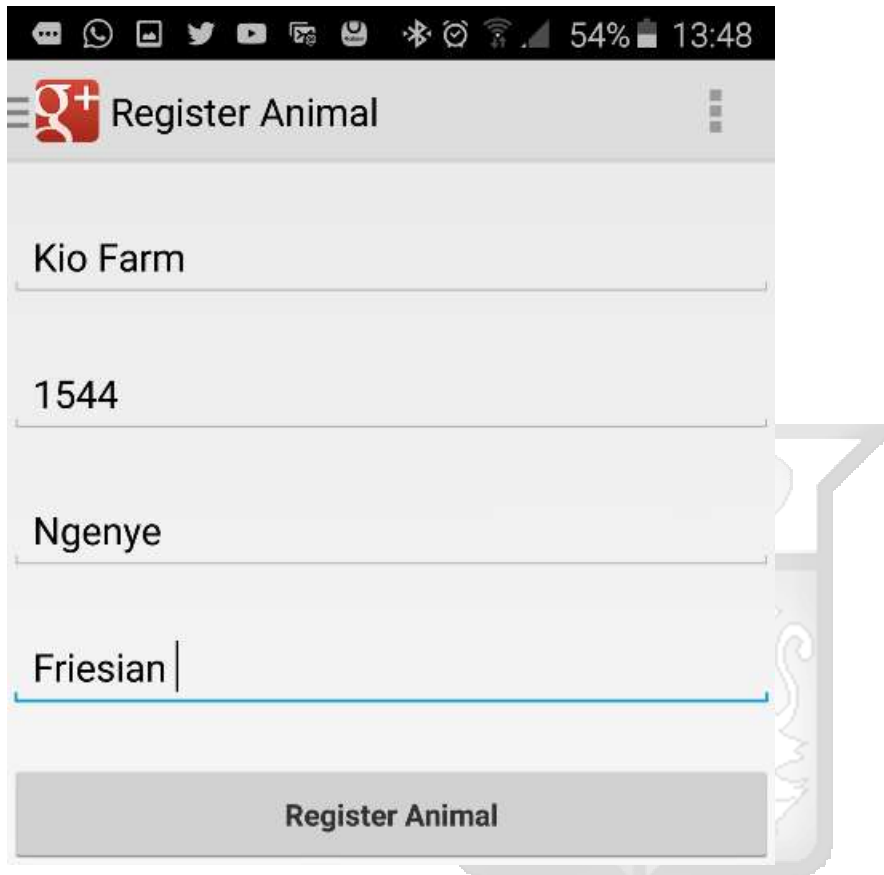


Figure 6.7: Animal registration screen

The Figure 6.8 shows the animal health monitoring and disease prediction model “disease characteristics entry screens”:

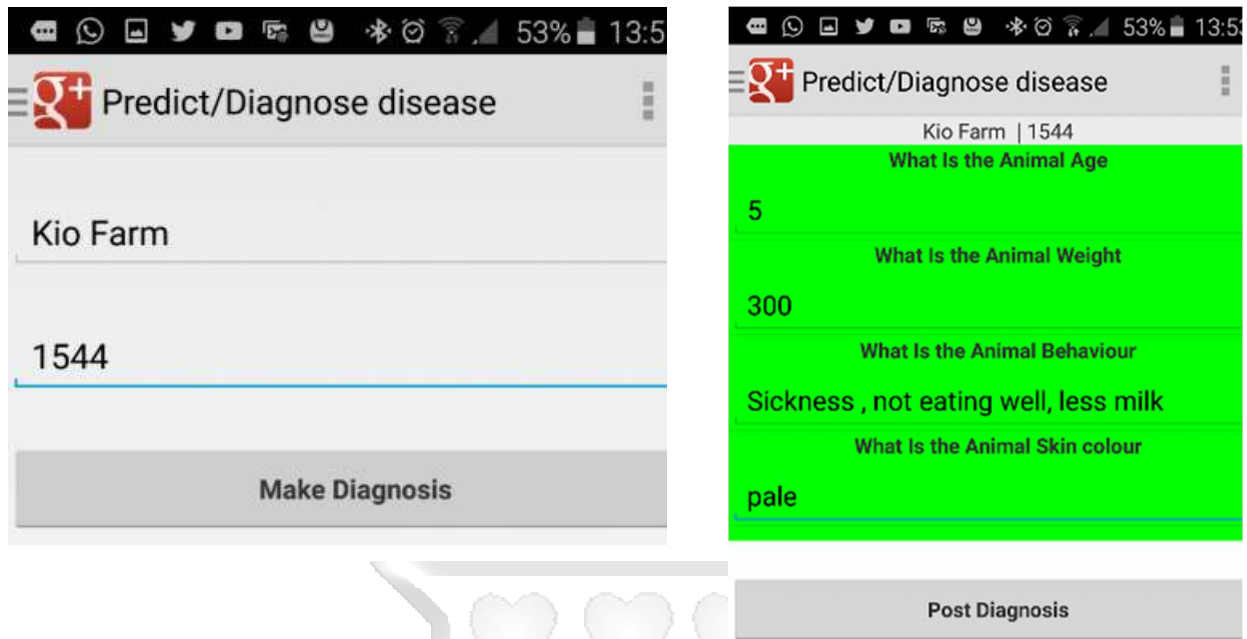


Figure 6.8: Disease Prediction screen

The Figure 6.9 shows the animal health monitoring and disease prediction model “prescription production screen”:

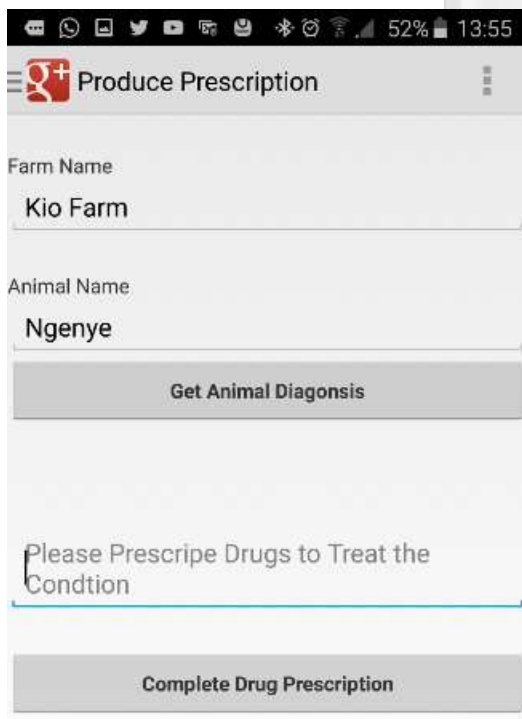


Figure 6.9: Prescription production screen

The Figure 6.10 shows the animal health monitoring and disease prediction model “Animal health monitoring screen”:

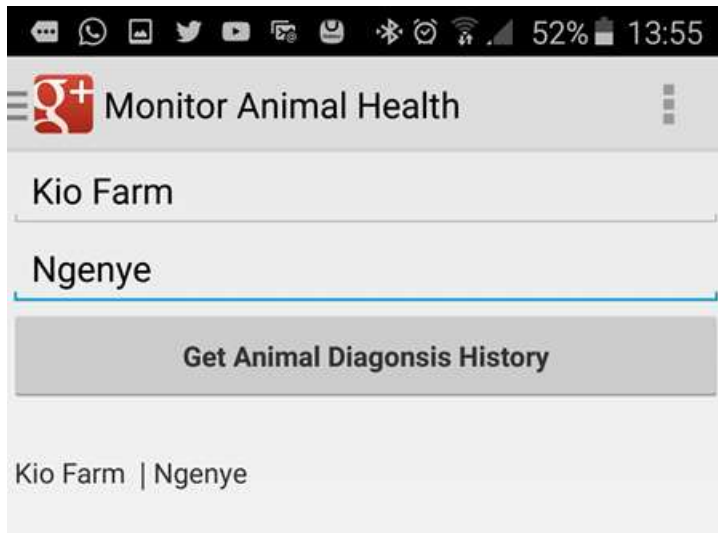


Figure 6.10: Prescription production screen

The Figure 6.11 shows the animal health monitoring and disease prediction model “report on Geospatial Details-Regions”

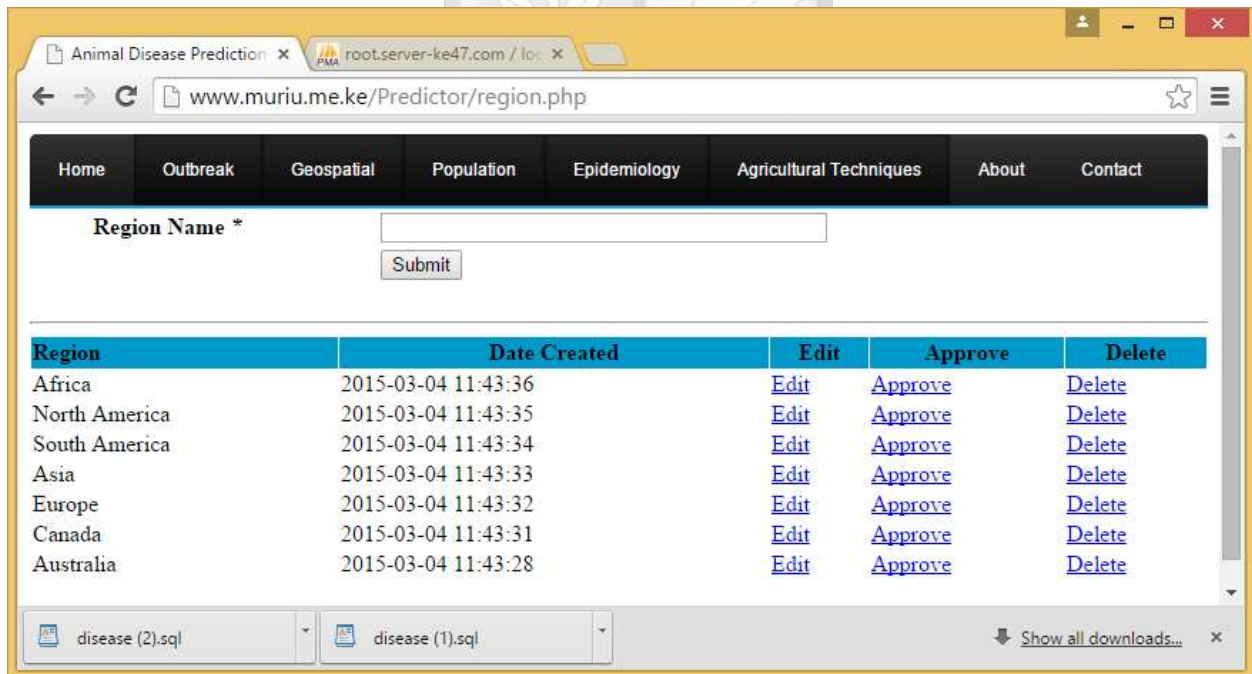


Figure 6.11: Sample Report

6.4 System Validation

To ensure that the model does what it's designed to do, a number of validations have been built in. Users are validated upon login and only registered users with valid credentials are granted access to the model. These users can only access functionality that has been assigned to them. Missing data in fields particularly mandatory once are validated and user prompted to key in the missing elements. To minimize data entry errors, controlled fields such as dropdown selections have been implemented. Upon successful entry and submitting of records, a message such the one in the Figure 6.12 is displayed:

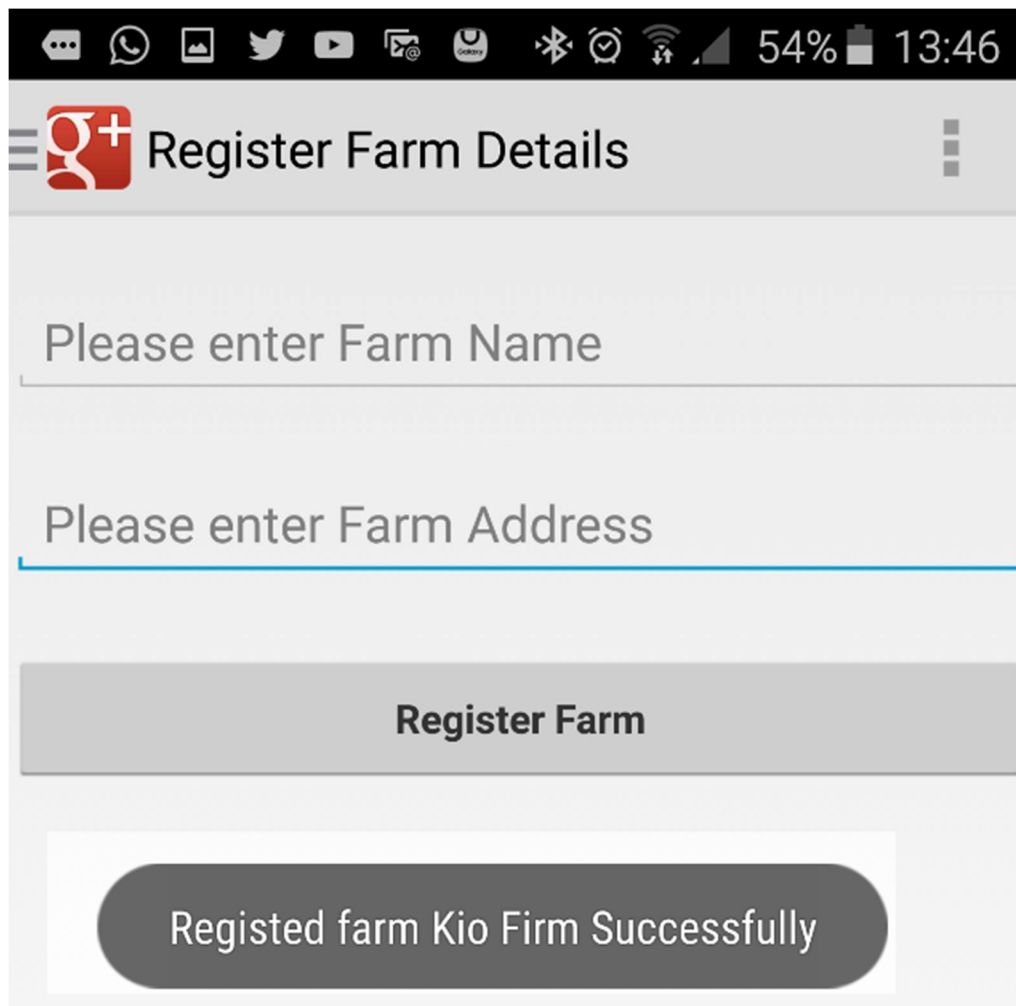


Figure 6.12: System Validation

6.5 System Testing

System testing brings together all of the programs that comprise the system to ensure that the entire system is tested comprehensively (Turban & Volonino, 2011). Emphasis here is laid to the evaluating end-user, functional and business requirements. Before it was put into use, the system went through a validated process. This process was carried out by the designer based on test data. The system was further subjected to a select group of stakeholder to perform various functions as per requirements.

6.6 Test Cases

To ensure the system operates as per end-user, functional and business requirements, several tests were carried out. A sample of the test cases are shown in the table 6.1 below:

Table 6.1 Test Cases

1	Register Self and Login		
1.1	Launch the application from your phone	Application launched successfully	Pass
1.2	Click on the "Register" button	"Register self" activity displayed	Pass
1.3	Submit without entering any details	Error dialogue box	Pass
1.4	Enter username, password, password confirmation and submit	Record saved successfully	Pass
1.5	Login to the system by supplying username and password	Login successfully	Pass
2	Register Farm		
2.1	Select "Register Farm" from the main menu	"Register Farm" activity displayed successfully	Pass
2.2	Submit without entering any details	Error dialogue box	Pass
2.3	Enter farm name, farm address and submit	Record saved successfully	Pass
3	Register Animals		
3.1	Select "Register Animals" from the main menu	"Register Animals" activity displayed successfully	Pass

3.2	Submit without entering any details	Error dialogue box	Pass
3.3	Enter animal tag id, animal name, animal breed and submit	Record saved successfully	Pass
4 Record behavior and characteristics			
4.1	Select "Record behavior and characteristics" from the main menu	Menu accessed successfully	Pass
4.2	Select Animal from the list of recorded animals in a farm	Affected animal selected successfully	Pass
4.3	Submit without entering any details	Error dialogue box	Pass
4.4	Enter Animal temperature, Animal weight, Animal Behavior, Animal Productivity, Any other Comments and submit	Record saved successfully	Pass

5 Predict/ Diagnose disease			
5.1	Access the "Predict/ Diagnose disease" data entry module	Menu accessed successfully	Pass
5.2	Select Animal from the list of recorded animals in a farm	Affected animal selected successfully	Pass
5.3	Submit without entering any details	Error dialogue box	Pass
5.4	Enter Predict/ Diagnose disease and submit	Record saved successfully	Pass

6 Produce prescription/advice			
6.1	Access the "Produce prescription/advice" data entry module	Menu accessed successfully	Pass
6.2	Select Animal from the list of recorded animals in a farm	Affected animal selected successfully	Pass
6.3	Submit without entering any details	Error dialogue box	Pass
6.4	Enter Produce prescription/advice and submit	Record saved successfully	Pass

7 Monitor animal health			
7.1	Access the "Monitor animal health" module	Menu accessed successfully	Pass
7.2	Select Animal from the list of recorded animals in a farm	Affected animal selected successfully	Pass

7.3	Health record and other details of the affected animal are displayed on the screen	Details of the selected animal displayed successfully	Pass
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6.7 System parameters and static Maintenance

Various parameters and static maintenances can be performed. This is to ensure the system remains dynamic and able to adopt to changes that may occur without consulting the developers. Some of these maintenances include “if...then” rules in the knowledge base, disease characteristics in the facts data base, demographic details among others.

6.8 Usability

Of the 29 participants that took part in this exercise, 69 percent were satisfied that the model fulfilled the intended functions of animal health monitoring. 76 percent of the respondents also found the model easy to use. The model was therefore successful in management of farm, farmers and animal records as well as continuous monitoring of animal health.

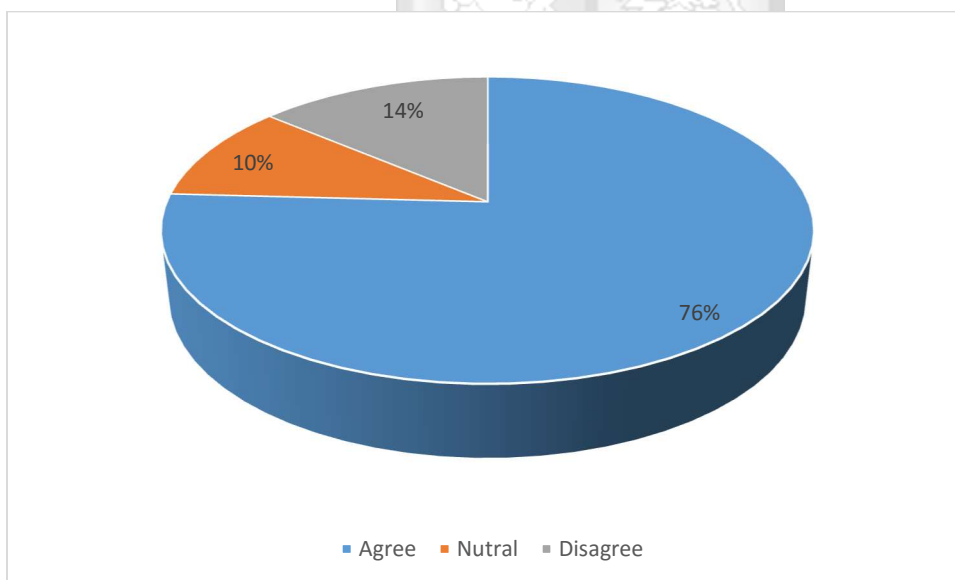


Figure 6.13: System Usability

6.9 Performance and Functionality

90 percent of the respondents rated the model's performance as acceptable in terms of speed of execution.

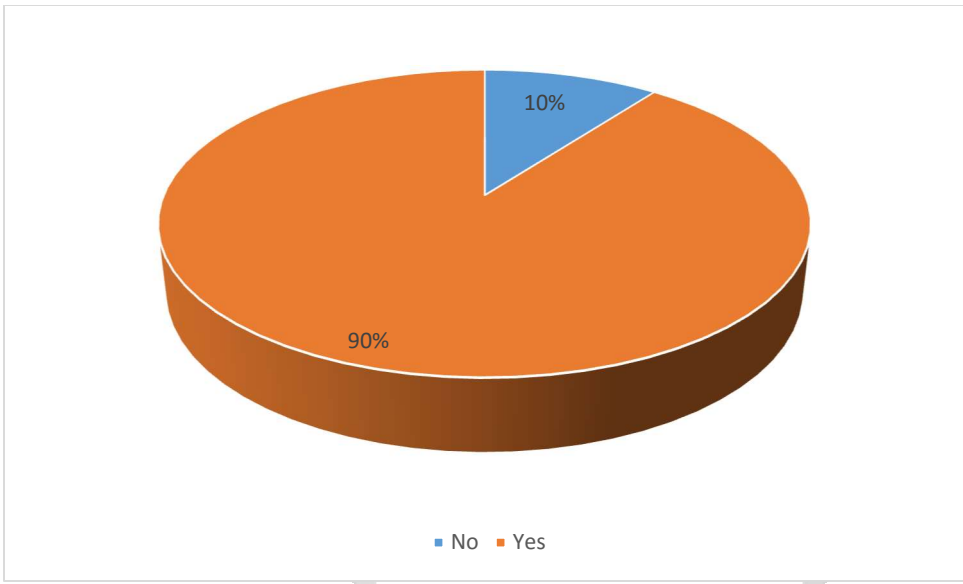


Figure 6.14: Acceptable Performance

6.10 Reliability

Only 10 percent of the respondents encounter failures while operating the model.

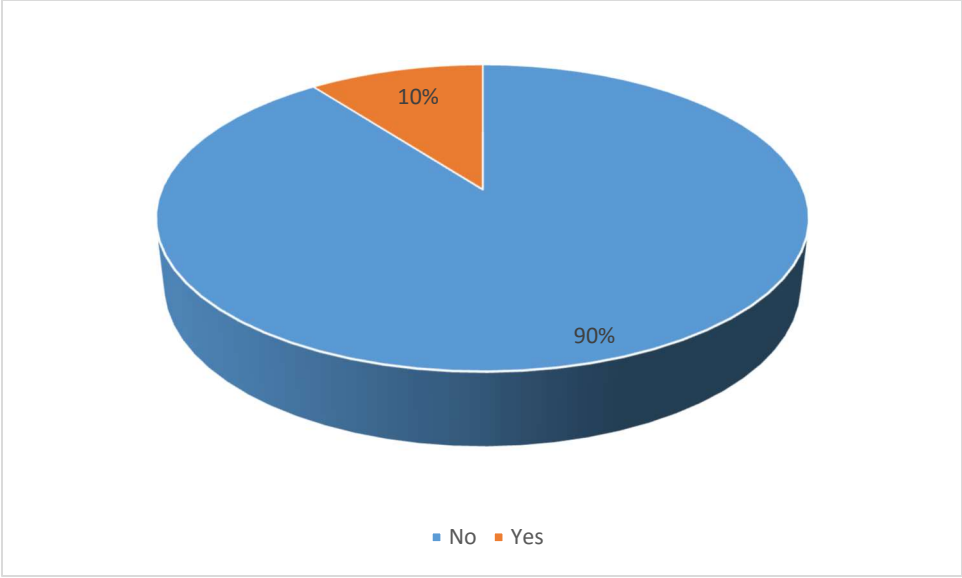


Figure 6.15: Failures encountered



Chapter 7. Conclusion and Recommendations

7.1 Conclusions

Animal disease affect many farmers' livelihoods. Globalization, free trade across nations and the advent of highly contagious disease outbreaks are big contributors to the risk of introduction and spread of disease. These have had tremendous societal and economic implications. Animal health monitoring and disease prediction model was proposed to record farm and animal details, predict occurrence of animal disease and continuous monitoring of animal health. This is to facilitate proactive control measures to reduce the risk posed by animal disease outbreaks.

The project realized an animal health monitoring and disease prediction model based of a rule-based expert system algorithm. The proposed model facilitates capturing of stakeholder details, registration of animal details, characterization and prediction of animal disease and associated prescription via a mobile application or web portal hosted in the internet. The mobile application allows stakeholders to access the system from any location and at any time. The web interface allows access to the model from any web-enabled devices, such as smartphones and portable web enabled devices, from any location with internet presence. Users can register their details and get a user name and password to log into the system.

The system administrator has administrative privileges to perform system related activities such as system maintenances and updating system parameters and static data. A farmer performs farm and animal registration process, uses the disease prediction module to predict diseases and monitors animal health status. The system provides preliminary prediction results and advices the farmer to take necessary action. The system also alerts a veterinary expert whose reviews the animal behaviour and characteristics and performs diagnosis. Extension officers, veterinary officers and other stakeholders can use the system to review status of animals, update animal condition details and perform prescription as required. A number of MIS reports exist to help in decision making.

Accuracy was the focal point of this model to ensure right diagnosis is arrived at and right prescription provided. This is the main reason why a veterinary expert is required to supplement

the prediction details from the system. This is key as it is beneficial to the stakeholders and the animals as well. A farmer is saved the time and costs associated with engaging experts physically. The experts are able to utilize their time more efficiently and effectively as such a system takes away some burden from their schedules. The animal too benefits. Early diagnosis ensure the right actions and measures are taken at the initial stages of the disease. This ensures that the symptoms are arrested early and the recovery is hastened. Most importantly, the model allows for follow up and continuous monitoring of the affected animal's health status. Management information reports help provide relevant information that improves decision making.

The overall objective was to design and implement a secure and accurate model for animal health monitoring and disease prediction. The farmer is able to predict diseases and take necessary action proactively saving time, money and efforts. Consistent with other research, this study tried to resolve the issue of predicting presence of a disease given certain characteristics using rule based expert system algorithm whose results are supplemented by a veterinary expert.

The study found that the model is realizable and can go a long way in elevating both human and animals wellbeing. The government, through the Ministry of Agriculture, Livestock and Fisheries and Ministry of Information, Communication and Technology should take up and implement this initiative.

7.2 Recommendations

- The research project proposed a model to predict animal disease and to monitor animal health. However, there is need for thorough testing and extensive optimization to ensure accuracy and integrity of data.
- A major challenge of prediction using expert systems is that of gathering the rules. Human experts are expensive and are often not likely to sit down and write out a large number of rules as to how they come to their conclusions. Wide consultation of veterinary experts and other relevant parties is required.

- Expert systems also tend to maintain large databases and challenges sometimes do exist using it efficiently. Proper sizing of technical infrastructure would be required to improve efficiency.
- There is also the issue of responsibility for example expert systems performing the work of experts, makes wrong prediction and wrong prescriptions is administered. Government should establish policies to govern operation of such a model.

7.3 Suggestions for Future Research

Further, the model needs more research and development to include other diseases and also to extend the scope to other regions. While the model is accessible through the android phones and other web-enabled mobile devices, there is need to build a mobile agnostic model that can run efficiently on a wide range of mobile devices and platforms such as Windows phones and IOS phones. Instead of running the model in isolation, future developments should ensure integration with other regional and international systems.



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Appendix A: Requirement Gathering Questionnaire

Mobile Based Animal Health Monitoring and Disease Prediction System Questionnaire

The data is needed for academic purposes only and will be treated with strict confidentiality. Personally identifiable information will not be collected and your response will not be traced back to you.

The overall objective of this questionnaire is to aid requirement gathering for the development of a mobile based system to i) capture farm records ii) capture animal disease characteristics; iii) predict occurrence or presence of animal diseases and iv) to monitor animal health to recovery right at the farm.

* Required



Section 1: About you

Please tell me about yourself.

1. **1. How often do you use animal products (for food, clothing, transport, pet, sport etc.)?**

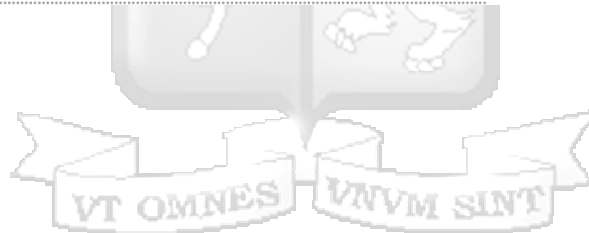
Mark only one oval.

- Multiple Times a Day
- Daily
- Multiple Times a Weekly
- Weekly
- Monthly
- Never

2. **2. What type of farming activity are you mainly engaged in?**

Mark only one oval.

- Livestock farming
- Crop Production
- Mixed farming (Both a Livestock farmer and Crop Production)
- Other:



3. 3. How long have you been farming?

Mark only one oval.

- Less than 1 Year
- 1-5 Years
- 6-10 Years
- 10-20 Years
- More than 20 Years

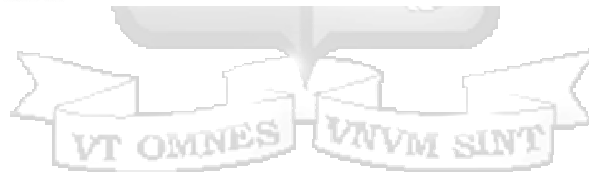
4. 4. What is the main purpose of your farming activity?

Check all that apply.

- Income generation
- Consumption
- Cultural reasons (dowry, prestige etc.)
- Hobby
- Other:

Section 2: About your farm

Please tell me about your farm.



5 5 Where is your farm located?

Mark only one oval.

- Baringo
- Bomet
- Bungoma
- Busia
- Elgeyo-Marakwet
- Embu
- Garissa
- Homa Bay
- Isiolo
- Kajiado
- Kakamega
- Kericho
- Kiambu
- Kilifi
- Kirinyaga
- Kisii
- Kisumu
- Kitui
- Kwale
- Laikipia
- Lamu
- Machakos
- Makueni
- Mandera
- Marsabit
- Meru
- Migori
- Mombasa County
- Murang'a
- Nairobi County
- Nakuru
- Nandi
- Narok
- Nyamira
- Nyandarua



- Nyeri
- Samburu
- Siaya
- Taita-Taveta
- Tana River
- Tharaka-Nithi
- Trans Nzoia
- Turkana
- Uasin Gishu
- Vihiga
- Wajir
- West Pokot

6. Location/Sub-Location:

.....

7. 6. What type of farming practice do you exercise?

Mark only one oval.

- Zero grazing,
- Free-lance,
- Mixed farming
- Other:

8. 7. What is the size of the farm in acres?

Mark only one oval.

- Less than 1 acre
- 1-5 acres
- 6-10 acres
- 11-20 acres
- More than 20 acres

Section 3: Challenges faced in livestock sector

(Adapted from Digital Equipment Corporation, 1986)

9 1 What is/are your main production constraints? *

Check all that apply.

- diseases
- poor fertility
- lack of feed
- low genetic potential
- conflict with local authorities and neighbours
- inadequate veterinary services
- stock theft
- lack of water
- lack of labour
- Other:

10. 2. What is your main source of advice on health management and treatment of the livestock? *

Mark only one oval.

- Private veterinary
- Government veterinary
- Extension officers
- Other:

Section 4: Animal health monitoring and disease prediction

11. 1. How do you relay/communicate characteristics of sick animals to the veterinary officer? *

Mark only one oval.

- Face to face
- Hand written note
- email
- phone call
- SMS
- internet (WhatsApp, Facebook, Twitter)
- Other: 89

12. **2 How does the veterinary officer relay/communicate prescription details for the sick animal? ***

Mark only one oval.

- Face to face
- Hand written
- email
- phone call
- SMS,
- internet (WhatsApp, Facebook, Twitter)
- Other:

13. **3. What type of mobile phone/device do you use? ***

Mark only one oval.

- Ordinary phone
- Smartphone
- Tablet/iPad
- Personal Digital Assistant(PDA)
- Other:

14. **4. How do you mainly access internet with your mobile phone/device?**

Mark only one oval.

- I don't access internet
- Wifi/ Wireless hotspot
- Fibre/Fixed line connection
- GSM (Internet on your mobile phone/ data bundles)
- Other:

Section 5: Data and information requirements

15. **1. What animals are mainly kept in your farm? ***

Mark only one oval per row.

	None (zero)	Less than 5 animals	5 to 10 animals	10-20 animals	Over 20 animal
Cattle	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Chickens	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Goats	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sheep	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pigs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

16 2 How do you mainly identify the animals?

Mark only one oval.

- Ear Notching
- Tagging (Ear, Neck, etc)
- Hot branding/Cold branding
- Electronic Identification (RFID, Transponders)
- Paint Branding
- Tattooing
- Other:

17. 3. What type of records are kept in the farm?

Check all that apply.

- Vaccination records,
- Deworming records,
- dipping and spraying records,
- Disease occurrence records,
- Treatment records
- Production records
- Other:

18. 4. How do you keep records on animals in the farm?

Check all that apply.

- Handwritten records, such as a ledger or notebook
- Off-farm computer record system
- On-farm computer record system
- Mobile system (such as iCow)
- No record keeping system.
- Other:

Section 5 General comments/recommendations

19. Please give any other comments/recommendations if necessary

91

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.....

.....

.....



Appendix C: Usability Questionnaire



Disease Prediction Tool Questionnaire

The data is needed for academic purposes only and will be treated with strict confidentiality. Personally identifiable information will not be collected and your response will not be traced back to you.

The simple application works as outlined below:

1. Access the application from <http://www.muriu.me.ke/Predictor/>
2. Select "Outbreak" menu then click on "Predict Disease Outbreak"
3. Select Region, Country and administrative division
4. Enter current Year and Month
5. Answer the series of questions and click "Predict" button
6. System will display prediction results and corresponding prescription.

The below diagram also show how the application works:

<http://www.muriu.me.ke/Predictor/Docs/SequenceDiagram.jpg>

* Required

Section 1: Introduction

How often do you use animal products (for food, clothing, transport, pet, sport etc)?

- Multiple Times a Day
- Daily
- Multiple Times a Weekly
- Weekly
- Monthly
- Never

Do you currently own a pet/domesticated animal?

- Yes

- No
- No, but I intend to do so in future

Section 2: Application Usability Survey

(Adapted from Digital Equipment Corporation, 1986)

1. I think that I would like to use this system frequently *

1 2 3 4 5

Strongly Disagree Strongly Agree

2. I found the application unnecessarily complex *

1 2 3 4 5

Strongly Disagree Strongly Agree

3. I thought the application was easy to use *

1 2 3 4 5

Strongly disagree Strongly agree

4. I think that I would need the support of a technical person to be able to use this application *

1 2 3 4 5

Strongly disagree Strongly agree

5. I found the various functions in this application were well integrated *

1 2 3 4 5

Strongly disagree Strongly agree

6. I thought there was too much inconsistency in this application *

1 2 3 4 5

Strongly disagree Strongly agree

7. I would imagine that most people would learn to use this application very quickly *

1 2 3 4 5

Strongly disagree Strongly agree

8. I found the application very cumbersome to use *

1 2 3 4 5

Strongly disagree Strongly agree

9. I felt very confident using the application *

1 2 3 4 5

Strongly disagree Strongly agree

10. I needed to learn new concepts before I could use this application *

1 2 3 4 5

Strongly disagree Strongly agree

Section 3: Application Performance and Functionality Survey

All of the functions I expected to find in the menus were present *

Yes

No

Does the application fulfill the intended function of predicting the occurrence of an animal disease? *

Yes

No

Is the application's performance acceptable in terms of speed of execution? *

- Yes
- No

Section 4: Application Reliability Survey

Did you encounter any failures while operating the disease prediction tool. *

- Yes
- No

Section 5 General comments/recommendations

Please give any other comments/recommendations if necessary

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Appendix D: Turnitin Report

Turnitin Originality Report

Thesis by Peter Muriu



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