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A Model for the Design, Development and Implementation of mAgriculture Applications

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DECLARATION

I, **Amos Njihia Gichamba**, do hereby declare that this PhD research thesis is entirely my own work and where there is work or contributions of other individuals, it has been dully acknowledged. To the best of my knowledge, this PhD research thesis has not been carried out before or previously presented to any other education institution or forum.

Signature: .... Date: ....

Amos Njihia Gichamba

I, **Prof. Peter Waiganjo Wagacha**, do hereby certify that this PhD research thesis has been presented for consideration for the admission to the degree of Doctor of Philosophy in Information Systems with my approval as the University of Nairobi Supervisor.

Signature: .... Date: ....

Prof. Peter Waiganjo Wagacha

I, **Dr. Daniel Orwa Ochieng**, do hereby certify that this PhD research thesis has been presented for consideration for the admission to the degree of Doctor of Philosophy in Information Systems with my approval as the University of Nairobi Supervisor.

Signature: .... Date: ....

Dr. Daniel Orwa Ochieng

DEDICATION

To my dear wife Carolyne

Thank you for enduring the cold nights, the missed treasured moments, and for your patience the times my PhD studies took me away from you. Your understanding and support is second to none, I thank God for you

To my sons Aaron and Joshua

Sorry for the times daddy could not play with you, fix your toys or cheer you up

To you my dear family, I dedicate this work

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ABSTRACT

Access to technology and usage know-how among the general population in developing countries has created a breeding ground for ICT for development innovations, which target key areas of economic and social impact such as agriculture, education, health and finance. The importance of agriculture as a key economic activity in Kenya and other developing countries has resulted to the provision of agricultural services through the mobile phone. These mAgriculture initiatives have been facilitated by the high mobile penetration in Kenya and other developing countries, and the appreciation of a mobile device as a potent force for economic development. However, among these innovations, only 16% reach widespread adoption. The low widespread adoption and long term usage of these technologies has been attributed to among other factors poor design, development and implementation strategies. Consequently, it has been of great importance to identify the design, development and implementation factors that result to wider acceptance, long term usage and clear impact of mAgriculture innovations among communities in developing countries.

The aim of this research was to inform mobile application developers, researchers and other practitioners in the mAgriculture domain, in the design, development and implementation of mAgriculture applications. The research commenced with a pre-study activity, whose major aim was to establish the penetration of mobile technology among different groups of farmers, and the exposure of mAgriculture technologies among farmers and challenges in their usage. This was done hand in hand with an in-depth study of related research, an exploration of ICT innovations in agriculture and studies that formed the theoretical grounding of the study such as technology adoption models, software engineering design principles and user-centred design principles. This led to the derivation of a conceptual model for the design, development and implementation of mAgriculture applications.

To validate the model, the researchers developed an mAgriculture prototype with a group of farmers, who were involved in the design, development and implementation stages. An iterative phase of design and development resulted into *DigitalFarm*, an mAgriculture system for agricultural extension via the mobile platform. The model validation process consisted of Pre-Prototyping, Prototyping, Post-Prototype stage 1 and Post-Prototype stage 2 phases. In research process, quantitative and qualitative was collected data using questionnaires, focus group discussions, observations and monitoring of system logs. Partial Least Squares Structural Equation Modelling was used to analyse the data in the various phases of cumulative measurement towards the validation of the model. The derived outcome revealed key factors that should be considered in the design, development and implementation of mAgriculture applications namely Trust, Effort Expectancy, Hyperlocalization, Feedback and Price Value. Contrary to previous research, Perceived Usefulness was found not to be highly significance towards technology adoption among rural farmers. This is due to other factors that strongly determine the usage of a technology more than the perceived usefulness of the technology such as cultural factors. The modelling process demonstrated that in Post-Prototype stage 1, 60.7% of the variance in *Initial Acceptance and Usage of Technology* and 85.6% of the variance in *Continuous Usage of Technology* were explained by the model respectively. During Post-Prototype stage 2, the modelling process established that 66.2% of the variance in *Initial Acceptance and Usage of Technology* and 84.9% of the variance in *Continuous Usage of Technology* was explained by the model respectively. The modelling process thus demonstrated that adherence to the identified constructs of design, development and implementation of mAgriculture applications lead to initial acceptance and usage of an mAgriculture application and eventual long term continuous usage.

The research demonstrated a process of model creation and validation using mixed methods, among a rural farming community. The derived model of design, development and implementation of mAgriculture applications identified the determinants of initial acceptance and usage of a technology, as well as the continuous usage. In addition, the research demonstrated a practical process that provided actionable guidelines for successful design, development and implementation of mAgriculture applications in developing countries. Moreover, the theoretical, methodological and technical guidelines demonstrated in this study provide a foundation towards the design, development and implementation of mobile-based solutions in other areas of ICT for development beyond agriculture.

Keywords: mAgriculture, PLS-SEM modelling, reflective construct, reflective model, Hyperlocalization, Post-Prototyping.

LIST OF ABBREVIATIONS

ACP – Asia, Caribbean and Pacific

AVE – Average Variance Extracted

**CA - ** Communications Authority of Kenya

FAO - Food and Agriculture Organization of the United Nations

FGD – Focus Group Discussion

GDP – Gross Domestic Product

GoK – Government of Kenya

GPS – Global Positioning System

GSMA – Global System for Mobile Communications Association

HCI – Human Computer Interaction

HTMT - Heterotrait-Monotrait ratio of correlations

ICT – Information Communication Technology

ICT4Ag – Information Communication Technology for Agriculture

ICT4D – Information Communication Technology for Development

IFAD – International Fund for Agriculture Development

IoT – Internet of Things

ISP – Internet Service Provider

IVR – Interactive Voice Response

KIPPRA – Kenya Institute for Public Policy Research and Analysis

KNBS - Kenya National Bureau of Statistics

MoALF – Ministry of Agriculture Livestock and Fisheries

M4D – Mobile for Development

NFC – Near Field Communication

NGO – Non-Governmental Organization

PDA – Personal Digital Assistant

PLS – Partial Least Squares

PLS-SEM – Partial Least Squares Structural Equation Modelling

RFID – Radio Frequency Identification

SACCO – Savings and Credit Co-operative

SIM – Subscriber Identity Module

SMS – Short Message Service

SPSS – Statistical Package for Social Sciences

UCD – User Centred Design

USAID – United States Agency for International Development

USSD – Unstructured Supplementary Service Data

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DEFINITION OF TERMS

Best practice: The exercise of applying the strategies that are known to work best in a particular domain, while efficiently achieving the best results.

Developing Country: A country that is seeking to become economically and socially advanced.

ICT4D: Information Communication Technologies for Development – the usage of ICT as a tool to enhance development, mostly in developing economies.

ICT4Ag: Information Communication Technologies for Agriculture – the application of ICT in agriculture.

Implementation: The process of installation, configuration, testing, running initial tests and training users on a new software product before commencement of use in its host and operational environment.

Literacy Level: The level of education among individuals or members of a community, characterized by their level of education and the ability to read, write and communicate in the designated official languages of that community or nation.

mAgriculture: The use of mobile phones to provide information and services in agriculture.

M4D: Mobile for Development – the application of mobile-based solutions as a tool to enhance development, mostly in developing economies.

Prototype: A preliminary model of a software product, from which other forms are built upon

Prototyping: The process of creating, making minimal deployments and testing a software prototype.

Smallholder farmer: A farmer whose production is carried out on farms averaging 0.2 – 3 hectares.

Technology Usage: The useful application of a technology by individuals or a group of people, including the related experiences and processes.

UCD: User Centred Design – A practice in information systems design that focuses on the target users throughout the stages of the development of a technology product.

CHAPTER 1: INTRODUCTION

1.1 Background

Over the years, the agriculture sector has remained as the backbone of the Kenyan economy, employing over 70 per cent of the population and accounting for about 65 per cent of the country's export earnings (International Fund for Aagricultural Development [IFAD] 2015). In Kenya, agriculture contributes 25 per cent of the GDP (Arndt, McKay & Tarp, 2016). In 2010, the government of Kenya went further to develop the Agriculture Sector Development Strategy in order to position the agricultural sector as the key driver for delivering the 10 per cent annual economic growth rate envisaged under the economic pillar of vision 2030 (Government of Kenya [GoK] 2010). Livestock farming is one of the major agriculture sub-sectors in Kenya, and it contributes 42 per cent to the agricultural GDP and about 10 per cent to the country's overall GDP (Kenya Institute for Public Policy Research and Analysis [KIPPRA] 2013). Dairy farming is one of the top sectors of agriculture in Kenya. Dairy farming is ranked as one of the top agriculture sub-sector in Kenya, recording sales of over KSh.20.7 billion in 2015 (Kenya National Bureau of Statistics [KNBS] 2016). Figure 1.1 shows the trends in national GDP and agriculture GDP over the past few years.

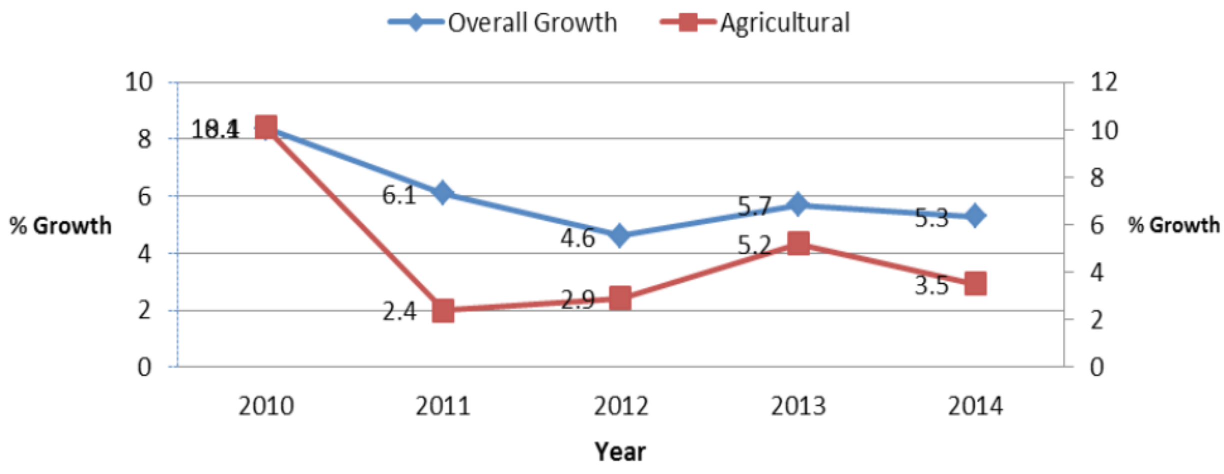


Figure 1.1: Trends in National GDP and Agriculture GDP in Kenya between 2010 and 2014 (Ministry of Agriculture Livestock and Fisheries [MoALF] 2016)

On the other hand, mobile technology penetration has continued to escalate in Kenya. At the end of September 2016, Kenya had 38.5 million mobile subscribers (Communications Authority of Kenya [CA] 2017), while during the previous quarter ending June 2016, the mobile subscribers stood at a total of 39.7 million (CA 2016). This translates to 87.3 per cent mobile penetration among the country's population (CA 2017), which is relatively high for a developing nation within ACP countries. As shown in Figure 1.2, the growth in mobile penetration currently stands at 87.3%. If the trend continues as it has been in the past few years, mobile penetration in Kenya will continue rising and hit the 100 per cent penetration mark in a few years' time.

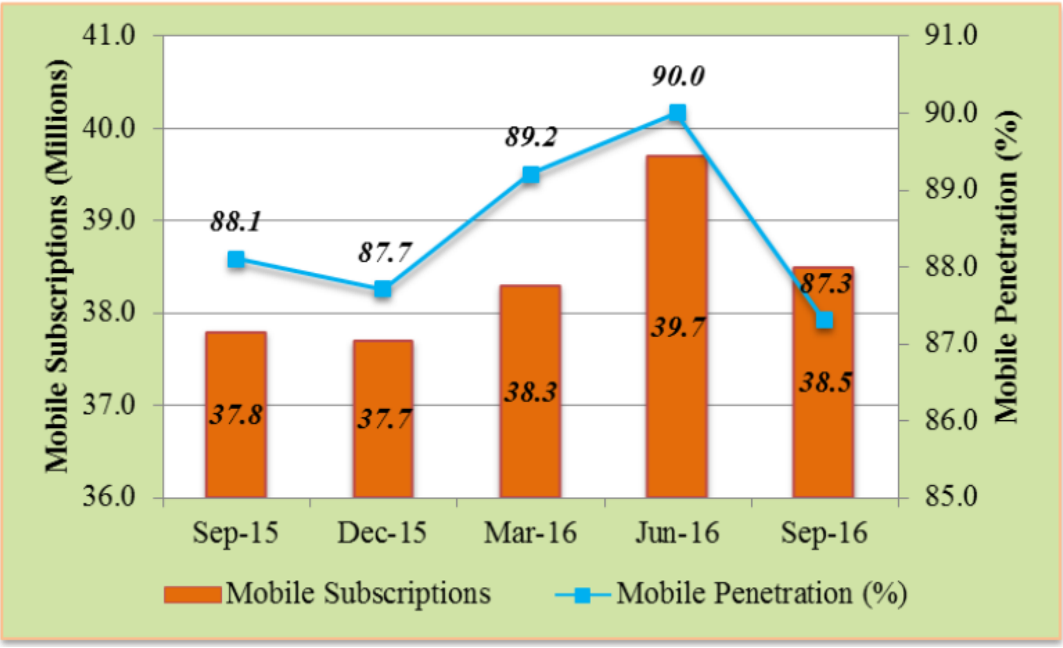


Figure 1.2: Growth in mobile subscriptions reported in the last quarter of 2016 (CA 2017)

With a strong agricultural system and a high mobile penetration, the mobile platform has a great potential to transform agribusiness processes in Kenya. Besides an efficient communication channel for stakeholders in agriculture, the automation of manual processes can be done on the mobile platform. This is especially based on the fact that most stakeholders would not need to re-invest in technological devices or machinery, given that they own mobile phones and the required infrastructure already exists to transform sector such as agriculture using mobile-based systems. The potential of a mobile phone has made it become a delivery platform (Aker & Mbiti 2010) and its rapid uptake perhaps the most successful economic and social development story of recent times (African Development Bank 2013).

The potential of the mobile phone being a catalyst to economic revolution cannot be underestimated, with *The Economis* (29 May 2008) stating thats it has become a potent force for economic development with a great possibility to facilitate financial, agricultural, health and educational services (Aker & Mbiti 2010).

According to GoK (2010), the key challenges facing the agricultural sector in Kenya are transformation of agriculture from subsistence farming to commercial farming and improved agribusiness, access to markets, efficient use of inputs and agricultural credit. Specifically, challenges facing the dairy sector in Kenya are disease, poor animal nutrition, reduced effectiveness of extension services, low absorption of useful modern technology, high cost of key inputs e.g. drugs, limited capital and access to affordable credit, inadequate disaster preparedness and response, insufficient water storage infrastructure, inadequate markets and marketing infrastructure (GoK 2010). Other challenges in the dairy include political interference, injustices in land rights, adverse changes in climate, land degradation and poor livestock breeding (Tully 2014). Additionally, the livestock industry has a high degree of vertical links with up-stream and down-stream industries, and therefore any shock in the industry will affect the supply chain (GoK 2010).

The potential of the mobile phone in agriculture gave birth to mAgriculture, which is the use of mobile phones to provide information and services in agriculture. A number of innovative solutions locally and outside Kenya have been developed to improve dairy farming and attempt to deal with some of the discussed challenges. FAO has partnered with the Royal Veterinary College and Vetaid, a local NGO to deploy a mobile based system called EpiCollect that helps track animal vaccination, reporting disease outbreaks and delivery of veterinary treatments (Food and Agriculture Organization [FAO] 2013). Another mobile-based system that targets the dairy sector is the iCow platform. The main purpose of the platform is to keep the small-scale dairy farmers up to speed with how to properly supply optimum health care for their livestock through information, access to veterinary doctors and Artificial Insemination agents, optimum animal nutrition among other features (Nsehe 2011).

These are just a few of the array of mAgriculture solutions implemented to target the dairy sector within Kenya. Unfortunately, most of the mAgriculture innovations have not achieved their anticipated impact among farmers. The challenges of these innovations have been attributed to poor design, development and implementation strategies. Poor design and development approaches have contributed to mAgriculture innovations that have less impact to the farmers (World Bank 2017). In addition, challenges at the implementation stage have highly affected the penetration and sustainability of mAgriculture applications (World Bank 2017; Battini et al. 2009). These challenges are experienced due to failures done at the design, development and implementation stages such as poor collection of user requirements and minimal involvement of the user, which is as a critical step towards successful design and development of mAgriculture applications (Gichamba, Waiganjo & Orwa, 2015). Moreover, guidance on proper design and deployment of ICT interventions in agriculture is not always accessible (InfoDev 2011). Therefore, it is critical for researchers to document the design, development and adoption models that can be applied in mAgriculture. The existing documented models are not specific to mAgriculture innovations for developing countries and may not be directly applicable in promoting best practices in the design and development of mAgriculture applications in order to achieve significant impact.

For effective implementation of such technologies, it is critical to have a clear adoption strategy for such technologies by farmers and all the involved stakeholders within the dairy industry.

1.2 Problem Statement

Among mobile innovations deployed for agriculture in developing countries, only 16% make it to widespread adoption (Qiang, Kuek, Dymond & Esselaar, 2012). In spite of the presence of several ICT-based solutions in Kenya's dairy sector, majority of the existing platforms are inefficient; they do not offer comprehensive and up to date best practice information, they have not properly plugged into the already unstructured value chain, and they have in-actionable advisory information that is not specific to farmer's needs. Consequently, most farmers do not use these innovations for a long period of time. In addition, there is limited documentation on the design and development models of mAgriculture applications in within a developing country such as Kenya.

Therefore, there is need to develop a model to guide the design and development of mAgriculture applications, so as to improve the chances of successful mAgriculture solutions, thereby better leveraging the potential of the dairy farming sector.

1.3 Research Objectives

The primary aim of this research was to inform mobile application developers, researchers and other practitioners in the mAgriculture domain, in the successful design, development and implementation of mAgriculture applications. The specific objectives were as follows:-

a) To investigate the challenges facing the usage of mAgriculture applications.
b) To establish the factors that lead to successful or unsuccessful design, development and implementation of mAgriculture applications.
c) To model the identified factors and challenges into a perspective that will guide the design, development and implementation of mAgriculture applications.
d) To validate the model using a user-centric mAgriculture prototype for dairy farmers which is informed by the developed model.

1.4 Research Questions

a) What are the challenges facing the usage of mAgriculture applications in Kenya?

b) Which factors lead to the successful or unsuccessful design, development and implementation of mAgriculture applications?

c) How can the identified factors be modelled into a perspective that will inform design, development and implementation of mAgriculture applications?

d) How can the derived model be used to validate the model through a prototyping process of an mAgriculture system?

1.5 Justification

Even though there is a high mobile penetration in developing countries, it has not been appropriately leveraged for usage in critical economic sectors such as agriculture. This has been attributed to among other factors the poor design and development of mAgriculture applications (Gichamba, Waiganjo & Orwa, 2015). In addition, mAgriculture penetration have been highly affected by implementation challenges (World Bank, 2017).

Moreover, most of the mAgriculture innovations do not reach a widespread usage threshold, due to factors related to the design, development, deployment and post deployment stages.

This research is important as it will help in identifying a working model towards the adoption of mobile technology in agriculture, specifically dairy farming. The model shall be a useful tool to software developers and researchers in the area of mAgriculture.

Consequently, stakeholders in the dairy sector such as farmers, farm produce buyers, veterinary officers and agriculture extension officers will benefit greatly.

This research will have the potential to inform policy makers in organizations such as the Kenya Dairy Board, the Ministry of Agriculture, county governments, investors and other agriculture stakeholders by acquiring useful information from the sector and how technology can be used to improve productivity.

1.6 Scope

The research project will concentrate on the adoption of mobile technology only in dairy farming and crop farming.

The factors identified and the adoption model created may later be replicated to other areas of agriculture.

1.7 Significance

There are few existing models that have been used to guide the design and development of mAgriculture applications. However, there are many challenges towards the adoption and usage of these technologies by the target stakeholders due to issues which are related to design and development (Gichamba, Waiganjo & Orwa, 2015), deployment and post deployment (World Bank, 2017). A model to guide the design and development of mobile agriculture solutions in Kenya will lead to the success of mobile based projects targeting farmers and other stakeholders in that domain.

1.8 Thesis Organization

This thesis is organized in six chapters, with each containing sub-sections that expound further on the key aspect covered by the specific chapter.

Chapter one begins by providing a background of the study. The background is followed by the problem statement, the research objectives, the research questions addressed by the study, the justification, the scope, and the significance of the study. The chapter ends by providing the assumptions made in the study.

Chapter two provides an in-depth review of related work. This chapter begins with a short discussion on agriculture domains in Kenya, followed by examples of ICT innovations in agriculture and thereafter the theoretical underpinnings of the study, followed by a summary of the reviewed literature. The chapter concludes with a detailed explanation of the construction process of the conceptual model and hypothesis formulation.

Chapter three tackles the methodology followed in executing this research work. The chapter commences by providing the research road map, followed by the selection of the study area and prototype development. The chapter ends with a discussion on the research philosophy and design.

Chapter four contains a discussion on the design and development of mAgriculture prototype, *Digital Farm System.* This user-centric mobile-based farmers' advisory and inquiry system was used to validate the developed model.

Chapter five elaborates on the results and discussions of the study. The results and discussions are done according to the stages that were followed in conducting the research, starting with the pre-study, followed by the pre-prototype stage, the post-prototype stage 1 and lastly the post-prototype stage 2. This is followed by a discussion on the retained and the dropped constructs from the conceptual model. The chapter ends with a discussion on the qualitative analysis and results.

Chapter six is the last chapter of this thesis report and contains a discussion on the contributions, conclusions and recommendations of this study. The chapter contains an explanation on the fulfilment of the objectives, the research contributions, the research conclusions and ends with the limitations and recommendations for further study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Review of related work and proper grounding is paramount towards a successful research exercise. In this, the researchers provided an in-depth review of related work. This chapter begins with a short discussion on agriculture domains in Kenya, followed by examples of ICT innovations in agriculture and thereafter the theoretical underpinnings of the study, followed by a summary of the reviewed literature. The chapter concludes with a detailed explanation of the construction process of the conceptual model and hypothesis formulation.

Agriculture plays a key role in Kenya's economy and in most developing countries majorly in Africa. In Kenya, the agriculture sector is comprised of six active sub-sectors namely industrial crops, food crops, horticulture, livestock, fisheries and forestry. The agricultural sector development strategy 2010-2020 cites that agriculture accounts for 65 per cent of Kenya's total exports, provides 18 per cent of formal employment and 70 per cent of informal employment in rural areas (GoK 2010). The report further claims that both livestock and fisheries subsectors have huge potential for growth that has not been exploited.

The livestock sector has a high degree of vertical links with upstream and downstream industries, and is a significant user of products from feeds, drugs, vaccines and equipment manufacturing. As per the last national census, the country's cattle population is 17,467,774; the goat population being 27,740,695 and the camel population 2,600,111 (KNBS 2009). The estimated dairy cattle population is 3.5 million (GoK 2010) and includes key dairy breeds namely Ayrshire, Friesian, Guernsey, Jersey and cross-breeds while the estimated dairy goats population is 251,100 and is dominated by Alpine, Toggenburg, Saanen, Anglo-Nubian and their crosses with local goat breeds (Origa 2012). Unlike dairy cows which are spread in many regions of the country, about 85 per cent of dairy goats are found in the higher rainfall areas of Central, Eastern and Rift Valley provinces under intensive and semi-intensive systems (Origa 2012).

Farmers have been exposed to various services that relate to knowledge and produce marketing. The government offers agricultural extension, training and information services in a bid to disseminate knowledge, technologies and agricultural information.

Some of the challenges faced by farmers in Kenya and specifically dairy farmers include a weak policy and legal framework for the dairy sector, low dairy productivity, erratic and unpredictable weather conditions, poor marketing of produce, prevalence of trans boundary animal, inadequate capacity for disease control, weak delivery of extension services, poor access to local and international markets, and unreliable data and information management in the livestock industry (GoK 2010; Origa 2012).

2.2 ICT Innovations in Agriculture

ICT4 for Development (ICT4D) involves the usage of ICT as a tool to enhance development, mostly in developing economies. This has increasingly become a vehicle through which critical services in developing countries are provided. ICT4D entails using ICT as a platform of service provision in sectors such as agriculture, health, education and finance in the developing world. Additionally, Mobile for Development (M4D) has emanated from ICT4D, with a keen focus on provision of mobile technology solutions in the aforementioned sectors.
Specifically for agriculture, ICT innovations entail the provision of agriculture related services on devices such as computers, tablets, mobile phones and any other hand-held computing device.
One of the areas that has potential for great impact on agriculture in developing countries is the use of ICT in the agriculture value chain, both in the crop and livestock sectors. The application of ICT to the agriculture industry, the largest economic sector in most African countries, offers the best opportunity for economic growth and poverty alleviation on the continent. This adoption of ICT in agriculture is of strategic importance to five main stakeholders: businesses, farmers, researchers, government and the general citizen (Deloitte 2012). Specifically, mobile applications for agriculture and rural development hold significant potential in advancing development (Qiang et al. 2012) in developing countries such as Kenya. In addition, innovations that are not directly linked to agriculture have been of huge impact. These include mobile money transfer services such as M-Pesa in Kenya. M-Pesa has been found to have a huge impact on agriculture, significantly increasing household annual income by about USD 224 (Kirui et al. 2013). Other initiatives that indirectly change the lives of farmers have been ICT4D projects aimed at poverty alleviation through various strategies. The Swedish Program for ICT in Developing Regions (SPIDER) network has been

actively using ICT in developing countries to raise the livelihoods of vulnerable communities. In Kenya, the group has initiated projects that focus on promotion of viable livelihood opportunities among rural communities using involving basic education and capacity building using ICTs (Wamala 2012).

Some of the challenges facing agriculture stakeholders in developing countries can be tackled by the use of ICT innovations. With the proliferation of affordable technology even among the poor small holder farmers, there is an immense opportunity to use ICT to improve yields, provide useful information and generally empower farmers. Increasing agricultural productivity, profitability and sustainability in the developing world depends on the ability of rural populations to adopt changes and innovations in their use of technologies, management systems, organizational arrangements, institutions and environmental resources (Qiang et al., 2012).

The application of ICT can be effected in almost every stage of the production chain in agriculture in both crop and dairy farming. For dairy farming, this would entail getting information on the best feeding and breeding practices, animal records keeping, diagnosis services, access to market information and cost analysis. Other applications of ICT in dairy farming include animal identification marking using RFID devices and general use of devices such as mobile phones to communicate for services related to livestock farming among stakeholders. Alternatively in crop farming, information on farm inputs e.g. fertilizers, pesticides may be provided on an ICT platform. Other services within crop farming include crop diagnosis, market information and notifications on diseases.

Given the challenges and constraints faced by farmers, coupled with the availability of available technologies, the impact of ICT innovations and their potential to transform the agricultural sector in developing countries cannot be underestimated. The ability of ICT to bring refreshed momentum to agriculture appears even more compelling in light of rising investments in agricultural research, the private sector’s strong interest in the development and spread of ICTs, and the upsurge of organizations committed to the agriculture development agenda (Qiang et al. 2012).

Agricultural services may be provided using the major communication and information access functionalities of ICT devices that include installable mobile applications, sending and receiving SMS, USSD, internet and voice. Other device features that enable a wide array of possibilities in ICT innovations for agriculture include the ability of devices to capture photos and videos, communicate via NFC and RFID, as well as GPS functionalities. Most of these innovations are made to work on basic phones, feature phones, smart phones, and IoT devices, mostly depending on the target users, the available ICT infrastructure and the service being provided.

2.2.1 Deployments of mAgriculture applications in developing countries

Majority of mAgriculture interventions have been done in developing countries. These include many countries in Asia and in Africa where the mobile phone is the primary computing device (Adkins 2013). In these parts of the world, most mobile handset owners possess a basic or a feature phone, although the trend is quickly changing with the introduction of low price smartphones.

mAgriculture services are critical in developing countries, as farmers lack access to relevant, actionable and timely agriculture information needed to inform better farming practise and facilitate great productivity (Global System for Mobile Communications Association [GSMA] 2015).

Most mAgriculture applications focus on improving agriculture supply chain integration and have a wide range of functions such as providing market information, increasing access to extension services and facilitation market links (Qiang et al. 2012). Different stakeholders in the agriculture sector such as farmers, produce buyers and brokers, agro vet dealers, content providers and cooperatives benefit from these services.

Most of the available services focus on the provision of information related to produce market, climate and disease, good agricultural practices, extension services, linkage between farmers, suppliers and buyers, recording, accounting and traceability, credit, insurance and payment methods.

In this study, we discussed eight mAgriculture interventions namely *iKilimo*, *iCow*, b2bpricenow, Kenya Agricultural Commodities Exchange(KACE), Open Data Kit, Cybertracker, GL CRSP Livestock Information and Knowledge System and an RFID project in Botswana used to prevent diseases among cows. These innovations were selected after an exploration of existing mAgriculture innovations in Kenya and other developing countries.

Information from the World Bank (Qiang et al. 2012), Technical Centre for Agricultural and Rural Cooperation (2014), GSMA(2015) was used to identify these innovations as points of interest and discussion. To profile the selected applications, we will use the goal-based typology developed by Kerry McNamara for the Swedish International Development Agency (Loucky 2012). This classification focuses on the benefits that are derived from the mobile agriculture solutions by the different stakeholders who either directly or indirectly interact with them. Table 2.2 shows the classification of mobile agriculture solutions based on the benefits of the service or platform and breaks into four categories: Education and Awareness, Commodity Prices and Market Information, Data Collection, and Pest and Disease Warning.

Some of the selected innovations would qualify for more than one classification because of their features. However, the researchers have grouped the innovations into the four categories based on their major strengths and what they are majorly known for and not necessarily the consideration of the whole suite of their functionalities.

Table 2.1: Goal-Based Typology of Mobile Agriculture Services1 (Hellstrom 2010)

GOAL	METHOD
Education and Awareness	Information provided via mobile phones to farmers extension agents about best practices, crop varieties and pest management.
Commodity Prices and Market Information	Prices in regional markets to inform decision making throughout entire agricultural process
Data Collection	Applications that collect data from large geographic regions
Pest and Disease Outbreak Warning	Send and receive data/warnings on outbreaks

a) Education and Awareness mAgriculture solutions

These innovations entail the provision of agriculture information for the purpose of advising farmers and educating them on various issues such as best practices, pest management, offering a question/answer platform as well as passing general announcements.

1 The classification is applicable to both crop and livestock mobile agriculture services and platforms

i) iKilimo

iKilimo is a mobile based farming reference and advisory tool developed by Avallain Foundation, that offers comprehensive information to farmers on various topics that include animal production, farm equipment, food processing, high value crops, plant production and marketing. The platform is available as a mobile web application, an android application available on Google Play store and an SMS inquiry service, as indicated during an interview with one of the key staff members of Avallain (E Muthoni 2014, personal communication, 10 February). The information is narrowed down to provide farmers with more details on a certain topic that they select. For example, the dairy cattle section under the animal production module on the mobile web and android application is divided into breeding, housing, feeding, heifers, calves, milking. Other available information include health management advisory such as mastitis symptoms, causes and prevention, milk fever, ketosis, acidosis, sore hooves, bloat and intestinal parasites.

The information provided on *iKilimo* has been created and edited by a team of agronomists and agricultural experts. The source of the information is reputable agricultural based journals, individual professional experience and other public domains. Avallain Ltd, the organization behind *iKilimo* has worked with the e-extension department at the Ministry of Agriculture Livestock and Fisheries in Kenya, in order to avail this information to agricultural extension officers who are assigned different regions of the country to train and advise farmers. This is one of the platforms available to the government extension officers, alongside National Farmers Information Service (NAFIS), the Infonet-Biovision platform and the Plantwise platform. Through the Ministry of Agriculture and Avallain Ltd., the researchers were able to interact with extension officers and farmers using these platforms, and the lessons learned were considered in the design of the mAgriculture prototype for this study.

Since its inception in 2013, *iKilimo* has over four thousand users, 54% of them being male, while 46% are women. The most popular sections of the platform among the users are the cattle and chicken farming modules.

ii) iCow

iCow is the invention of Green Dreams Ltd based in Kenya. The mobile based service provides extension and advice using various technologies such as USSD, SMS and the web (Qiang et al. 2012). The platform helps dairy farmers to maximize the breeding potential by tracking the fertility cycle of their animals, giving them valuable tips on breeding, animal nutrition and milk production efficiency to help increase milk yields and ultimately their income (Brown, 2014). Farmers register for iCow by dialling a USSD code where their registration information is recorded and they can start using the available services. Some of iCow's modules include *Mashauri* farmer tips where farmers receive 3 SMS tips per week at KES 3 (~0.03 USD) per SMS. iCow also provides a gestation calendar for dairy animals, where farmers receive customized information throughout the gestation period of the registered animal. In addition to the described features, the system also provides a feature known as *Vetenari* Find, that allows farmers to locate the nearest veterinary doctor within their location. A farmer is charged KES 3 per SMS to receive information on the nearest veterinary doctor that they may contact. The same module offers information on Artificial Insemination services within the vicinity of the farmer, also at KES 3. Surveys conducted on the impact of iCow have indicated an increased yield of 3 liters per animal per day over a 10 month lactation period, which results in an annual increase of 318 USD for a knowledge investment of USD 4.9 (iCow, 2014). The strategic partnership between Green Dreams and Safaricom has led to an increased uptake of iCow among the younger demographic of farmers.

b) Commodity Prices and Market Information mAgriculture solutions

Innovations under this category provide a platform where farmers, farm produce marketers and buyers share information about prices for various agricultural commodities.

i) b2bpricenow

The b2bpricenow is a platform that provides current market price information to farmers and cooperatives in Philippines. The service links sellers to buyers and can process financial transactions using bank accounts or debit cards via a mobile phone. Since its inception, the platform has handled a volume of trade that is nearly 30 million USD and has impacted over 26,000 farmers (Qiang et al. 2012).

The system was developed to assist farmers in the Philippines from around the 7,100 islands who had difficulty in getting reliable information on how much supply is out there and what the going prices are (Herbosa & Paua 2003). Through its various features, the platform eliminates intermediary costs, expands market reach, enhances distribution efficiencies, facilitates delivery of relevant research, and other useful information to farmers, and reduces transaction costs. The primary stakeholders of b2bpricenow were cooperatives, cooperative buyers and buyers. The application started as an e-commerce service for the cooperatives and major farmers but is now expanding the service to include farmers that are not account holders with the major banking stakeholder, LandBank.

ii) Kenya Agriculture Commodities Exchange – KACE

The platform provides daily market information on 20 commodity prices. It also facilitates offers and bids to match farm outputs with demand from wholesalers, and facilitates links between farmers and buyers (Qiang et al. 2012) .

Several ICT tools are applied to enable service delivery on the platform. SMS messages are used for information delivery to farmers, where a farmer sends an SMS with the name of the commodity they are interested in, e.g. dairy cow to a short code number and instantly receives a reply citing the day's wholesale prices for that commodity in the main markets, as collected and compiled by KACE staff. KACE frequently classifies the poorest and most vulnerable farmers into groups to buy mobile phones where KACE pays 50 per cent and group members pay 50 per cent. In such a case one of the members downloads the information daily and informs the group members (Karugu n.d.). The platform also provides an Interactive Voice Response (IVR) service where a user dials a specific phone number to access the information through simple steps. KACE has also set up Marketing Information Centers (MCIs) that serve as liaison points between KACE and the remote marketing information points. The MCIs are located in major markets within the country where employees routinely record the prices of farm produce and commodities daily (Karugu n.d.). As a result of the services provided by KACE, 75 per cent of the farmers using the service and 60 per cent of the commodity traders have reported higher incomes.

The project required 40 per cent donor funding during its inception stage, but has a clear business plan that will require spending much more on marketing and investing in the development of an enhanced platform, neither of which was possible under donor funding (Qiang et al. 2012).

c) Data Collection mAgriculture solutions

mAgriculture innovations in this category have been used as data collection platforms in agriculture.

i) Open Data Kit

Open Data Kit (ODK) is not an mAgriculture application in itself, but an open source data collection platform designed so that components can be customized to the user's data collection needs. The platform has been featured in this section of the study to represent the numerous open source tools that are customizable to various contexts e.g. mAgriculture, mHealth, mLearning, etc. The mobile client called ODK Collect runs on the Android platform and can collect various types of data including text, geo location information, photos, video, audio and barcodes. The server side component is called ODK Aggregate, which is a web server built on Google's App Engine infrastructure. The server provides a free and scalable repository that allows storage of collected data. The stored data can be exported in various formats and visualized on tools such as Google maps. ODK also enables interoperability with other tools for the purpose of data sharing e.g. OpenMRS, EpiSurveyor and JavaRosa (Qiang et al. 2012).

ODK has been used in different parts of the world in the mAgriculture space. In Kenya, the International Livestock Research Institute (ILRI) has used ODK for livestock data collection. ILRI had been using the traditional paper-based system to collect livestock related data in the field but recently started investigating ways in which data capture and analysis can be automated, and thus the usage of ODK in their data collection exercises (Gashaw 2013). Several other deployments from different parts of the world have been featured on ODK deployments (ODK n.d.) and they include using ODK in monitoring agricultural practices; crop productivity and farmer yields in Haiti; collection, treatment and dissemination of livestock and agricultural market prices in Niger; monitoring and evaluation in agricultural work in Zambia.

ii) CyberTracker

This is a platform for collecting data to protect local knowledge and ecosystems. Both public and private agencies have a limitation to the extent with which they can collect data from a wide range of rural locations. One of those ICT solutions is CyberTracker, originally used to track animals and plants for conservation in South Africa. The platform has created opportunities for poor, rural and illiterate people to collect useful information on a variety of subjects (World Bank 2012).

CyberTracker can be installed on a PDA or a smartphone and enables data collection with spatial references through a GPS. The user interface is created using words and icons, and is simple enough to allow non-expert civil society groups collect important data on various agriculture aspects in rural areas. The system can be customized for different types of devices and users' needs, so as to improve efficiency during data collection e.g. users can select which icons to be shown on their screen. Furthermore, the system can be customized to support different languages.

The collected data is transferred to a computer, where analysis is done and the results displayed on interactive maps that show detailed patterns of ecological features for different agricultural regions, and animal movement and concentration. The analysis has a high potential to project future trends, especially when the data is collected from a large range of locations (Technical Centre for Agricultural and Rural Cooperation [CTA] n.d.).

The usage of CyberTracker has since moved to other parts of the world for many other purposes. However in Africa, the system is used to track animals and plants, with the intention of monitoring ecosystem changes caused by climate change. Local people, with little or no education are paid to track ecological change using the technology, because of the system's simplicity. The technology captures valuable local knowledge that may be lost as indigenous populations disperse. Besides civil societies improving the understanding of local needs in agriculture, they can also use the technology to capture social data through digitized surveys (CTA n.d.).

d) Pest and Disease Outbreak Warning mAgriculture solutions

The innovations under this category provide warning messages on disease outbreaks, pest epidemics, and natural calamities that have an impact on agriculture.

i) Global Livestock Collaborative Research Support Program Livestock Information Network and Knowledge System (GL CRSP LINKS)

LINKS is a Livestock Information Network and Knowledge System which provides regular livestock prices and volume information on most of the major livestock markets in Ethiopia, Kenya and Tanzania along with information on forage conditions, disease outbreaks, conflict and water supply to support decision making at multiple levels (Qiang et al. 2012). The system targets farmers and traders in these regions and runs under the (GL CRSP) funded by United States Agency for International Development (USAID).

ii) Radio Frequency Identification for animals

The Livestock Identification Track-Back System in Botswana is one of the largest and most innovative forms of ICT for animal husbandry, involving over 300 million cattle (Burger, 2004). The system, developed by Inala Identification Control (IIC) in South Africa uses radio-frequency identification (RFID) and serves many purposes including meeting beef import requirements for European Union (EU), the destination for 80-90 per cent of Botswana's beef exports (Qiang et al. 2012). The system is also used to improve veterinary services and dairy livestock health.

A device known as a *bolus* marked with a unique ID and a transponder is implanted into a cow's rumen, where it collects information that allows both the herdsman and the government to monitor new registrations, look for possible disease outbreaks, identify lost or stolen cattle, track weight gain, and plan for animal treatments.

About 300 fixed RFID readers scan the unique cattle IDs and relay the information to databases in 46 district offices.

The bolus is protected from criminal tampering, and is safe for the animals. Moreover, it can be recycled, thus keeping the operational costs of the project low. The owner of the cattle can optimize feeding schedules, select bulls for breeding and keep updated health records of the cattle, therefore improving productivity by reducing susceptibility to disease and planning for yields (Qiang et al. 2012).

In Kenya, the RFID bolus is used in the identification of animals by one of the local insurance companies, in their livestock insurance scheme.

The featured innovations demonstrate the potential that mAgriculture has in a developing country such as Kenya. Most of the solutions have utilized the existing technology among stakeholders with the need for minimal investment in the facilitating technology to use the service. Also, they have majorly concentrated on the teething problems among agriculture stakeholders in a developing country. An important factor that has been considered throughout is the profile of the stakeholders and mostly the farmers in terms of their needs, the kind of mobile devices they have, their literacy levels and proficiency in a language, their level of income and ability to spend financial resources on mAgriculture services and social factors such as their community setting. This has led to continuous use of the mAgriculture products and services, creating trust and confidence in the tools availed to the stakeholders in different regions of the world.

However, the above featured mAgriculture innovations have demonstrated both successes and failures in various stages of their existence. While most of them started with a lot of excitement and hope among the initiators and potential beneficiaries, not many of them moved to the wide-scale usage stage. Most of the innovations either perpetually remain at the pilot stage, or experience minimal adoption, but very few have made it to full scale deployments. Nevertheless some of the mAgriculture innovations have benefited farmers and other stakeholders in a great way and have had a direct impact in their productivity, income and general improvement of their farming experience. The successes have been attributed to among other factors awareness of the existence of the innovations, thorough and continuous training on their functionality, technical support and affordability.

In addition, a majority of the innovations were initiated using donor funding and there were no sustainability mechanisms put in place for the continuous running of the project beyond the funding. Such projects have ended up not surviving long after funding stopped, because no self-sustainable revenue model was established at the onset of the initiative. On the other hand, the success of some of the innovations has been attributed to good value proposition, ownership among the users and establishment of long term partnerships among various stakeholders that focus on mutual benefit and long term existence of the innovation.

In a later section, the researchers will discuss some of the reasons why most of the mAgriculture innovations have failed to reach large scale deployment or widespread adoption stages.

2.2.2 Challenges of mAgriculture innovations

Despite the numerous mAgriculture interventions in different parts of the world, most of them have faced challenges that have rendered them non impactful in their areas of implementation. The challenges are experienced at different stages of the innovation's cycle, starting from pre-implementation to full adoption attempts. While there is credible, though limited evidence of positive impact, questions remain about how to make these innovations replicable, scalable, and sustainable for a larger and more diverse population (World Bank2012).

In this study, we grouped the challenges using a framework of project development and sustainability initiated by USAID's Development Innovation Ventures (DIV) office.

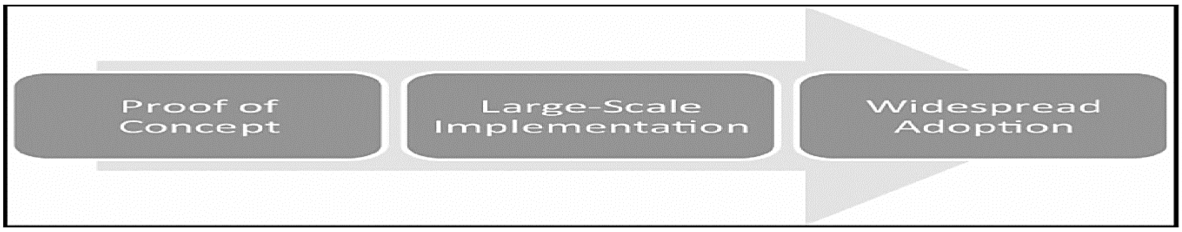


Figure 2.1: USAID DIV Framework (USAID n.d.)

The researchers amended the framework to include an initial phase of needs assessment and analysis, a stage that is crucial for ICT4D projects and especially mAgriculture. Figure 2.2 shows the modified DIV framework that was used to explore the challenges faced in mAgriculture, prior and after the deployment of an mAgriculture innovation.

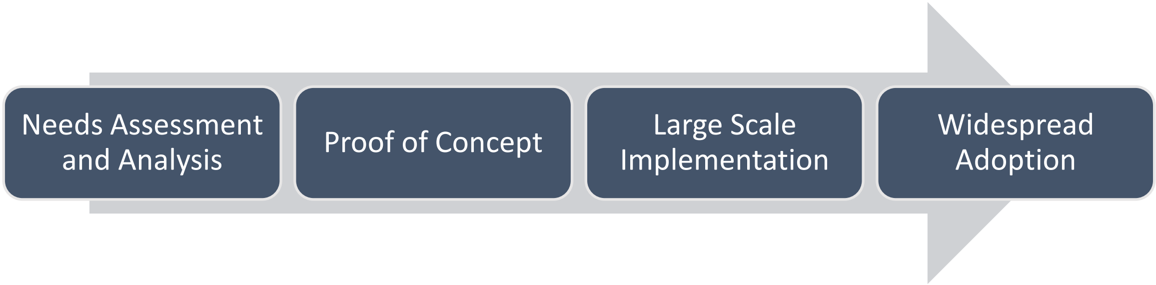


Figure 2.2: Revised DIV Framework

Phase 1: Needs Assessment and Analysis

This stage of mAgriculture innovations is mostly overlooked by practitioners who assume they have sufficient knowledge of the farmer's needs or the needs of other stakeholders in the agriculture domain. Consequently, the stakeholders are not consulted during the thought process of the innovation for which they are consumers. The organizations or individuals behind the innovation would mostly use secondary information to identify the needs of farmers and stakeholders in the agriculture sector, thus missing important primary information that should have been considered even before the design of an innovation's proof of concept. As observed in the pre-study exercises of this research, it is important to note that farmers' needs and sources of information are varied and change throughout the agriculture production cycle.

During an interaction with e-extension officers working under the Ministry of Agriculture, it was observed that none of the users of the various e-extension platforms provided by the government was consulted during the design of the services intended for use on the ground to advise farmers. The agriculture extension platforms were designed by a group of technical and agriculture content experts, with no iterative prototyping involving the would-be users: the e-extension officers. Unfortunately this happens in numerous mAgriculture deployments, which is more of a path for failure than success in later stages of the innovation's life cycle.

It would also be important to understand the current sources of information or services that are utilized by the population being targeted by the mAgriculture intervention. Other factors of importance to consider would be their literacy levels, language proficiency, technical capabilities and the technologies available to them.

From the above discussion, it is crucial to involve all the stakeholders in the identification of needs before proceeding to develop a proof of concept, which is based on secondary information about the needs of the beneficiaries. Engaging all those involved in the value chain in needs assessment and participatory action research enables the development of sophisticated, integrated, multi-channel systems (APPG-AGDEV 2014).

Phase 2: Proof of Concept

This stage is also known as the piloting stage. Under this phase, an mAgriculture system is deployed to a small group of users and feedback is collected on its usage. An effective proof of concept stage is iterative and allows a rapid feedback loop that immediately takes into consideration the preferences of farmers or stakeholders of the innovation. The *release early and often* concept of software engineering rapid prototypes is normally applied to create a continuous mechanism to improve the technology during the proof of concept phase. However, the majority of mAgriculture innovations never go beyond this stage.

The biggest obstacles at this stage of project development revolve around the first two components of the mobile agriculture business model: developing a clear and compelling Value Proposition and organizing the key resources necessary to deliver that service or product (Loucky 2012).

In this stage, majority of projects are funded by either the government, private sector or an independent donor. Most practitioners fail to plan beyond the funding and therefore don't design business models that will take the project to sustainability and into the full adoption phase when the funding is no longer there. While there is sufficient funding at the pilot stage, donors who provide the most funding at this stage are not operationally suited to provide long-term funding. Moreover, donors are usually not able or inclined to finance a large-scale marketing effort, often one of the key elements needed to raise funding (World Bank 2012).

In some cases, the mAgriculture innovators try to do too much at this stage, without zeroing down to a few functionalities that should be implemented and perfected. The most popular mobile money transfer service in the world, M-Pesa, credits its success to the introduction of a simple person-to-person money transfer service, which has over time grown to include other features. The simplicity and value proposition at the inception stages led to its widespread adoption. Trying to do everything has doomed projects, while initiatives that start small and focused such as M-Pesa can evolve into diverse offerings

In addition, barriers to adoption seem not to be well factored in at this stage. These barriers involve technology, and factors that have to do with the target population for instance the consumers' current way of doing things. Understanding traditional or current sources of information and services is critical for understanding the farmer's willingness to adopt or potentially pay for a new technology (Loucky 2012)

Another crucial aspect of an mAgriculture intervention at this stage is the buy-in and ownership by the target population. Bringing in communities into the early stages of the project fosters local ownership, a key component to sustainability (World Bank 2012). When there is a sense of ownership attached to a product or service, there are higher chances of continuous usage and value attachment when the target population has a sense of ownership of the innovation.

Phase 3: Large Scale Implementation

Once an mAgriculture innovation goes through a successful pilot phase, it now aims to enter the market as a product targeting the masses. This is a crucial phase for any product, and a lot of resources are required at this stage to run the operational costs, marketing, and support functions. The organization behind the innovation should have a proper structure and plan to finance these activities, otherwise the innovation may not survive beyond this stage.

This phase is also characterized by reduced external funding and therefore seeks to raise revenues through different models established in the innovation's ecosystem. Some of the popular ways to raise funds is charging the farmer a subscription fee, purchase of the application/service, or transactional fees based on the requested service or information. If the revenues do not match the cost of running the innovation, it may be difficult to continue offering the services/information consequently leading to the incapacitation of the project.

In addition, this stage requires good attraction and maintenance strategies for the user base, which includes the participants of the pilot phase. Creating a good relationship with users of the innovation, as well as building their trust is very critical. Aspects such as user support, complaints management and continuous feedback are crucial at this stage of the innovation's life. Additionally, having strategic partnerships is critical for the survival of an mAgriculture innovation beyond this stage. Building multi-sector partnerships in the initial stages of a mobile platform development can lead to significant cost savings in the initial start-up and widespread adoption phases (Loucky 2012).

Phase 4: Widespread Adoption

This phase is also known as the sustainability stage. Because of the aforementioned challenges, most mAgriculture applications do not make it to the sustainability stage. Researchers, development agencies and governments have cited the movement of an mAgriculture platform from large scale implementation to widespread adoption as the most difficult of all the other phases (Gichamba, Waiganjo & Orwa 2015; World Bank 2012; World Bank 2017).

A study done involving 92 mobile based platforms for agriculture and rural and development revealed that only a mere 16 per cent of the studied innovations made it to the widespread adoption phase (World Bank 2012).

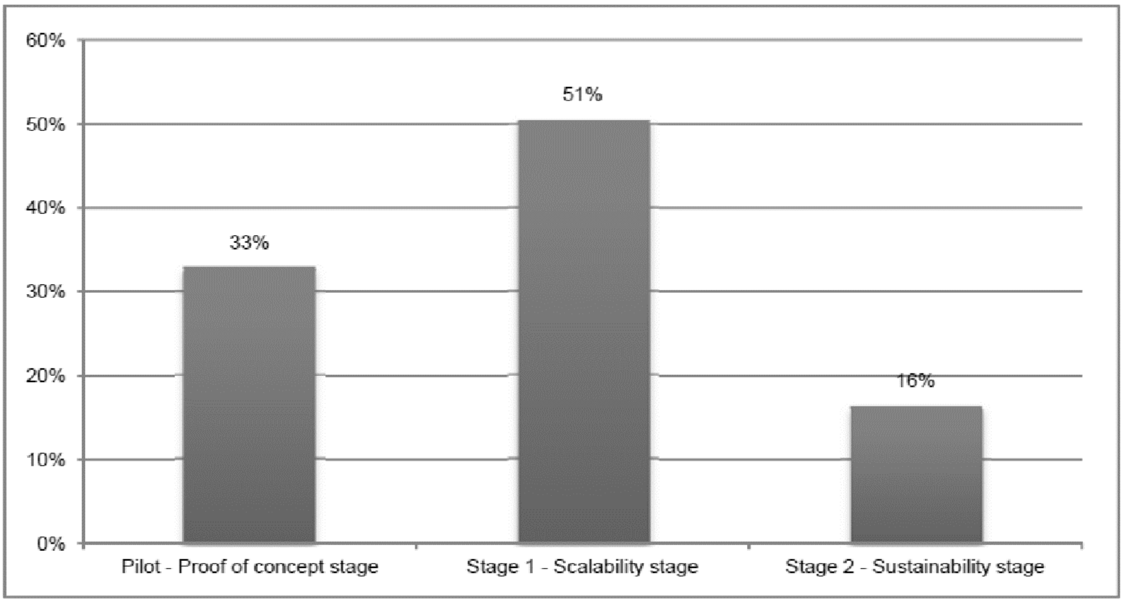


Figure 2.3: Stages of Business Development for mAgriculture applications (World Bank 2012)

Unlike in Phases 1 to 3 where financing may be available, it is very difficult to secure financing at the widespread adoption stage of an innovation. Table 2.2 shows the different types of mAgriculture innovations funding at the various phases of an innovation.

Table 2.2: Forms, types and sources of mAgriculture innovations financing (World Bank 2012)

Forms of financing	Types of financing (examples)	Typical sources
Grants and sub-grants (mainly pilot stage and stage 1)	Direct grants Grant matching Public-private partnerships Corporate social responsibility funds	Governments Donors Private companies Foundations Trust funds
Equity (pilot stage and stage 1)	Seed / startup Stages 1 and 2 Syndicate Crowdsourcing / social networking	Angel financing Venture capitalists Institutional investors Friends and family
Others, including business relationship-based and asset-backed (stages 1 and 2)	Franchises Joint ventures Licensing Leasing Factoring	Business partners Commercial banks Factors
Loans and debt (mostly stage 2)	Mezzanine Commercial loans Loan guarantees	Commercial banks Governments Donors

From Table 2.2, it is evident that a lot of financial sources are available at the pilot, and scalability stages, and rarely for the large scale implementation and sustainability stages. The available funding options at the sustainability stages mostly entail full responsibility of the technology owner, and they include loans and debts. An organization with no alternative source of income or business line to support the sustenance of their innovation may never bring it to this stage, consequently never up scaling to widespread adoption.

If farmers were not charged or received a product at a subsidized rate during the first phases of the project’s existence, they are less likely to pay for subsequent usage when the rates are not subsidized. Their willingness to pay would be determined by the value accrued in using the service, and results from using the mAgriculture service. Other factors such as the farmers' income either from agriculture or other sources, level of education and age group also determine if farmers and other agriculture stakeholders will pay to receive the services offered by an mAgriculture innovation. However, some stakeholders may be very willing to pay for a service because of the benefit they get from it, but are unable to pay for it because of financial constraints.

Poor value chain management is another factor that contributes to low widespread rate of mAgriculture innovations. With a large user base, decentralized operations and distribution channels, proper coordination is key in all stages of the product's process.

In addition, lack of proper feedback mechanisms for the users leads to a poor relationship between the community of users and the technology owners. A strained relationship may lead to the de-marketing of a product by current users such that they influence negatively potential users of the platform. In the life cycle of an innovation, it is critical to implement key measures to ensure the success of a platform take off and sustainability (Gichamba, Waiganjo & Orwa, 2015).

2.2.3 Lessons learnt from existing mAgriculture innovations

Important lessons can be drawn from the current mAgriculture innovations that would provide guidance for all development phases of an innovation's cycle. These lessons are of great importance to mobile agriculture application providers, researchers, governments, development agencies, as well as donors.

Using the information gathered during the literature review of this research as well as information gathered during the series of pre studies done towards this research, the researchers came up with the following lessons for the benefit of different stakeholders in the mAgriculture space. The recommendations have been classified in five phases, as established in the revised DIV Framework presented in Figure 2.2.

i) ***Phase 1***

This is a very critical phase of an mAgriculture system. The decisions and steps taken in this phase highly determine whether the next phases will be successful. The following key lessons have been drawn concerning the initial stage of any mAgriculture system.

a) Clear identification of needs

An mAgriculture system can only be helpful if it is satisfying the needs of the target users either by replacing a technology or mechanism they already have, or using technology as a medium to create efficiency in a process within the value chain. It is therefore crucial to identify the exact needs that the system will meet and establish those that can be met using ICT channels such as mobile technology.

The developers of the solution must take enough time to understand the needs of the target users, and establish how they fulfil those needs without using technology. Effective needs assessment strategies such as ethnographic research need to be conducted. At this stage, farmers and other stakeholders need to be fully involved in the identification of needs where technology can be of assistance in order to establish trust, interest and ownership. A clear value proposition to the farmers will create interest and demand for the mAgriculture solution. In addition, the focus at the initial stage of an mAgriculture system should not be merely on the technology but on the need itself. In fact, an overemphasis and focus on technology may be a distraction at this stage.

b) Technology Availability and Appropriateness

Once the needs are clearly established, a consideration of the available technology and its appropriateness in meeting those needs should be established. For instance, the researchers may consider what kind of technology is at the disposal of farmers and other target stakeholders. As much as it is possible, mAgriculture systems should utilize the technology available among the stakeholders without the need to have them invest in newer or different technology. A mixture of technologies can be used for the same purpose depending on what is available to stakeholders.

c) Education and Literacy Levels among the target users

Education and literacy levels among the target users determine among other things the language of choice for the mAgriculture system, the kind of user interfaces to develop, kind of content to develop, mode of content delivery e.g. SMS, voice etc. It is therefore very important to know the literacy and education profile of the majority of users targeted by a system.

d) Willingness to Pay for a service

In most cases, the willingness of a farmer to pay for a service is determined by their income level and what they perceive to be benefits from the service provided. Determining their income levels and demand for the service will guide the mAgriculture solution providers on the kind of business models they need to consider as well as the kind of services that will be affordable and sustainable to provide on the platform. However, the solution providers may seek alternatives to provide the service at a subsidized cost or for free to benefit the target audience to whom the innovation is very useful but are not in a position to pay for the provided services.

ii) ***Phase 2***

In this phase, we present lessons learnt that can be implemented in the proof of concept phase of an mAgriculture platform.

a) User involvement in system design

User involvement during the design of an mAgriculture platform is very critical. Paper prototypes or throwaway prototypes may be used to show the user what the system would look like. An iterative prototype design process should take place until the user is satisfied with the design. At this stage, different profiles of users may be presented in classification levels of education, age and gender. The prototypes should also be tested across the available devices among the target audience.

b) Agile Approach of development

A process where requirements specification, design and development interleave should be adopted. This agile development approach ensures that the system is developed as a series of iterations, where all the stakeholders are involved in each version. An agile process requires a highly skilled team in order to produce results in a timely and organized manner.

Besides the involvement of users captured earlier, principles of agile development include incremental delivery, focusing on people not the process, embracing change and maintaining simplicity (Sommerville 2015).

iii) ***Phase 3***

Once the mAgriculture solution provider works with farmers and other stakeholders in the design of a working mAgriculture platform that meets their needs, proper strategies need to be put in place to ensure that the system survives the next phases. One of the key things at this stage is the establishment of partnerships that foster the sustainability of the solution. This leads to cost saving by different partners taking up different roles in the innovation's ecosystem e.g. provision of technology channels, marketing and user base mobilization and management. The solution providers may also leverage on existing relationships among the different target stakeholders. In the mAgriculture space, the solution provider may partner with telecommunication companies, agricultural input suppliers, extension service providers, established market networks, farmer organizations, farmer groups, value add processors and government and non-government agencies that support agriculture.

A proper business model needs to be implemented at this phase to ensure that the system continues to function and at the same time is affordable to the users. Since this phase would have little or no external funding, available revenue streams would need to be exhausted to ensure continuous provision of the service.

iv) ***Phase 4***

A platform in this phase would have overcome a lot of challenges and gained a significant user base. The efficiency within the value chain and system's ecosystem would ensure continuous growth and widespread adoption. In this phase, measures to ensure the platform is sustainable need to be implemented. Very efficient customer support is also critical to ensure the platform gains sustainable widespread adoption.

It is also at this phase where the solution providers should be keen on the changing needs of users. The system should be allowed to undergo evolution based on new demands, change of technology, change of user base profiles, geographical areas and scope of services provided.

Besides the recommendations presented using the revised DIV framework, several other approaches have been suggested on recommendations for various stages of mAgriculture innovations. One of the recommendation models is the Collective Impact model developed by John Kania and Mark Kramer. The model recommends that long-term multi-stakeholder social impact must take place at the Governance and Infrastructure level, Strategic Planning, Community Involvement and Evaluation and Improvement levels. Table 2.3 shows the phases of collective impact as proposed by Hanleybrown, Kania & Kramer (2012) for the Stanford Social Innovation Review.

Table 2.3: Phases of Collective Impact (Hanleybrown et al. 2012)

Components for Success	PHASE 1 Initiate Action	PHASE II Organize for Impact	PHASE III Sustain Action and Impact
Governance and Infrastructure	Identify champions and form cross-sector group	Create infrastructure (backbone and processes)	Facilitate and refine
Strategic Planning	Map the landscape and use data to make case	Create common agenda (goals and strategy)	Support implementation (alignment to goals and
Community Involvement	Facilitate community outreach	Engage community and build public will	Continue engagement and conduct advocacy
Evaluation and Improvement	Analyze baseline data to identify key issue and gaps	Establish shared matrics (indicators, measurement, and	Collect, track, and report progress (process to learn and improve)

In the mAgriculture context, the collective impact model can be applied to fill the gaps identified in the implementation of mAgriculture innovations from pilot to widespread adoption stage. The components of success namely Governance and Infrastructure, Strategic Planning, Community Involvement and, Evaluation and Improvement may be applied in different phases of an mAgriculture system.

The government in partnership with the private sector has the ability to mobilize resources, and put in place procedures and an environment that would foster the growth of mAgriculture innovations. For example, in 2013, the Kenyan government gave a grant of 1.6 million USD to a local innovation hub NaiLab as part of its efforts to support small and medium sized enterprises in a bid to lower entry barriers for ICT entrepreneurs who wanted to implement and scale their business in Kenya.

With evidence of willingness to work together to foster innovation, entrepreneurship and the development of sustainable solutions to key problems in our society, the government and the private sector may spearhead the following actions as a first step towards dealing with mAgriculture innovation challenges.

2.2.4 Understanding the readiness for mAgriculture apps among farmers

The adoption and usage of mAgriculture applications would be more successful if the target population has experience in using other mobile applications such as games, social media applications, mobile banking applications and money transfer applications (Gichamba & Lukandu, 2012).

At the commencement of this research, the researchers conducted a pre-study in several regions in order to understand the dairy farming system in Kenya; establish the level of exposure of farmers and agriculture stakeholders to mAgriculture systems; assess the readiness of farmers and other stakeholders to mAgriculture innovations and to understand the needs of dairy farmers in various regions of the country.

The study was conducted in different ecological zones where dairy farming is practiced, and produced a rich variation of farmers, ranging from pastoralists to large scale dairy farmers. The areas covered during the pre-study were Kirinyaga, Embu, Isiolo, Wajir and Marsabit.

The needs of farmers across the different regions were nearly similar. However, there was a difference in their exposure to mAgriculture systems and their level of dairy farming. Kirinyaga and Embu represented regions where dairy farming is carried out in middle to large scale levels, and majorly as a commercial activity. These two regions also combine dairy farming with other related economic and income generating activities such as breeding animals for sale, breeding to create pure high production breeds or cross breeds, sale of manure and biogas generation. Farmers in these regions are keen to observe best practices, have access to agricultural extension and livestock officers, and expert farmers who have demonstration farms in collaboration with major companies in the dairy industry. On the other hand, farmers in Wajir and Marsabit majorly keep their livestock as a sign of wealth, for dowry purposes and on a smaller scale to sell milk. These regions are characterized by pastoralism, and therefore dairy farming best practices are not necessarily adhered to and are not of great priority as simply keeping the livestock as a sign of wealth and for the aforementioned cultural purposes.

A group of 28 e-extension officers from 16 different regions of the country were also involved in the study. This is part of a group working in the Department of Extension services under the Ministry of Agriculture. This group has been provided with electronic content on mobile phones and computers, and their mandate is to educate and advise farmers using the content availed to them. This initiative came as a result of challenges that included inadequate staff/farmer access to ICT infrastructure and facilities; absence of appropriate skills among extension staff, farmers and other stakeholders in agriculture; inadequate presence and use of online agricultural repositories and lack of adequate/accessible local extension content in appropriate digital format (Rono 2013). The platform provides e-agriculture platforms relating to precision agriculture, e-commerce and agriculture information exchange and communication. The services are rendered through mobile phones (installable apps and broadcast SMS features) as well as the internet via portals and social media platforms. When they are being deployed to the field, the e-extension officers are equipped with a shock proof laptop computer, a 3G USB modem loaded with data bundles, a smartphone with loaded airtime and training of trainers on application of ICT in agriculture extension (Rono 2013).

The e-extension officers provided information on their experience working with farmers via various eAgriculture and mAgriculture tools. The top three modules accessed on the e-extension platform were plant production, produce marketing and animal production respectively. 32 per cent preferred to use the e-extension services via a computer, 25 per cent via a mobile website, 21 per cent via SMS services while via 18 per cent preferred to use an installable application such as Android. 3.6 per cent reported that they did not have any preferred platform and were comfortable with all the available options.

It was evident that the mobile based services (mobile web, SMS and applications) were the most preferred means of accessing the e-extension services, commanding a cumulative 64 per cent against 32 per cent who preferred a computer-based platform. Some of the reasons cited for preferring the mobile based platform included ease of access, ability to reach more farmers, convenience and lack of electricity to power computers in rural areas, making the mobile device a preferable medium of accessing services.

2.3 The Theoretical Grounding of the Study

This study has been grounded on existing theories of technology adoption and usage, user centred design and software engineering design and development principles.

2.3.1 Relevant Mobile Software Engineering Design and Development Models Considered in the Study

Mobile software engineering is the process of developing a mobile-based software system, from the initial stages of requirements gathering to the deployment and testing of a complete product.

However, in many respects, developing mobile systems is similar to software engineering for other embedded applications (Wasserman 2010). In addition, design patterns in general are reusable solutions of a commonly appearing problem in software development (Choluba 2010).

In most cases, mobile systems used in M4D domain such as agriculture, health, education, transport, trade, etc are normally built on a three tier model that contains a presentation layer, a business layer and a data layer. Different technologies may be used at each of the layers depending on the environment, resources and technology capabilities. For example, the presentation layer could be an installable mobile application, an SMS system, a USSD system, an IVR system or a mobile web application. The multi-tier architectural design could either be a rich client or a thin client. Figure 2.5 demonstrates a rich client architecture for a mobile application.

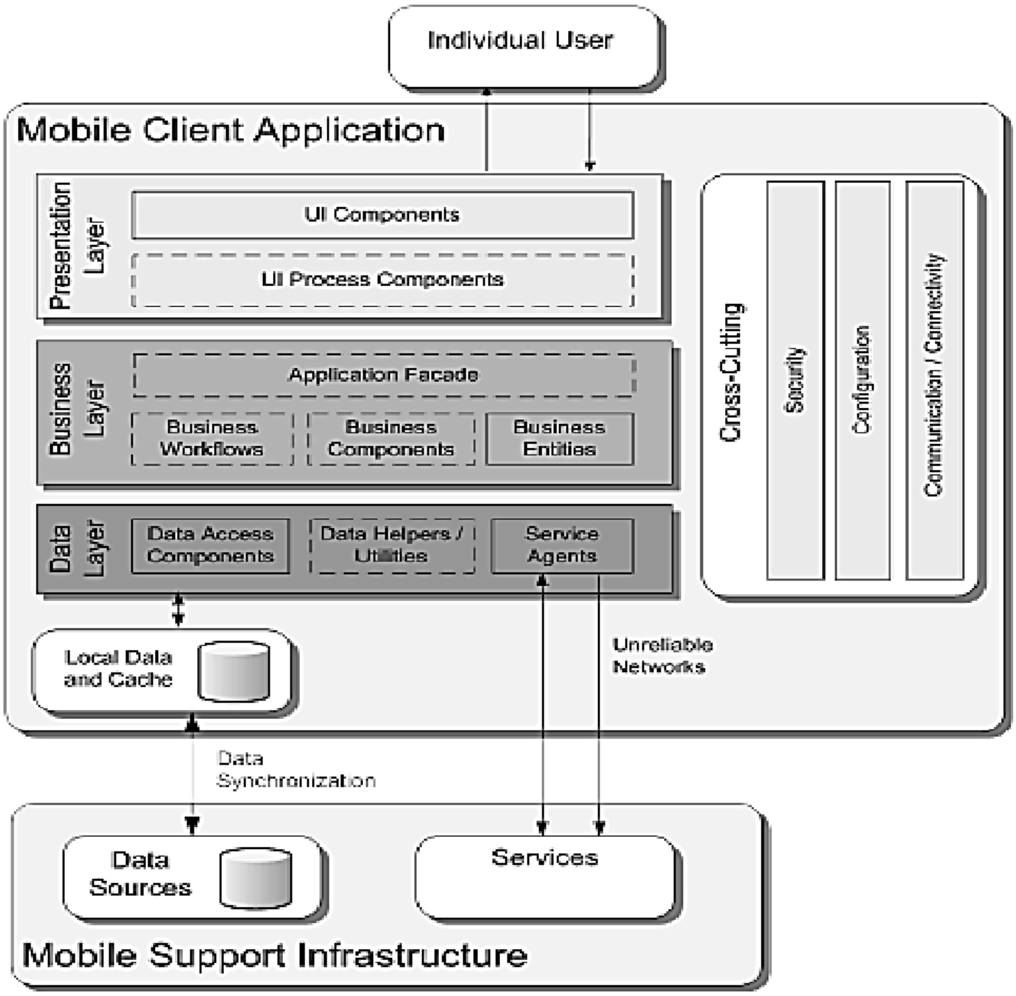


Figure 2.4: A rich client mobile application architecture (Microsoft 2008)

Rich client architectures are appropriate in scenarios where the mobile system will require to process operations locally without frequent connections to a server. Rich client applications require devices with good processing power, good primary memory capabilities for successful execution of the application as well sufficient storage for offline data. The most appropriate platforms for such applications are smartphone operating systems such as Android, iOS, Windows, and Blackberry.

On the other hand, thin client applications would require frequent connection to the server. In this case, the server becomes the primary processing device while the application passes and receives data and information from the server. These kinds of applications are best applied in environments where there is sufficient mobile network coverage and affordable mobile data, Voice or SMS services. Thin client applications do not require high powered mobile devices to run as the user interface is light and basic as opposed to a rich client application. As opposed to rich client applications, thin client applications can run on basic phones, feature phones and smartphones. The interaction with the user is either via SMS, using the default SMS capability on the mobile device; via IVR using the default calling capability on the mobile device; or via a mobile application installed on the mobile device. Where network coverage is good, and SMS/Data plans are affordable, this architecture is the best for mAgriculture applications in developing countries, as it allows farmers and stakeholders to have access to services regardless of the capabilities of their mobile device.

(Microsoft 2009) provides guidelines that should be adhered to when designing mobile based systems. Even though the provided guidelines are classical and generic in nature, in this research they were discussed in the perspective of mAgriculture applications in a developing nation environment.

2.3.2 Relevant User Centred Design Principles Considered in the Study

User-centred design is also known as human centred design. The *human centred design processes for interactive systems*, ISO 9241-210 (2015) states that 'human-centred design is an approach to interactive system development that focuses specifically on making systems usable. It is a multi-disciplinary activity'.

Research in user centred design has matured over the years, with the initial work by Gould and Lewis (1985) setting the pace. In their paper *Designing for Usability: Key Principles and What Designers Think* , the authors presented three principles for user centred design: early focus on users, empirical measurement using prototypes and iterative design. Other early works on user centred design was by Rubin (2008). In his book *Handbook for Usability and Testing: How to Plan, Design and Conduct Effective Tests*, the author gave similar principles for user centred design focusing on users and tasks, empirical measurement and testing of product usage as well as iterative design. In modern days, several phrases are being interchanged to mean user centred design, they include *user experience(UX) design, user interface (UI) design, graphical user interface (GUI) design, user-centred design (UCD),* *interaction design (IxD), user interface developer (UIDev)* among others (Wallach & Scholz 2012).

According to Hassenzahl (2003) a product is defined by its features, which include the content, presentation style, functionality, interaction style that are chosen and combined by a designer to create a product character. In his more recent work, Hassenzahl (2013) claims that the aspect of content is normally overlooked in HCI research studies and implementation. In his proposal, experienced design must be implemented as a vessel to address the ignored content aspect of HCI. The focus should shift to the design of pleasurable, meaningful and even treasured moments as when it comes to designing experiences, we can neither ignore the content and the purpose of the envisioned experience nor the question of whether we want to have this experience out of the world at all (Hassenzahl 2013).

The hedonic quality of interactive products such as software has been further developed in user-centred design and HCI in general. Hedonic measurement scales have been used in consumer research and technology acceptance models such as TAM (Davis 1989).

The activities performed in a typical user-centred design project can be assigned to the following five categories: Scope, Analyse, Design, Validate and Deliver. These steps are done sequentially, with a feedback mechanism in order to make any necessary revisions in a prior step.

Previous work has attempted to create a strong link between software engineering and user centred design principles. Various approaches have been used in this attempts such as using both software engineering and usability engineering to create elaborated process models to create software solutions (Nebe & Zimmerman, 2007).

2.3.3 Technology Adoption Models Considered in the Study

A number of technology adoption models and theories have been proposed and used in research work as well as ICT project implementations. The researchers explored the models in ICT adoption, that are applicable in this study on mobile agriculture. Of interest was a model that focuses on Design and Implementation aspects, in order to provide a thorough step by step study of the technology before it is deployed to its intended users. While most adoption theories focus on the deployment and usage of a technology, TAM3(Venkatesh & Bala 2008) accommodates aspects of design, development and implementation. Among the existing technology adoption models TAM3(Venkatesh & Bala 2008) was found to be the most appropriate as a theoretical foundation for this study. This was due to its intensity in tackling both Design and Implementation aspects. The proposed pre-implementation interventions and post-implementation strategies used in TAM3 are well applicable in situations where the user of a technology should be involved in the development of the technology, and also well trained and monitored during initial use, in order to increase the possibility of adoption and continuous use.

TAM3 is a combination of TAM2(Venkatesh & Davis 2000) and the model of determinants of perceived ease of use (Venkatesh 2000). This is a key success ingredient for initial acceptance, use and diffusion of innovations in ICT4D such as mAgriculture, eHealth, mLearning and rural finance. In the pre-implementation stage, which occurs during the development and deployment of the technology, Venkatesh and Bala(2008) suggest that administrators should allow the target technology users to pick the new technology as a way to encourage user participation. Besides emphasizing the need for good managerial support, the researchers also suggest that the administrators should implement an incentive alignment involving matching the individual's perception of the new technology with their job requirements and value system (Venkatesh & Bala 2008). In the post-implementation stage, which occurs after the deployment of the technology, Venkatesh and Bala(2008) suggest that members of an organization should receive sufficient training and support through dedicated help desks, hiring system and business process experts and sending employees to off-the-job training, which is linked to increasing users' perception and adoption of the new technology.

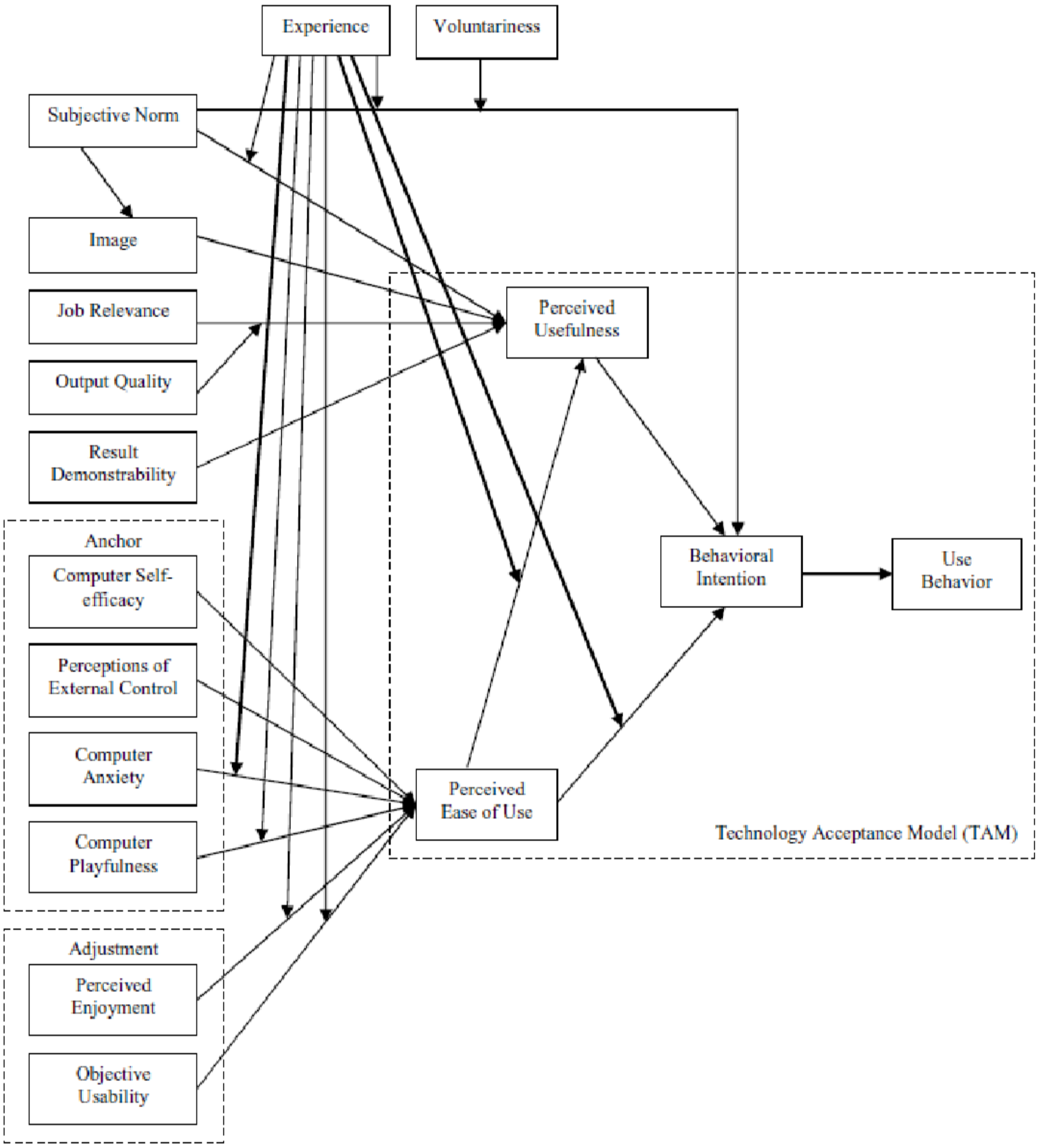


Figure 2.5 Technology Acceptance Model 3 (Venkatesh & Bala 2008)

Table 2.4 The constructs associated with TAM 3 and their respective meanings (Venkatesh & Bala 2008)

Construct	Definition
Attitude	Individual's positive or negative feeling about performing the target behaviour (e.g., using a system).
Behavioural intention	The degree to which a person has formulated conscious plans to perform or not perform some specified future behaviour.
Computer anxiety	The degree of an individual’s apprehension, or even fear, when she/he is faced with the possibility of using computers.
Computer playfulness	The degree of cognitive spontaneity in microcomputer interactions.
Computer self-efficacy	The degree to which an individual beliefs that he or she has the ability to perform specific task/job using computer.
Effort expectancy	The degree of ease associated with the use of the system.
Facilitating conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.
Image	The degree to which use of an innovation is perceived to enhance one's status in one's social system.
Job relevance	Individual's perception regarding the degree to which the target system is relevant to his or her job.
Objective usability	A comparison of systems based on the actual level (rather than perceptions) of effort required to complete specific tasks.
Output quality	The degree to which an individual believes that the system performs his or her job tasks well.
Performance expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.
Perceived ease of use	See the definition of effort expectancy.
Perceived enjoyment	The extent to which the activity of using a specific system is perceived to be enjoyable in it’s own right, aside from any performance consequences resulting from system use.
Perceived usefulness	See the definition of performance expectancy.
Perception of external control	See the definition of facilitating conditions.
Result demonstrability	Tangibility of the results of using the innovation.
Social influence	The degree to which an individual perceives that important others believe he or she should use the new system.
Subjective norm	Person's perception that most people who are important to him think he should or should not perform the behaviour in question.
Voluntariness	The extent to which potential adopters perceive the adoption decision to be non-mandatory.

2.4 Literature Review Summary

The literature reviewed in this chapter formed the theoretical background of the research. The discussions began with the contextualization of the study by highlighting the agriculture domains and sectors in Kenya. The researchers further explored the various ICT innovations in agriculture, and the various technologies behind them before narrowing down to mAgriculture technologies. Different deployments of mAgriculture applications in developing countries were discussed, where the goal-based typology of mobile agriculture services was used to point out innovations that address various problems in the agriculture domain using technology. Most importantly, the challenges of existing mAgriculture innovations were discussed, giving an insight on the teething issues that have affected initial usage and acceptance of technology as well as the continuous usage of mobile-based technologies in agriculture. The researchers then outlined the lessons learnt from the existing mAgriculture innovations that were discussed and how they can be applied in the initial phase of an innovation which comprises the needs assessment analysis of the project, the proof of concept phase, the large scale implementation phase and the widespread adoption phase.

The researchers discussed a series of preliminary studies conducted in five different regions of Kenya in order to establish the level of exposure farmers and agriculture stakeholders had to mAgriculture systems; assess the readiness of farmers and other stakeholders for mAgriculture innovations and to understand the challenges being faced by dairy farmers in various regions of the country. Highlights of the interaction with farmers during the pre-study exercises were discussed, and key aspects that informed the theoretical background of this research were elaborated. The discussion further outlined the prior experience of farmers with mAgriculture technologies and their needs that would be met using mobile technology.

In addition, different mobile software engineering design and development models were discussed. The various items of consideration in a mobile software engineering model were elaborated, and their importance towards the successful design, development and deployment of an mAgriculture platform discussed.

Also, the user centred design aspects were covered, an aspect that forms a key formation of the conceptual model of this research. The importance of this factor was discovered during the pre-study exercise, and it was discovered that it highly determines the success or failure of mAgriculture innovations. In relation to this, the researchers also discussed the adoption of mobile technology as well as technology adoption models that have been widely studied and applied in different contexts.

Figure 2.6 summarizes the theoretical grounding of the work as detailed on Section 2.3 and summarized in Section 2.7.

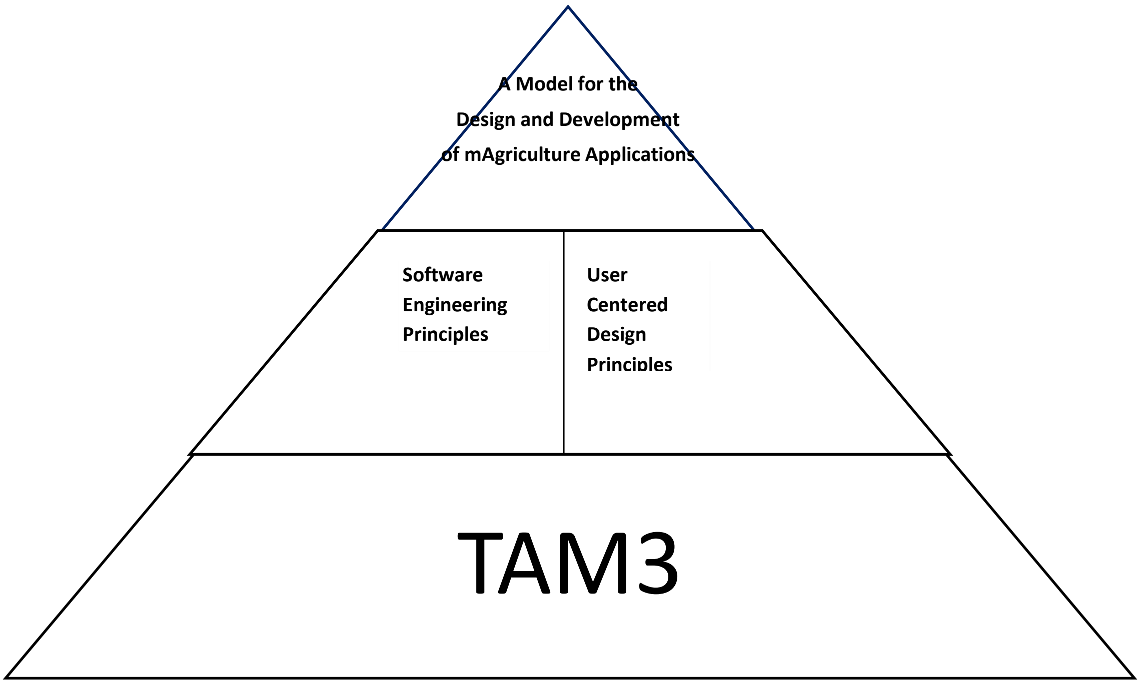


Figure 2.6: Theoretical Grounding of the Study

2.5 The Conceptual Model

The constructs of the proposed model have been derived from the pre-study discoveries and experiences; lessons learned from existing mAgriculture innovations; the discussed technology acceptance models; mobile software engineering design and development guidelines; and user-centred design principles. These theoretical foundations and pillars of the conceptual model have been discussed at length in previous sections of this work.

The constructs have been categorized into Human Aspects, Technology Aspects, Need Aspects, and Cost and sustainability. The constructs' source of derivation, context definition and the variables to be measured have been outlined on Table 2.5.

Table 2.5 Proposed model constructs and variables to be measured

Construct Category	**Constructs**	**Derived from**	**Context Definition**	**Variables to be measured**
Human Aspects	Trust(Tr)	TAM3(Venkatesh and Bala 2008) Lessons learned from mAgriculture deployments in developing countries (Section 2.2.1 of this work)	Assured reliance on the character, ability, strength, or truth of an mAgriculture application	Level of confidence in the product
	Perceived Usefulness (PU)	TAM 3(Venkatesh and Bala 2008)	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.	Subjective Norm(Religious beliefs, cultural beliefs, government/administrative support)
Technology Aspects	Effort Expectancy	TAM3(Venkatesh & Bala 2008)	The degree of ease associated with the use of the mAgriculture application.	Product features Consequences of product use

	Delivery Channel (DC) or Type of Application	Pre-study Analysis Mobile Software Engineering Design and Development Models (Microsoft 2008; Microsoft 2009; Wasserman 2010) User Centred Design Principles(Gould & Lewis 1985; Rubin 1984; Wallach & Scholz 2012; Hassenzahl 2003; Hassenzahl 2013)	The specific type of a mobile application or system accessible via a mobile device	Preferable type of application
Need Aspects	User Involvement in Requirements Gathering (UIRG)	Pre-Study Agile development approach (Sommerville 2015) User Centred Design Principles (Gould & Lewis 1985; Rubin 1984; Wallach & Scholz 2012)	The involvement of the user during the requirements gathering process.	User contribution to identification of needs

		TAM3 (Venkatesh & Bala)		
	Hyper localization (HL)	Pre-study Analysis Challenges of mAgriculture Innovations (Section 2.2.2 of this work) Lessons Learnt from Existing mAgriculture Innovations (Section 2.2.3 of this work)	The ability to present application features and content in the actual context of the user, considering their physical location, day to day activities and environment.	Localization of product content Consideration of the user's operating environment
Cost and Sustainability Aspects	Price Value (PV)	Lessons learned from mAgriculture deployments in developing countries (Section 2.2.1 of this work)	The consumers' cognitive trade-off between the perceived benefits of the applications and the monetary cost of using them	Cost of acquisition Running cost of the technology Value for money

	Feedback (Fb)	Challenges of mAgriculture Innovations (Section 2.2.2 of this work) UCD Principles(Gould & Lewis 1985; Rubin 1984; Wallach & Scholz 2012)	The channelling of information about an mAgriculture innovation from a user to the vendor/solution provider to promote continuous enhancements and user interests	Available feedback mechanism Responsiveness to the feedback
	Support (Sp)	TAM3(Venkatesh & Bala 2008) Deployments of mAgriculture applications in developing countries (Section 2.2.1 of this work) Lessons learnt from existing mAgriculture innovations	The provision of services by an mAgriculture innovation provider such as user training, responding to usage inquiries and fixing bugs	Initial training Continuous support during usage

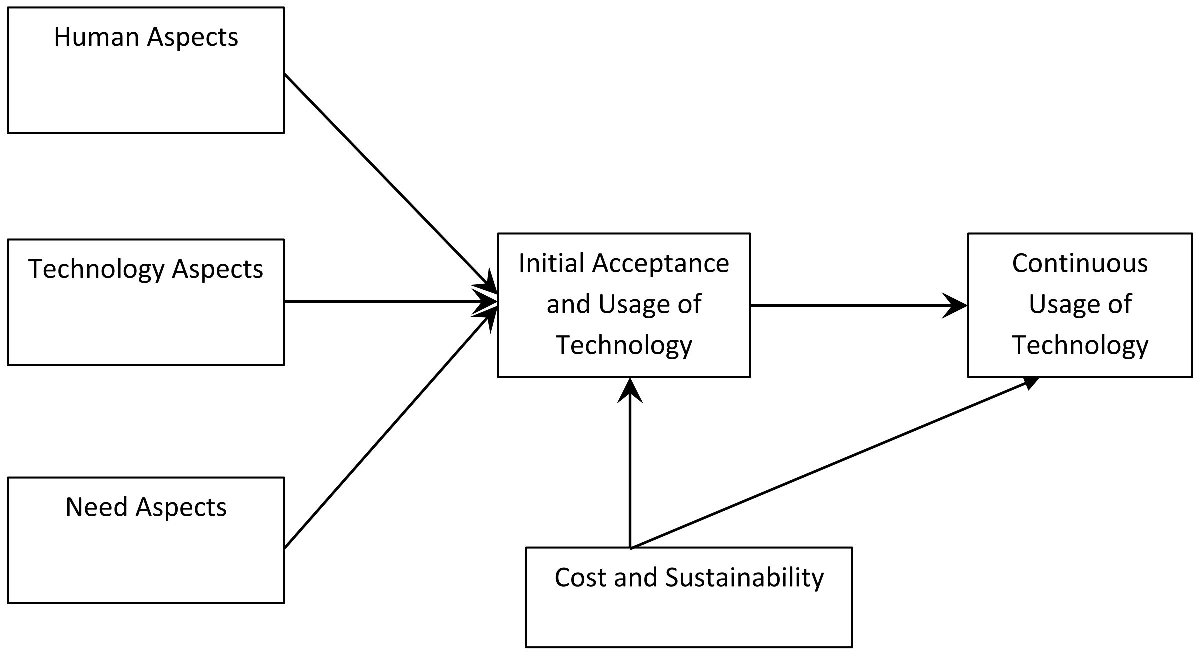


Figure 2.7: Basic view of the proposed conceptual model

The identified human aspects (Trust and Perceived usefulness), the technology aspects (Effort Expectancy, Application Type/Delivery Channel and User involvement in design), the need aspects (User Involvement in Requirements Gathering and Hyper Localization of content and context) and Cost and Sustainability aspects (Price Value, Support and Feedback) all have a direct impact in the initial acceptance and usage of the technology. The constructs addressing Cost and Sustainability have an impact on both the Initial Acceptance and Usage of Technology. Sustainability is critical from the beginning of an innovation to its continuous usage. At the later stages of continuous usage, factors such as a favourable policy framework that enables the continuity of the innovation is important, among any other contextually applicable condition backed by empirical evidence (Luqmani, Leach & Jesson 2017).

The approach of technology acceptance into studying the adoption and usage of mobile technology has been widely used before in studies involving mobile services (Knutsen 2005; Carlsson et al. 2005; Amberg et al. 2004; Pagani 2004; Teo & Pok 2003). In this study, the identified aspects will act as the direct determinants of initial acceptance and usage, further leading to continuous usage when the cost and sustainability factors are implemented as per the user's expectations. The identified aspects namely Human, Technology and Need aspects, influence whether or not the user will be interested in the technology in the first place and spend some time on it before becoming a continuous consumer of it.

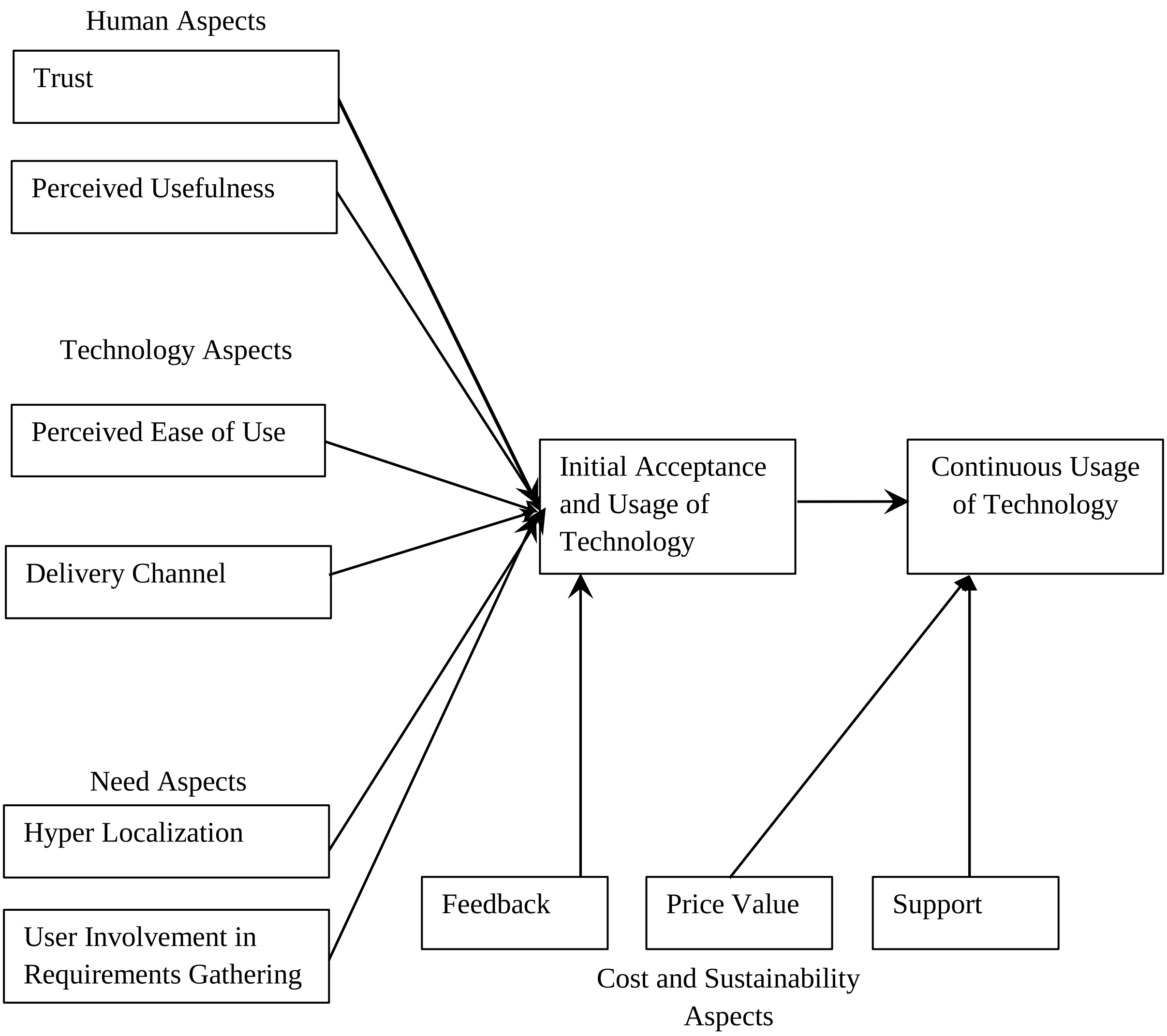


Figure 2.8: A detailed view of the conceptual model

The attributes of constructs presented in the research model were derived, and measurement metrics defined for each one of them. Findings of the literature review and the pre-study exercises informed the formulation of the model, their constructs and thus the attributes to be measured.

A 5 likert scale was used to measure the quantitative data. The scale was found to have sufficient granularity to lead to conclusive impartial responses, unlike a higher scale that might be very granular for the group of respondents, or an even-numbered scale that may lead to measures where an indifferent option is not accommodated. Table 2.6 shows the measurement metrics of the model.

Table 2.6 Measurement Metrics of the model

Constructs	Attribute to Measure	Items of Measurement	Measurement Metric
Trust (Tr)	Level of confidence in the product	I have full confidence in *DigitalFarm* and that is why I accepted to use it	5 Likert Scale
	Referral to others	*DigitalFarm* is useful for me	5 Likert Scale
		I would refer *DigitalFarm* to other farmers	
Delivery Channel (DC)	Preferable type of application	The delivery channel (SMS, Voice, etc) would influence whether I should use *DigitalFarm*	5 Likert Scale
Effort Expectancy (EE)	Ease of use of the application	The *DigitalFarm* SMS service is user friendly	5 Likert Scale
		The *DigitalFarm* Voice service is user friendly	5 Likert Scale
		DigitalFarm is good for me	
Perceived Usefulness (PU)	Subjective Norm(Religious beliefs, cultural beliefs, government/administrative support)	My religious beliefs would influence whether I would use *DigitalFarm*	5 Likert Scale
		Approval from an administrator e.g. a chief would influence whether I would *DigitalFarm*	5 Likert Scale

		The opinion of a community elder would influence if I should use *DigitalFarm*	5 Likert Scale
User Involvement during Requirements Gathering (UIRG)	User contribution to identification of needs	I was asked to specify which information/services I would like to receive from *DigitalFarm*	5 Likert Scale
		The possibility of getting information/services that I am interested in influenced my decision to use *DigitalFarm*	5 Likert Scale
Hyper Localization (HL)		The possibility of getting information which is specific to my region, my category of farming and use of my preferred language influenced my decision to use *DigitalFarm*	5 Likert Scale
	Regional Localization of the product	The information and services I receive from *DigitalFarm* are specific to my region	5 Likert Scale
	Domain Localization of the product	The information and services I receive from *DigitalFarm* are specific to my category of farming/agriculture	5 Likert Scale

	Language Localization of the product Consideration of the user’s operating environment	The information and services I receive from *DigitalFarm* is provided in my preferred language I feel that my operating/working environment has been considered by *DigitalFarm*	5 Likert Scale 5 Likert Scale
Price Value (PV)	Cost of acquisition Running cost of the technology Value for money	I considered the cost of acquisition and continuous cost before accepting to use *DigitalFarm* The cost of acquiring *DigitalFarm* is affordable to me The continuous cost of using *DigitalFarm* is affordable to me *DigitalFarm* is worth the amount of money I am spending on it	5 Likert Scale 5 Likert Scale 5 Likert Scale 5 Likert Scale
Feedback (Fb)	Available feedback mechanism Responsiveness to the feedback	I know how to give feedback concerning *DigitalFarm* I considered the possibility of giving feedback before accepting to use *DigitalFarm* I feel that the feedback I give is usually acted upon	5 Likert Scale 5 Likert Scale 5 Likert Scale

		The response to my feedback will determine whether or not I will continue using *DigitalFarm*	5 Likert Scale
Support (Sp)	Initial training	I considered the possibility of getting Support before accepting to use *DigitalFarm*	5 Likert Scale
	Continuous support during usage	I was given instructions on how to use *DigitalFarm*	5 Likert Scale
		I receive continuous support while using *DigitalFarm*	5 Likert Scale

2.6 Hypothesis Formulation

Following the theoretical arguments brought forward in the reviewed literature, the proposed model and the conducted pre-study of this research, hypotheses were formulated. They were developed based on the influence of various determinants towards initial acceptance and continuous usage of technology. The hypothesis were meant to test:-

- Whether the determinants (Trust - Tr, Perceived Usefulness - PU, Effort Expectancy - EE, Delivery Channel - DC, HyperLocalization - HL and User Involvement in Requirements Gathering - UIRG) may have any significant influence on Initial Acceptance and Usage of Technology.

- Whether Initial Acceptance and Usage of Technology may have significant influence on Continuous Usage of Technology

- Whether the moderators (Price Value-PV, Feedback - Fb and Support - Sp) may have any significant impact on Initial Acceptance and Usage of Technology or Continuous Usage of Technology.

It is on this basis that the hypothesis below were formulated.

Trust (Tr)

Trust was defined as the assured reliance on the character, ability, strength, or truth of an mAgriculture application. Previous research has shown Trust to be a key element in the Initial Acceptance and Usage of Technology (Kim et. al 2009; Quelch & Klein 1996; Disabatino 2000), where it has been found to have positive significant effect towards the initial acceptance of using a system, such as the mAgriculture applications which were the focus of this research. Failure to address the trust barrier is one of the biggest challenges that mobile agriculture services face in building or maintaining their customer base (Loucky 2012). On the other hand, a high level of trust towards a system encourages people to use it (Hoffman et. al 1999) while any mistrust may lead to the initial rejection and subsequent lack of usage of a system. In other instances, Trust may be associated with other supporting services that may not be in the control of the solution provider/vendor such as network capabilities. For example, lack of reliability and reduced responsiveness of the network may contribute towards eroding the users' trust subsequently making them lose the interest in using the technology (Sarker & Wells 2003). In addition, technology interventions that do not involve farmers during planning and design result to lack of trust and interest (World Bank 2012). We therefore hypothesized that:-

H1: Tr has a positive significant influence on Initial Acceptance and Usage of Technology

Perceived Usefulness (PU)

Defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance, this construct has been widely researched on in studies focusing on acceptance of new technologies (Davis 1989; Venkatesh 2003; Venkatesh & Bala 2008). In the referenced studies and others, this has been found to be a key influencing factor towards a user's decision to utilize a technology. This construct has been researched under different mobile for development contexts such as mobile banking (Omwansa 2012), mobile health (Pynoo et. al 2013) and mobile agriculture (Loucky 2012; Orwa 2012). We therefore hypothesized that:-

H2: PU has a positive significant influence on Initial Acceptance and Usage of Technology

Effort Expectancy (EE)

Defined as the degree of ease associated with the use of the mAgriculture application., Effort Expectancy has been a key factor towards the initial acceptance, leading to the continuous usage of a technology (Venkatesh & Bala 2008; Venkatesh 2012).
Mobile user experience brings to consideration that the mobile phone is a personal device most users have an emotional relation to (Advanced Interface Research 2013). The researchers investigated the user friendliness of the system, based on their interactions with the provided interfaces. We therefore hypothesized that:-

H3: EE has a positive significant influence on Initial Acceptance and Usage of Technology

Delivery Channel (DC)

Delivery Channel was defined as the specific type of a mobile application or system accessible via a mobile device. The construct was derived from pre-study analysis, after establishing that the mode of interaction (i.e. SMS, Voice, Installable Application, USSD or IVR) had an impact towards the choice and initial acceptance of using an mAgriculture technology. This was also supported by previous research work done on mobile software engineering and development (Microsoft 2008; Microsoft 2009; Wasserman 2010). We therefore hypothesized that:-

H4: DC has a positive significant influence on Initial Acceptance and Usage of Technology

Hyperlocalization (HL)

Hyperlocalization was defined as the ability to present application features and content in the actual context of the user, considering their day to day activities, language of communication, region and environment. The establishment and subsequent observation of this construct was informed by the pre-study done by the researchers, the identified challenges of mAgriculture innovations, and the lessons learnt from existing mAgriculture innovations. Previous research on mAgriculture applications recognized the importance of localizing information as per the needs of the farmers (Lokanathan 2010; McNamara 2009; Mittal et. al 2010). This was supported by the positive significance the construct demonstrated towards the Initial Acceptance and Usage of Technology. Moreover, ICT innovations are regarded as an effective way to ensure that rural farmers receive localized and customized information, in a comprehensible format and appropriate language (World Bank 2012). We therefore hypothesized that:-

H5: HL has a positive significant influence on Initial Acceptance and Usage of Technology

User Involvement in Requirements Gathering (UIRG)

This construct aimed at looking at the effect of the user's involvement in the identification of needs (requirements gathering) towards the Initial Acceptance and Usage of the Technology. The importance of this aspect has been highlighted in previous work on critical components to consider before the design and development of a system (Sommerville 2015; ISO 9241-210 2015; Hoffman 2008). Moreover, this was one of the important preimplementation intervention identified in TAM3 (Venkatesh & Bala 2008). We therefore hypothesized that:-

H6: UIRG has a positive significant influence on Initial Acceptance and Usage of Technology

Price Value (PV)

Defined as the consumers' cognitive trade-off between the perceived benefits of the applications and the monetary cost of using them, the cost aspect of a technology is one of the key factors that determine its initial acceptance and also continuous usage. In Kenya, farmers pay between USD 0.06 and USD 0.12 for mAgriculture SMS services, which is considered expensive given that most of them are not large scale farmers and they do not get good prices for their farm produce (Gichamba 2015). In this study, the researchers observed this phenomenon by putting into consideration the cost of initial acquisition of a technology, the running cost and the value for money. Price Value has been widely researched in technology acceptance models (Venkatesh et al. 2012; Kleijnen et. al 2004). Moreover, cost is a key component that determines the continuous usage of a technology (Aker, 2011; De Silva & Ratnadiwakara 2010). We therefore hypothesized that:-

H7: PV has a positive significant influence on Initial Acceptance and Usage of Technology

Support (Sp)

The investigation of this construct was motivated by existing deployments of mAgriculture applications in developing countries, observations made during the pre-study of this research and lessons learned from existing mAgriculture innovations. Support was defined as the provision of services by an mAgriculture innovation provider such as user training, responding to usage inquiries and fixing bugs.

Support has been regarded as a key aspect of initial acceptance, but more so continuous usage of a technology or a product. In mobile-based services, it has also proven to be critical in determining continuous usage of a technology (Pfitzer & Krishnaswamy 2007). We therefore hypothesized that:-

H8: Sp has a positive significant influence on Initial Acceptance and Usage of Technology

Feedback (Fb)

Feedback was defined as the channelling of information about an mAgriculture innovation from a user to the vendor/solution provider to promote continuous enhancements and user interests. Of interest to the research was the impact of the availability of a feedback mechanism which can be used by users, as well as the responsiveness of that feedback by the solution provider/vendor. Majority of mobile-based services are yet to move beyond providing information to providing responsive systems with feedback mechanisms (World Bank 2012). As supported by the positive significance score towards the Initial Acceptance and Usage of Technology, Feedback has been regarded as a critical component for mobile-based services in development such as mAgriculture (World Bank 2012; InfoDev 2011).

Availability of feedback mechanisms promotes ownership of a system by the target users since it makes them feel well considered and an important stakeholder (Qiang et. al. 2012). Effective feedback channels are critical to enable the provision of feedback. Stakeholders in a project can also partner and collect feedback for each other (Lokanathan 2010). We therefore hypothesized that:-

H9: Fb has a positive significant influence on Initial Acceptance and Usage of Technology

Having laid out the various constructs that the researchers believed to be the initial acceptance and usage of technology, we believe that ultimately the initial acceptance should lead to continuous usage of the technology, as it has been demonstrated in majority of the technology acceptance, adoption and diffusion models (Venkatesh & Bala 2008 ; Venkatesh 2012). We therefore hypothesized that:-

H10: Initial Acceptance and Usage of Technology has a positive significant influence on Continuous Usage of Technology

2.7 Conclusion

In this chapter, discussions were done on the pre-study activities, mobile software engineering design and development models, the user centred design principles, and the various technology adoption models.

In addition, the last section of this chapter outlines the formation of the conceptual model as informed by the literature review. A detailed discussion on the step-by-step process in the conceptual model formation has been discussed.

The chapter was finalized by the hypothesis formulation process, where the hypotheses to be accepted or rejected were outlined.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The first interaction with the research participants was through the pre-study activities discussed in the previous chapter. These interactions formed the basis of this research, and gave the researchers a clear picture of the research context, environment, profile of participants and the general status of the mAgriculture research domain. The pre-study also gave the researchers an opportunity to identify and interact with the various stakeholders in the agriculture domain, as well as getting valuable input from them that was useful in the commencement of the actual study on the ground.

In this chapter, the research process and the research design are elaborated. We also discuss data collection, data management as well as data analysis. The chapter also explains the thought process, design and development of the *DigitalFarm* System, a system that was designed out of the farmers' needs and which was piloted with farmers in Sagana, located in Kirinyaga county, and Runyenjes in Embu county.

3.2 The Research Road Map

The previous chapter discussed in detail the existing literature in the research domain. Several aspects were explored such as the ICT Innovations in agriculture, mobile software engineering design and development models, user centred design principles, adoption of mobile technology and technology acceptance models. With a solid literature, technology models reviews and the pre-study results, the conceptual model was formulated. During the pre-study exercise , the researchers interacted with groups of farmers and collected information relating to their nature of farming, exposure to mAgriculture innovations, as well as investigated what user needs could be met using mobile technology. This was followed by the design of a mobile –based farmers advisory and information system known as *DigitalFarm* which was addressing the needs raised by the farmers, as well as providing a platform to test and proof best practices in the design and development of mAgriculture applications. The system was deployed on the ground, with users in the research group being automatically registered, with a provision for the public to join the service for free. Figure 3.1 shows the entire research process.

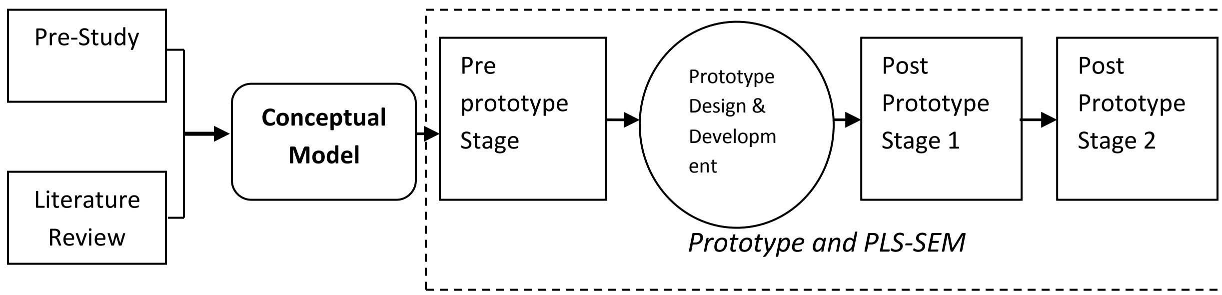


Figure 3.1: The Research Road Map

The *DigitalFarm* prototype, which was deployed among farmers was used to validate the conceptual model. Continuous interaction was maintained with the farmers and agriculture advisors using the system. Feedback on the system was then incorporated in the improvement of the system. The pre-study results and identified challenges among dairy farmers formed key informants towards the design, development and implementation of *DigitalFarm.*

3.3 Selection of Study Area and Needs Identification

As discussed in Chapter 2, a series of pre-studies were conducted in the regions of Wajir, Marsabit, Isiolo, Embu and Kirinyaga. The number of farmers involved in the exercise was 14, 36, 15, 34 and 44 respectively for the five regions. For the actual study, the researchers reduced the areas of research coverage to two: Sagana (Kirinyaga) and Runyenjes(Embu). Farmers in the two regions kept both dairy cattle and dairy goats, which are the two key dairy animals in Kenya. Moreover, the two areas represented the typical environment of a Kenyan dairy farmer, who practices dairy keeping as well as crop farming. A study of crop-livestock combinations in Kenya shows an optimum combination of animals and crops in most parts of the country (FAO, 2001) to enable farmers gain the benefits of both livestock and crop farming. Farmers in

Kirinyaga and Embu, unlike their counter parts in Wajir and Marsabit practiced dairy farming for commercial purposes and not for prestige and cultural purposes.

Sagana is located 100 Kilometers North of Nairobi, within Kirinyaga county. The region is named after Kenya's second longest river, which is also called *Thagana*. The area is popular with dairy and crop farming. For dairy, these farmers keep both dairy cows and goats. For crops, farmers grow maize, beans, tomatoes, potatoes, mangoes, water melons among other crops. The area experiences wet and dry periods over the year and has a good environment for high yield dairy farming and favourable environment for both dairy cows and goats.

On the other hand, Runyenjes is located 152 Kilometers North of Nairobi, within Embu county. Majority of farmers keep dairy cows and also practice subsistence and commercial farming. Crops grown in this area include bananas, maize, beans, butternut, tomatoes and passion fruits.

3.4 Needs Identification

The pre-study exercise in Kirinyaga and Embu lead to the understanding of the farming environment, the farmers' way of life, interaction and exposure to various farm technologies and market dynamics within these regions. The interaction with farmers during the pre-study session lead to a needs assessment exercise that assisted the researchers in identifying which areas ICTs are most applicable among dairy farmers in these regions.

Table 3.1 highlights the areas of need identified among the farmers in Embu County while Table 3.2 highlighted the needs in Kirinyaga County.

Table 3.1: The needs identified in Embu County

Identified Need	SMS	Internet	Voice
Need to receive animal feeding tips from experts	67.9	17.9	17.9
Need to know where to market my produce	35.7	10.7	50
Need for information on the price of milk in the market	39.3	7.2	46.4
Need to receive responses from an expert	46.4	14.3	32.1
Need for an animal diagnosis service	28.6	7.2	53.6
Need to ask questions to an expert	39.3	10.7	39.3
Need to contact an agricultural extension officer	21.4	7.2	60.7
Average	39.8	10.74	42.86

Source: Research

Table 3.2: The needs identified in Kirinyaga county

Identified Need	SMS	Internet	Voice
Need to receive animal feeding tips from experts	81.3	12.5	12.6
Need to ask questions to an expert	62.6	18.8	12.5
Need for an animal diagnosis service	50	18.8	25.1
Need to receive responses from an expert	62.5	18.8	6.3
Need to know where to market my produce	56.3	12.5	12.5
Need to contact an agricultural extension officer	43.8	12.5	18.8
Need for information on the price of milk in the market	43.8	12.5	12.5
Average	57.19	15.2	14.33

Source: Research

The issues highlighted were identified as the top needs to be implemented on the ground in an mAgriculture platform. The most preferable channel of communication for the provision of the desired services by the farmers was SMS.

Since majority of the identified needs concerned the need for information and interaction with experts, the researchers sought to consult a group of extension officers allocated to different regions of the country. Access to the extension officers was given by the Extension Management sector of the Ministry of Agriculture, Livestock and Fisheries. The researchers interacted with 28 government e-extension officers who were distributed in various regions of the country. The 28 respondents came from Kikuyu(2), Turkana(2), Machakos(1), Embu(3), Taita Taveta(1), Meru(5), Kitui(2), Lamu(1), Nakuru(2), Kiambu(1), Makueni(1), Nairobi(1), Kakamega(1), Nyeri(1), Kajiado(3) and Muranga(1). The e-extension officers were selected on the basis of being active in advising farmers using computerized extension platforms availed by the Ministry of Agriculture, Livestock and Fisheries. These platforms are accessible to the e-extension officers via computers, tablet devices and mobile phones. They also offer multiple channels of interaction including web, SMS, and installable mobile applications.

The researchers sought to engage the e-extension officers in a bid to understand their experience with using ICT to advise farmers. The observations below were made:-

a) Frequently used modules on e-extension platforms

Animal Production	**8**	28.6%
Farm Equipment	**4**	14.3%
Food Processing	**7**	25%
Plant Production	**19**	67.9%
Marketing	**12**	42.9%

Figure 3.2: The distribution of questions as asked on the government e-extension platform

b) Means of accessing platforms that e-extension officers use to advise farmers

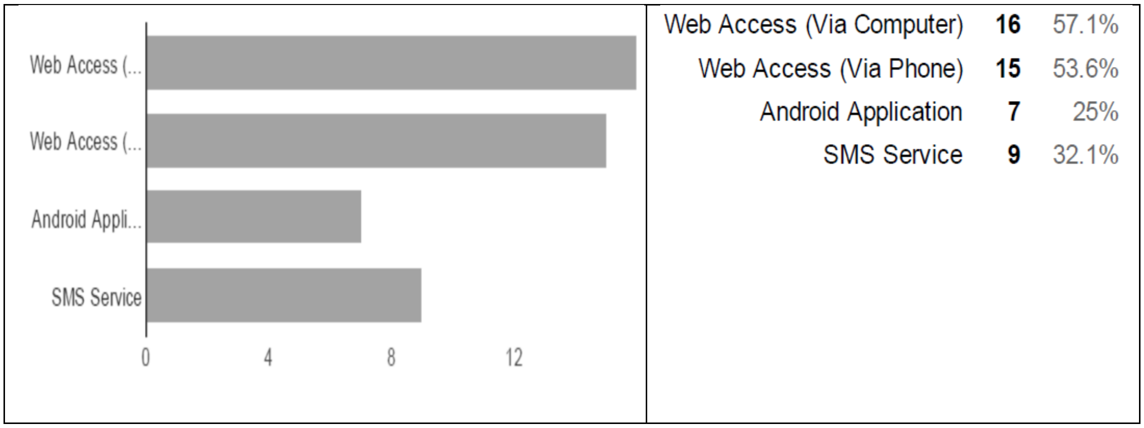


Figure 3.3: The different types of platforms used to access the government e-extension platform

c) Most preferred channel of accessing e-extension platforms

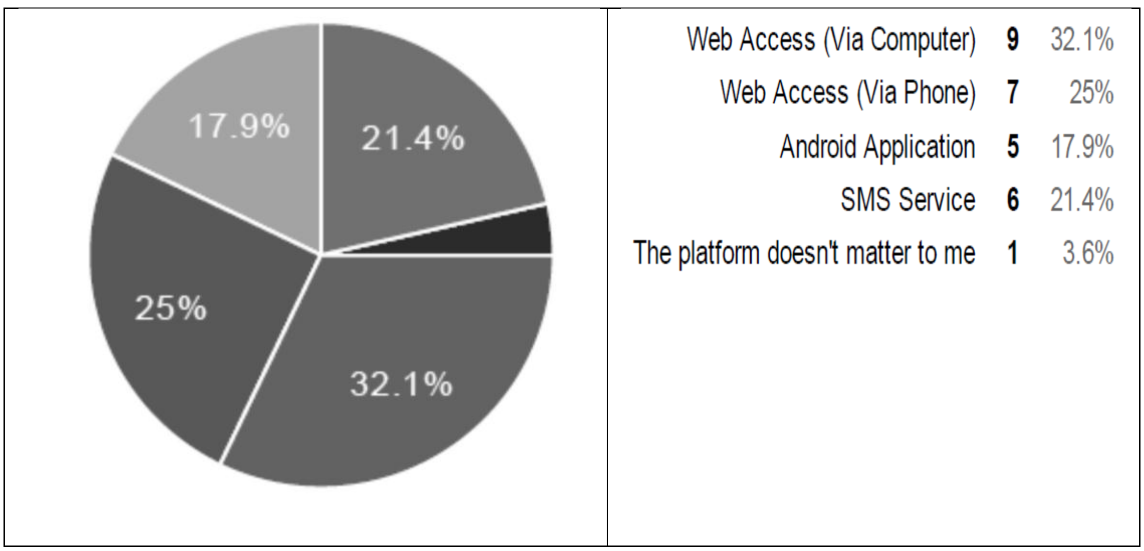


Figure 3.4: The distribution of access channels on the government e-extension platform

Majority of the e-extension officers preferred to access the platform via web access on their computer.

d) Involvement and Consultation during the design and development of e-extension platforms

We sought to find out if the e-extension officers are involved in the design and development of e-extension platforms, as well as being given the opportunity to provide feedback that can be used to improve the platforms. Only 7% mentioned to have been consulted, while 7% were neutral. Among the respondents, 86% mentioned they were never consulted in the design, development or implementation of the system.

e) Suggestions on how e-extension platforms can be improved

The interviewed extension officers gave ideas on how the current e-extension platform provided by the Ministry of Agriculture, Livestock and Fisheries can be improved. Below are some of the suggestions:-

i) Putting rich graphics such as pictures and drawings

ii) Connection to social sites where farmers can interact and share

iii) Avoiding many steps before accomplishing a task on the platform

iv) Facilitation of officers with sufficient internet bundles

v) Frequent updating of new farming techniques

vi) Packaging appropriate materials for specific areas

vii) Provide templates for agriculture business plans and gross margin calculations that can be shared with farmers

viii) More information on emerging crops and dairy breeds

ix) Awareness to farmers concerning the availability of e-extension platforms and how they can engage

f) Challenges in using current e-extension platform

The e-extension officers highlighted the challenges they face when using the e-extension platform. They include:-

i) Technical and detailed language on the platform
ii) Lack of internet bundles to access the online platform
iii) Lack of internet access in some regions of the country, thus making it difficult to access information
iv) Poor usability of the e-extension platform
v) Lack of information on some crops and animals farmers are inquiring about
vi) Following up farmers
vii) Illiteracy among farmers
viii) Lack of electric power in remote areas making it difficult for the e-extension officer to frequently access information
ix) Poor mobile network coverage in some regions of the country

3.5 Prototype Development

Based on the discussions of the literature review and the findings of the pre-study exercises, a sufficient foundation was formed with regards to the design and development of a prototype. The requirements were gathered from interactions with farmers via questionnaires and focus group discussions. The top needs identified on Table 3.1 and Table 3.2 formed the initial scope of the prototype. In addition, the preference of the platform informed the choice of the implementation platform that was selected by the researchers.

The prototype was useful in validating the developed conceptual model, and making further investigations during the interaction of the farmer with technology, as discussed in the results section of this work. Using the prototype, it was clear to identify the factors that influence the initial acceptance and usage of an mAgriculture technology, and the continuous usage of the same technology over a period of time by farmers and other stakeholders in agriculture.

Farmers were involved during the design and development of the prototype, whereby the researchers used the agile development approach in order to develop a user-centred design product. The feedback provided was used to continuously improve the system to the satisfaction of the users. The full details of prototype design and development are discussed in Chapter 4.

3.6 Research Philosophy and Design

This research took a positivism philosophy. In this viewpoint, the researchers relied on the values of truth and validity gathered throughout the research process by direct observations. In addition, existing theory was used to develop hypothesis which were tested and confirmed or rejected leading to further development of theory (Saunders, Lewis & Thornhill 2008) and which led to the derived research model. Several approaches were considered during the execution of this research exercise. This section provides information on the philosophy and design of the research. The approach used is highlighted, together with a discussion concerning the sample methods and size, and the data analysis plan.

The following steps were taken in carrying out this research exercise:-

i) Selection of research participants from groups of farmers, which was based on gender, age, mobile phone ownership, dairy animal ownership and ability to read and write in either English, Swahili or mother tongue.

ii) The selected group of farmers was educated on the usefulness of mobile phones in agriculture, and the potential transformation mAgriculture can bring to farmers. Information was collected from the group of farmers using the FGD guide and questionnaires on Appendix A at different stages of the research.

iii) The questionnaires and FGD discussions were analysed, and specific needs were identified among the group of farmers. The need for information was key to the majority of respondents.

iv) Consultation with e-extension officers attached to the Ministry of Agriculture, Fisheries and Livestock was done in order to put their experience into consideration as they have worked with farmers all over the country. Specifically, this group of extension officers used ICTs to carry out their advisory duties and therefore their lessons learnt over time was paramount to this research. The questionnaire on Appendix A2 was used to collect information from the e-extension officers.

v) The initial design and development of the prototype was done. It was launched for the group of farmers as an SMS and Web-based service.

vi) Continuous feedback and evaluation was done on the prototype, while considering the feedback of farmers.

vii) Partial Least Squares (PLS) predictive modelling technique was used to predict the effect of independent variables that influence the initial acceptances and usage, and continuous usage of an mAgriculture platform.

3.6.1 Data Collection Methods

In order to achieve good quality, a mixture of approaches to achieve qualitative and quantitative data was employed in this research. The following data collection methods were used:-

a) Questionnaires

Data from farmers was collected using physical paper-based questionnaires with the assistance of research assistants during the Pre-Study, Pre-Prototype, Post-Prototype stage 1 and Post-Prototype stage 2 phases of the study. In addition, the e-extension officers questionnaire was administered electronically using Google Forms, an online data collection tool provided by Google.

Questionnaires provided the best way to collect primary data from farmers on the ground as well as the extension officers. Moreover, they provided the opportunity for the researchers to ask further questions in order to get a better understanding of a concept or phenomena. In addition, during the model validation phase, the exact same questionnaires were used in the different stages of measurement, thus ensuring consistency and reliability of the responses received from the farmers. Also, the easy coding provided by questionnaires provided the most appropriate inputs for a mathematical modelling process used in this research.

The questionnaires were administered by the principal researcher, with the assistance of two research assistants.

b) Focus Group Discussions

This was conducted during the Pre-Study phase of the research. The researchers used a Focus Group Discussion guide shown on Appendix A5.

Using an FGD approach during the Pre-Study phase of this research provided an opportunity for the researchers to discover how different groups thought and felt about using mobile phones in agriculture. It was also a forum where farmers suggested potential solutions with regards to using mobile technology in agriculture. Through this, the researchers were able to gather useful perceptions and opinions from farmers, acquired a wealth of information gathered from experience and picked key inputs that shaped the course of the research work.

The FGD was moderated by the principal researcher and local research assistants for each of the different groups of farmers engaged during the Pre-Study.

c) Observations and assessment of feedback logs on the usage of the prototype were made and recorded during the post- prototype stages.

This approach was appropriate as it provided the researchers with an opportunity to collect objective views with regards to the usage of the system, which was key for the model validation process. This also enabled quick reviews and revisions of the system as the usage was going on, thus ensuring improved value and satisfaction among the users.

3.6.1.1 Exploratory Research Phase

The exploratory phase of this research was meant to enable the researchers grasp a deeper understanding of the mAgriculture space. This was carried out among groups of farmers during the pre-study phase, as well as during the actual research phase. Through this approach, the researchers directly interacted with farmers whilst within their farms, in *baraza* settings and in training sessions as a Focus Group formation. Expert surveys were also used to gather information from specialized groups such as agriculture e-extension officers and expert farmers. More importantly, information was gathered via the observation of the usage of the developed prototype. The gathered information also included system logs and recorded interactions between the farmers and the system. In addition, the designed questionnaires included open-ended questions to provide the respondent with an opportunity to express views that would have been difficult to express using close-ended questionnaires.

3.6.1.2 Questionnaire and FGDs Guideline Design

The attributes to be measured from the research model provided a guideline on the items of measurement to be considered for each attribute, and the constructs from which it was derived. The items of measurement were used as a guideline to the design of the questionnaire.

The questionnaire was piloted before the main data collection exercise, and revised to ease the data collection exercise and be understandable to the respondents. The FGD guidelines were also revised in consultation with agriculture experts in the area where the research was taking place.

3.6.2 Sampling and Sample Size

The research exercise involved different numbers of participants for the various stages that took place. Table 3.3 shows the number of participants involved during each stage of the research exercise.

Table 3.3: The participants involved in different stages of the study

Stage of Study	**Type of Participants**	**No. of participants**	**Total Participants**
Pre-Study	Farmers	143	143
Pre-prototype	Farmers	78	106
	e-Extension Officers	28	
Prototyping Stage 1 and Stage 2	Farmers	78	80
	e-Extension Officers	2	

During the pre-study exercise, the researcher interviewed 143 participants drawn from five different regions of Kenya namely Kirinyaga, Embu, Isiolo, Wajir and Marsabit. The participants from Isiolo, Wajir and Marsabit involved full participation of the selected groups, while for the participants from Kirinyaga and Embu, the researchers used the sampling method below to select a smaller section of farmers from a group of 200. In the Pre-prototype stage, the researchers narrowed down to participants from Kirinyaga and Embu. Participants from the two regions were found to satisfy the selection criteria required in the development of the mAgriculture prototype, which included variation of gender, mobile phone ownership, dairy animal ownership and ability to read and write in English, Swahili or mother tongue. The regions also satisfied the telecommunication infrastructural requirements to design, develop, test and implement an mAgriculture prototype, given its network coverage, and the variation of mobile devices among farmers. In addition, the Pre-prototype stage involved 28 e-extension officers who assisted in the providing insights into the socio-technical requirements of the mAgriculture prototype. The 28 participants were purposively selected from a group of 46 e-extension government officers, to represent different regions of the country. The Post-prototype stages targeted the 78 participants involved in the Pre-prototype stage, and only 2 e-extension officers who had the required expertise to interact with farmers by answering their questions and offering advisory information via the developed mAgriculture prototype.

To acquire the minimum sample size for the Pre-prototype and Post-prototype stages, the researchers used the finite population formula (Kothari, 2004) as below:-

$$n = \frac{z^2 \text{ x p x q x N}}{e^2 \text{ (N} - 1) + z^2 \text{ x p x q}}$$

$$n = \frac{1.96^2 \text{ x } 0.02 \text{ x } 0.98 \text{ x } 200}{0.02^2\ (200 - 1) + 1.96^2 \text{ x } 0.02 \text{ x } 0.98} = 97$$

Although 97 participants are required, only 78 were recruited based on the criteria used to select an adequate sample of participants as described earlier on this section. Based on the selection criteria used, the number of selected participants made a statistically significant number. Moreover, Partial Lease Squares Structural Equation Modeling (PLS-SEM), which is the analysis approach applied in this research, can be satisfactorily done with small sample sizes. Goodhue, Lewis and Thomson (2007) demonstrated that reliable PLS results can be achieved with a sample size of 40 participants. It is also important to note that sample sizes in research would vary from one type of study to another (MacCallum et al. 1999), and what is critical in evaluating the adequacy of the sample, such that the sample is unbiased and of high quality (Kothari 2004). Furthermore, while covariance-based SEM requires cases that exceed 100 observations (Nasser & Wisenbaker 2003) , and other researchers recommending at least 200 cases (Marsh et al. 1998), PLS is applicable in conditions of small sample sizes (Haenlein & Kaplan 2004). Earlier research by Chin and Newsted (1999) demonstrated that it is possible to perform PLS with a sample size of 50. Chin, Marcolin and Newsted (2003) further cited earlier studies that showed PLS can be used to analyze 27 variables using two latent constructs with a data set consisting ten cases. Mobile-based services for development for example mHealth have also been studied using PLS approach (Mburu 2014).

In these two regions, the common dairy animals are cows and goats. The average number of dairy animals per farmer was 4 cows and 3 goats. Besides dairy farming, the farmers also practice other economic activities such as crop farming, business establishments of varying nature and formal employment.

3.6.3 Data Management

Both qualitative and quantitative data was collected from the research exercise. The data was coded and analysed, and later interpreted to give the different perspectives using the research model. The interpretation results were used to accept or reject the research hypothesis outlined by the researchers. Specifically, the process below was taken in the management of data:-

a) Data Preparation

In this stage of data management, the following was done:-

i) *Checking the questionnaires and FGD guide to eliminate unacceptable questions*

This involved checking the questionnaires and FGD guide for completeness, ensuring that the respondent followed the instructions provided, checking for variance in responding to answers (e.g. providing the same answer for all questions), physical completeness of pages, as well as ensuring the selected participants are the only ones who participated in the research.

ii) *Coding and Transcription*

The responses provided in the questionnaires were coded to numerical values which were fed into SPSS and SmartPLS for analysis.

Notes were taken during the FGD sessions from where various themes were identified.

iii) *Cleaning*

This involved checking the responses for inconsistencies, missing values and outliers.

With regards to data collected using observations, the researchers involved more research assistants in order to avoid observer-bias among the participants. Moreover, observations made by the researchers and assistants were harmonized and evaluated for consistency. In addition, data collected through assessment of feedback logs from the system was categorized into different themes, and used as input towards the design, development and implementation of the prototype during the post prototype stages.

b) Data Processing

PLS-SEM technique was used for predictive modelling using SmartPLS tool.

PLS is a modelling approach to Structural Equation Modelling (SEM) where assumptions about data distribution are not made (Vinzi, et al. 2010). PLS-SEM is a good alternative to the widely used Covariance-based Structural Equation Modelling (CB-SEM), which is the preferred data analysis method for today for confirming or rejecting theories through testing of hypothesis, when there is a large data sample size, normal distribution and correct model specification (Wong 2013).

PLS-SEM is especially preferable to CB-SEM when the following circumstances are encountered in research (Wong 2013; Hwang, Malhotra, Tomiuk & Hong 2010):-

i) Small sample size

ii) Little available theory about applications

iii) Predictive accuracy is vital

iv) Correct model specification cannot be guaranteed

This approach to data analysis has been widely used in many areas including management information systems (Chin et al. 2003), business strategy (Hulland 2009) and behavioral sciences (Bass, Avolio, Jung & Berson 2003).

This process began by making a pre-test assessment among the participants, which was done in February 2015. The main purpose of this pre-test activity was to understand their current exposure, experience, understanding and perception about mAgriculture. The information gathered in the pre-test phase, combined with the learning from literature was used to conceptualize the research model, which was followed by a deployment of the mAgriculture platform among the research participants in May 2015. After the mAgriculture platform was deployed on the ground, two sets of Post-Prototype activities were carried out in order to validate the proposed model, consequently validating the proposed model in the study. The first Post-Prototype activity was done in November 2015, while the second was done in February 2016. In this process, repeated measures were conducted at each stage in the three phases of the study process.

3.6.4 Reliability and Validity Tests

In the four cycles of data collection, the instrument was tested to ensure it is of unquestionable reliability and validity. During the pre-study and pre-prototype phases, the research instrument was piloted among 12 farmers in the different regions where the study took place. Feedback was collected and improvements were made to the research instruments. Some of the improvements included re-phrasing some questions, and reducing the number of questions to a sizeable number that would capture critical aspects of the research, at the same time not burdensome to the respondent. In all the phases of data collection, the researchers engaged the local community through community leaders, in order to receive acceptance especially among conservative communities.

The instrument used to conduct the Post-Prototype tests of the research was tested for reliability and validity by piloting the questionnaires, and making a further analysis of the collected data to ensure it was fit for use in evaluating the constructs that each of the data items was being used to measure. 15 farmers from Kirinyaga county in Sagana area were asked to fill the questionnaire. The farmers were randomly selected from the group of participants, who were involved since the pre-study period. They gave their responses concerning the structure of the questions, the length of the questionnaire, the phrasing of the questions, understanding and usage of certain terms used in the questionnaire and refinement of ambiguous questions. The researchers also observed the time it took to fill in the questionnaire, in order to consider possible time reduction during the filing of the actual study questionnaire. The questionnaire was also reviewed by three professional colleagues who gave their feedback on the content, length of time, structure of questions, and made useful proposals to enhance it. The feedback from both the farmers and professional researchers was collected individually and informed the design of the actual study questionnaire.

The researchers also used methodological triangulation during the data collection exercise. This was done by combining qualitative and quantitative techniques in data collection. To ensure sampling adequacy, the data obtained was from unbiased and of a high degree of quality (Kothari 2004). Comprehensive details on the reliability and validity tests undertaken in the research were captured in Chapter 5, for the data collection cycles that took place.

CHAPTER 4: THE DESIGN, DEVELOPMENT AND IMPLEMENTATION OF *DIGITALFARM* PROTOTYPE

4.1 Introduction

The pre-study sessions carried out with various groups of farmers as described in Chapter 2 and Chapter 3 gave insights of the level of exposure of farmers to mAgriculture applications and also identified different needs among them that were to be tackled using technology. The existing mAgriculture applications were studied at length, and critical observations made in various stages of their life cycle. This informed the researchers on the issues facing farmers in the use of mAgriculture applications and what consideration during the design, development and deployment of such applications needed to be made. Most of these observations were documented in Chapter 2 under the review of existing mAgriculture innovations.

The observations made among farmers in the use of mAgriculture applications and their needs led to the identification of constructs that were fed into the conceptual model. Notable contributions that were fed into the model include the farmer's ease of use with regards to the system (Effort Expectancy), channel of interaction between farmers and experts, user involvement in requirements gathering, and other factors such as price value, support and trust.

DigitalFarm System is a user-centric mobile (SMS and Voice) and web-based solution that provides farmers with a platform to interact with agriculture experts, acquire market information, get actionable advise on dairy and crop farming, and continuous learning on various matters concerning dairy and crop farming.

During the design and development process, the researchers used the constructs of the model as a blueprint to guide the prototyping process. Table 4.1 below shows how the constructs were mapped into the design, development and implementation processes.

Table 4.1: The design, development and implementation matrix in relation to the constructs

Construct	Application	Design	Development and Implementation
Trust	Instilling confidence among farmers and creating ownership in the Design and Development process	Keen focus on farmers needs e.g. choices of menu options	Implementation of specific needs as desired by the user
Delivery Channel	Being selective on the specific technology of delivery preferred by farmers	Design of user interfaces that match farmers' expectations and based on their devices	Implementation of features to consider the channel of delivery e.g. SMS (short inputs and short responses), voice (clarity, accent, etc)
Effort Expectancy	Being in the user's shows and developing a service which is easy to use	Iterative design to accommodate easiness of use; Design of user friendly interfaces ; mock / paper prototyping	Implementation of interfaces as designed and envisioned during mock prototyping; Focus on user friendliness and ease of service (3 step process to task completion)

Perceived Usefulness	Understanding what personal, group, and society beliefs and norms influence usage of technology	Get the view of opinion leaders (e.g. expert farmers), respected extension officers, include opinion leaders as key prototyping team	Implementation of features supported by opinion leaders , and community models in agriculture.
User Involvement in Requirements Gathering	Making the user a key contributor to the requirements engineering process	Specification of features by the farmer; Design of responses/content format	Implementation of features that are specifically addressing the requirements given by the farmer
Hyperlocalization	Localizing information based on region, category of farming, language of the farmer	Design of various interfaces for different groups of users	Implementation to accommodate the variety of users in terms of language, region, content and environment
Price Value	Considerations of all possible cost aspects from acquisition, running cost and value for money	Lowering cost of entry; minimal running cost; light platform for low bandwidth consumption (web portal)	Implementation of a cost effective pricing that favors the farmer, ensures continuous usage and value for money

Feedback	Provision of feedback mechanisms and responsiveness of feedback	Providing an easy feedback mechanism within the system; considering preferable feedback channels	Implementation of effective feedback mechanisms/ channels; modalities and ways of implementing feedback to enhance user satisfaction
Support	Provision of support during deployment and continuous usage	Inclusion of support mechanisms as part of the eco-system of the innovation;	Implementation of support mechanisms to enhance usage and satisfaction

4.2 Requirements and choice of the platform

The requirements for the *DigitalFarm* system were gathered during the pre-study exercise, where farmers gave their opinions concerning the services they would wish to receive, as described in tables 3.1 and 3.2.

Farmers were asked to select which channel they wanted to use to interact with the mobile-based system. The top four needs indicated that the farmers would wish to receive the information via SMS and Voice, followed by the Internet. Table 4.2 below shows the analysis of needs versus the platforms of choice for the various identified areas of needs by the farmers for the four top needs identified in both regions, that included:-

a) The need to receive animal feeding tips from experts

b) The need to know where to market produce

c) The need to know the price of milk in the market

d) The need to ask questions and receive responses from an expert

Table 4.2: The identified needs among farmers and the choice of information delivery technology

Identified Need	SMS	Voice	Internet
The need to receive animal feeding tips from experts	74.6	15.3	15.2
The need to know where to market produce	46	31.2	11.6
The need to know the price of milk in the market	41.6	29.5	9.9
Need to ask questions to an expert	51	26	14.8
Average	**53.3**	**25.5**	**12.9**

For each of the question, farmers selected their platform of interaction for the service. The first top need was to receive animal feeding tips from experts. 74.6 per cent of the farmers preferred to receive animal feeding tips from experts via SMS, while 15.3% per cent preferred to receive the same information via Voice. Almost a similar percentage (15.2) preferred to receive the information on internet.

The second top need for farmers was to know where to market their produce. For farmers in both Kirinyaga and Embu, it was critical for them to know the up to date prices in the market for milk and commercially farmed crops. The crops included maize, beans, bananas, kales, tomatoes, sweet potatoes, arrow roots, water melons, capsicum, cabbages, butter nuts, coffee and tea.

Farmers in both regions were also interested in knowing what information there was with regards to milk in the market, these being regions where dairy farming is highly practiced by majority of farmers.

The need for advisory information and interaction with experts was evident among the farmers in the study. The farmers wanted to have an method of interaction with experts, especially agriculture extension officers. Currently, the ratio of extension officers to farmers in Kenya is

1:1500 against the FAO recommendation of one extension officer for every 400 farmers (Akuku, et al. 2014). This means that it is very difficult for farmers to access the services of the extension officer due to the large number of farmers they have to handle. This research exercise showed there is a great need on the ground for proper farming advice among farmers.

4.3 Design and Development of *DigitalFarm* System

4.3.1 Modelling Tools and Techniques

The modelling involved developing abstract models of the system, with each representing a different view or perspective of the system. For this purpose, graphical notations were used as per software engineering practices.

4.3.1.1 Use case modelling

The use case diagrams were used in the requirements elicitation phase in order to adequately uncover the requirements and establish the entities interacting with tasks related to the requirements.

i) Farmer Use Case

This use case was used to model the interaction between the farmer and the system.

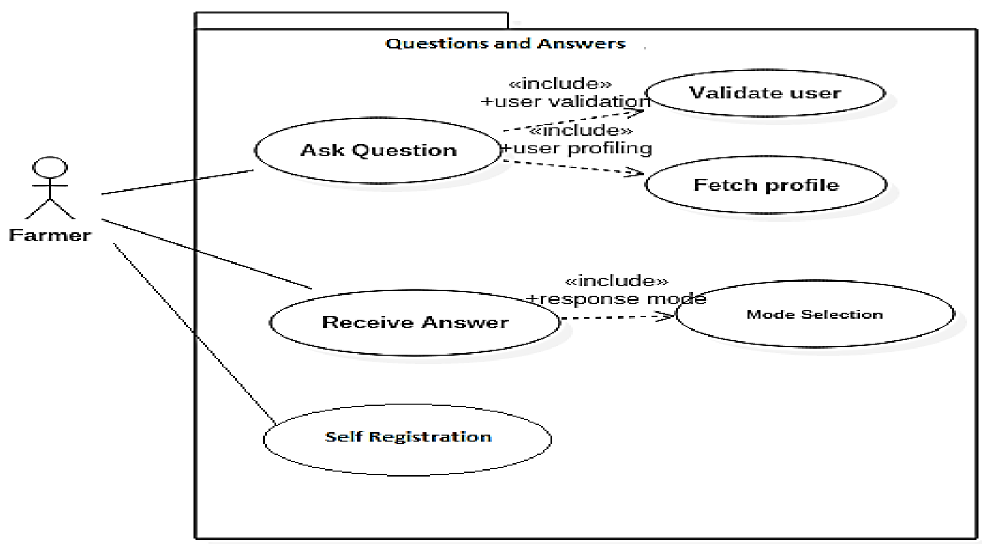


Figure 4.1: The Farmer Use Case diagram

ii) Extension Officer Use Case

This use case was used to model the interaction between the agricultural extension officer and the system.

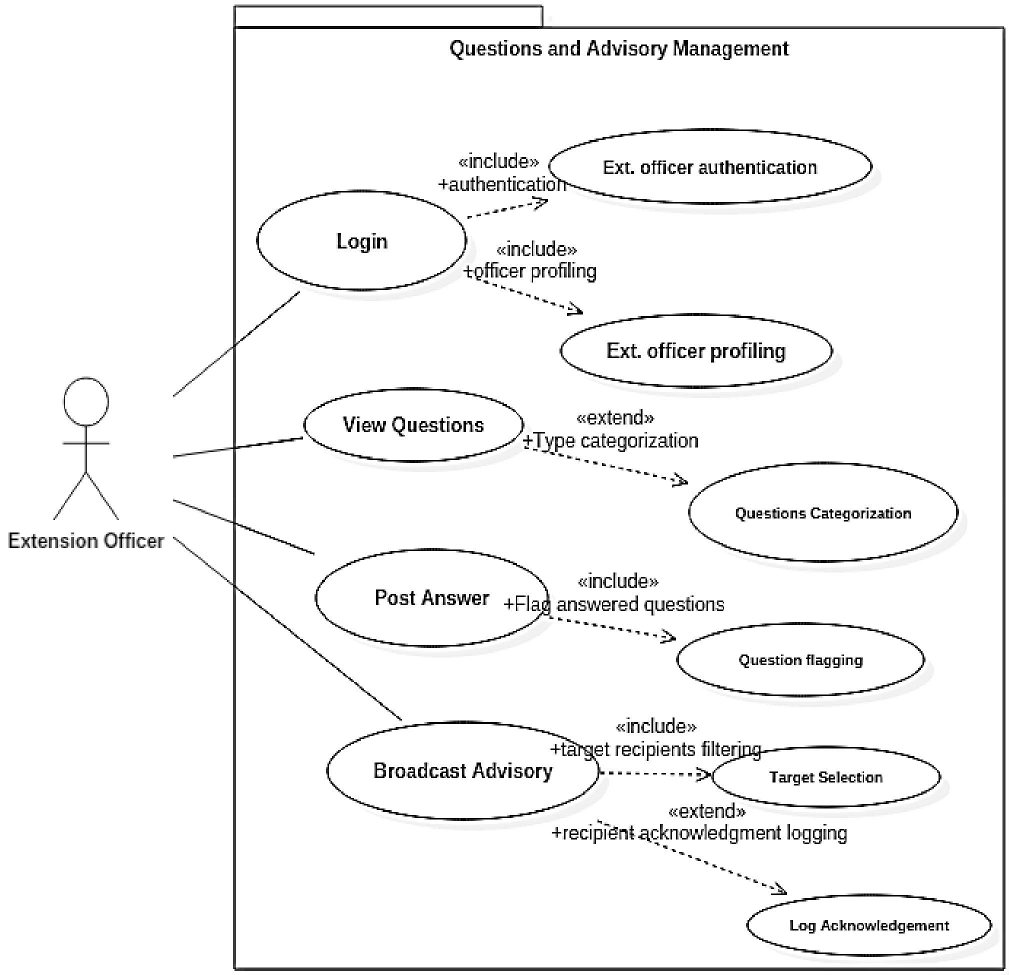


Figure 4.2: The Extension Officer Use Case diagram

iii) DigitalFarm Extension Clerk and System Administrator Use Case

This use case was used to model the interaction between the extension clerk, system administrator and the system.

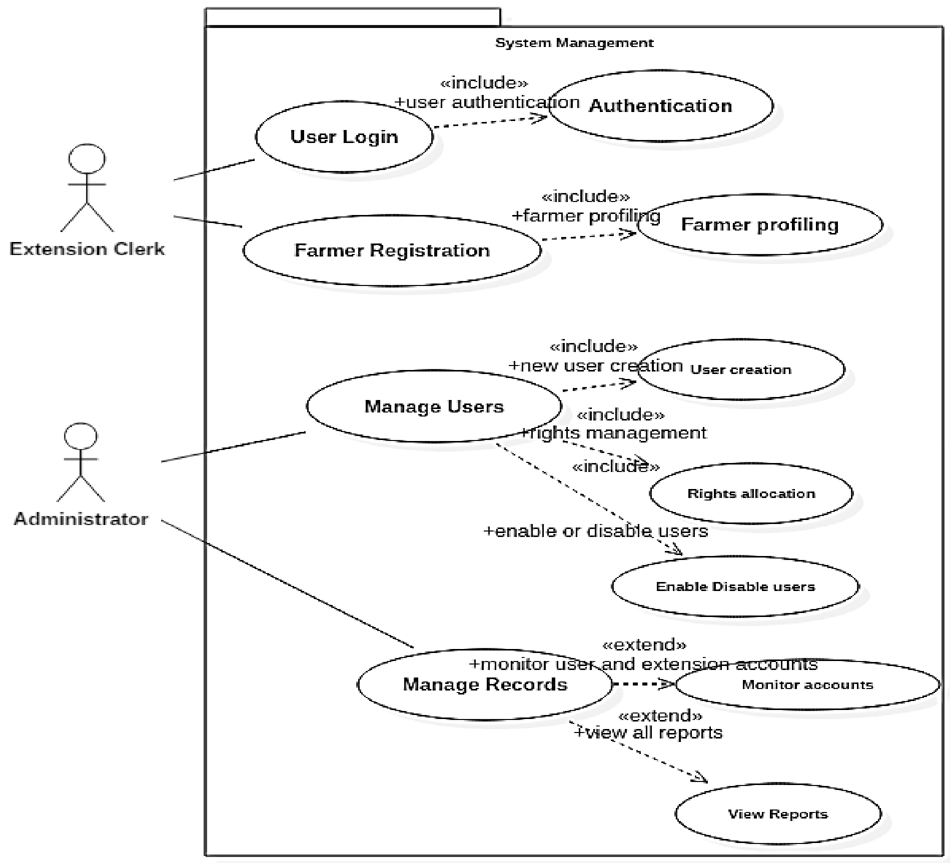


Figure 4.3: The Extension Clerk and System Administrator Use Case diagram

4.3.1.2 Class Diagram

The class diagram was used in the early stages of the software engineering process to represent the relationship between classes in the system and their associations, from which the objects are created.

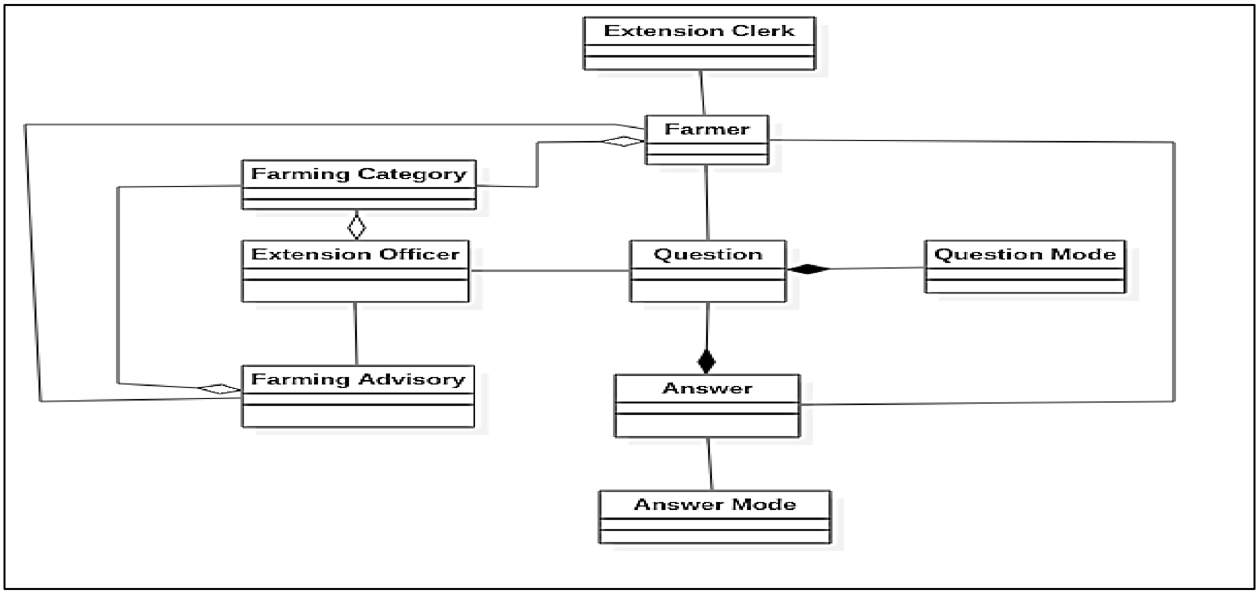


Figure 4.4: The DigitalFarm Class diagram

4.3.1.3 Entity Relation Diagram

The Entity Relationship Diagram was used to illustrate the relationship between the system's entities and the relationships between them. Moreover, it was used as the conceptual and representational model of data used to represent the entity framework infrastructure in preparation to the implementation of the database schema.

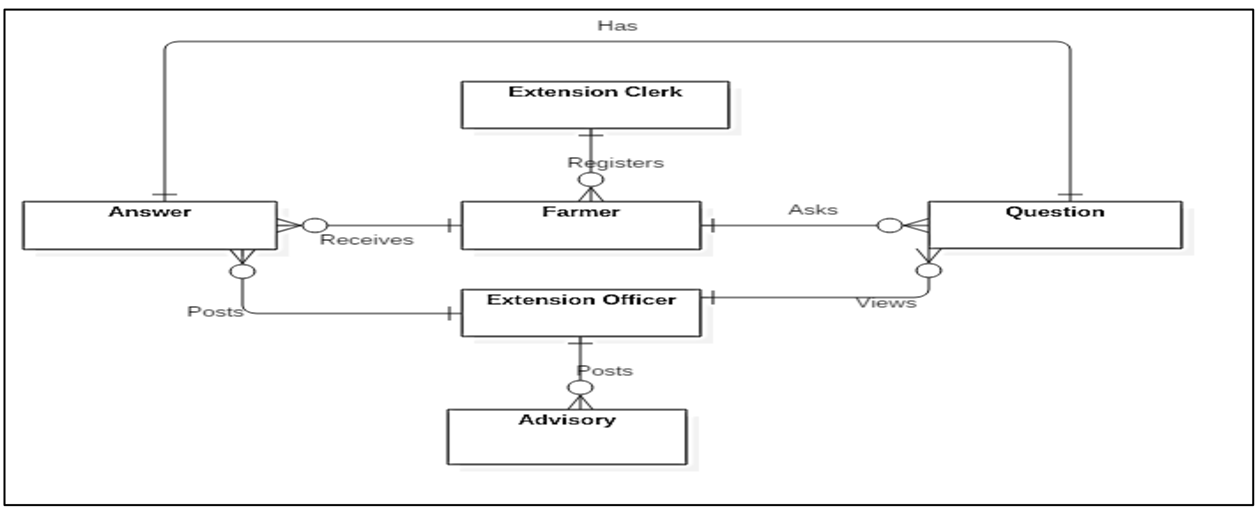


Figure 4.5: The DigitalFarm Entity Relationship Diagram

4.3.1.4 System Architecture

The designed system constituted of various sub-components, which were determined by the needs of the farmers on the ground, the technology available among the farmers and the technological infrastructure exposed to them. Figure 4.1 below shows the architecture of the *DigitalFarm* system as designed and developed in close consultation with farmers.

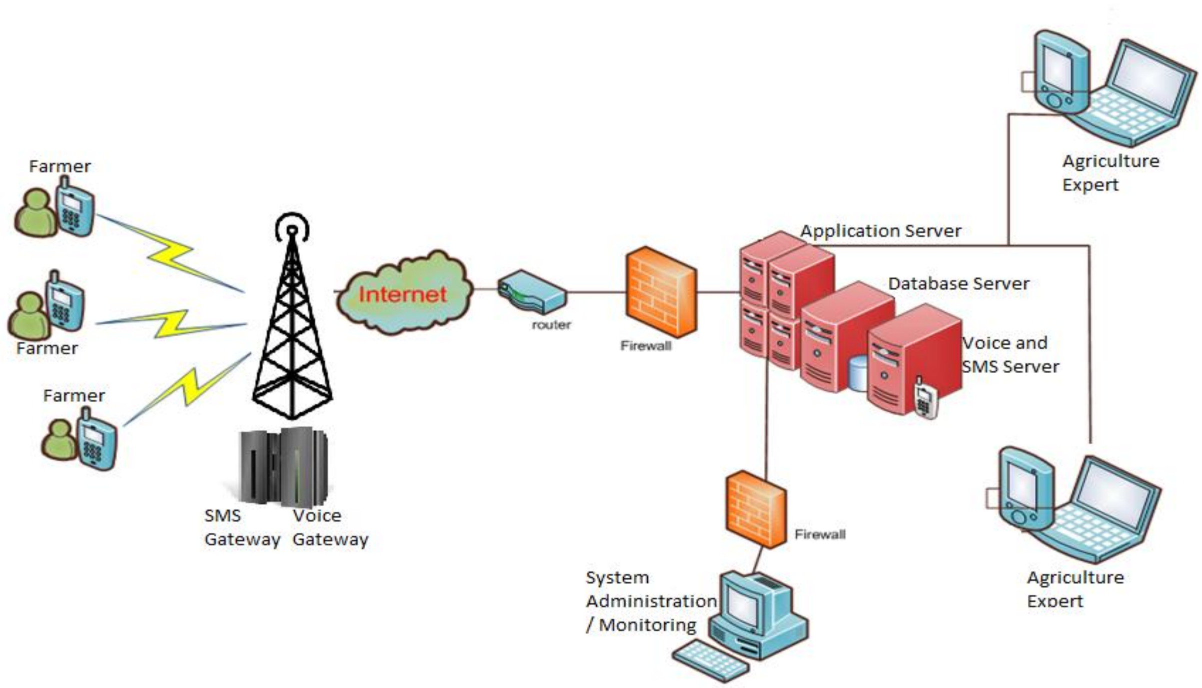


Figure 4.6: The system architecture of DigitalFarm system

The architecture diagram shows that the system allows for two-way interaction, which is via SMS and voice channels facilitated by mobile operators. The system was designed to work with two mobile telecommunication operators namely Safaricom and Airtel. The two networks form the majority of mobile subscribers in Kenya with a subscriber base of 26.6 million and 6.7 million respectively (CA 2017).

The application server contained back-end applications to integrate SMS, Voice and Web platforms. The three sub-components played the following roles:-

a) SMS

- Used by farmers to ask experts questions, using the language of their choice
- Used by agriculture experts to respond to farmers, using the same language the farmer used to ask questions
- Used by agriculture experts to broadcast advisory information to a group of farmers in a specific region

b) Voice

- Used by farmer to ask experts questions, using the language of their choice
- Used by farmers to listen to responses to their questions
- Used by agriculture experts to respond to questions posed by farmers

c) Web

- Integrated voice and SMS components
- Provided an interface through which agriculture experts could view and respond to questions either via SMS or via Voice
- Provided an interface where agriculture experts could broadcast information to farmers

4.3.2 Development Approach

The design and development of the prototype followed an agile approach. By using an agile approach as opposed to a plan-driven approach, the following was achieved:-

i) The farmer was involved in the requirements gathering, design and development process, as well as providing reviews of the system as it was developed.
ii) The system was done incrementally with new features being introduced, as the farmers used the already existing features.
iii) Requested changes were easily accommodated and the system updated to reflect them
iv) The researchers focused on delivering a simple system

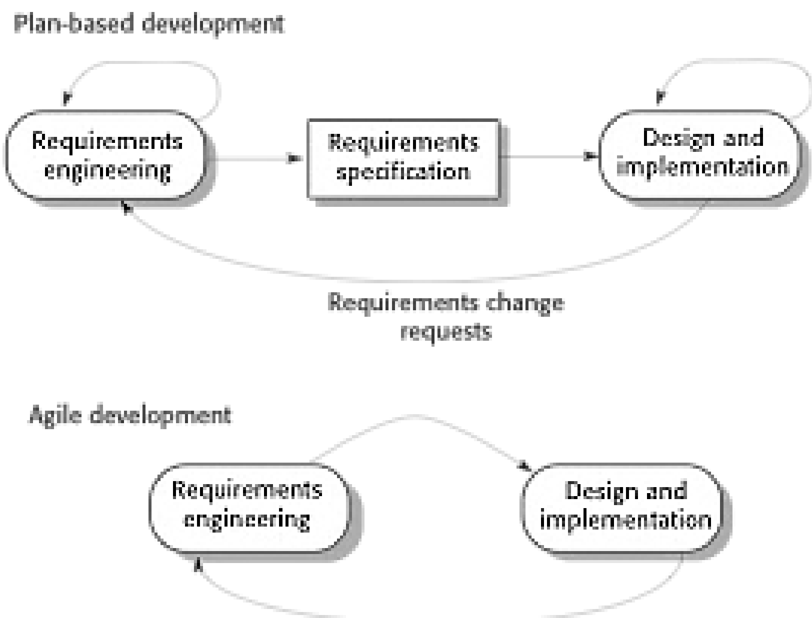


Figure 4.7: Plan-based development vs Agile development (Sommerville 2015)

The researchers sought to use the *lean software development approach*, an agile approach of software development which expands theoretical foundations of agile software development by applying known and accepted lean principles to software development (Poppendieck & Poppendieck 2003). Lean software development is ideal where the development team focuses solely on providing value to the customer, based on lean principles that ensure a timely, efficient, and cost effective means of innovating a product, software or otherwise.

The researchers followed the following process in order to implement the system using this approach:-

Selection of Necessary Top Requirements

The lean development approach emphasizes on the *elimination of waste* as a key factor towards the successful implementation of a software product (Poppendieck & Poppendieck 2003). This waste is regarded as extra features, partially done work and defects related to software development.

Short Iterations

The development process constituted of short iterations that included collection of feedback from farmers. The iterations created a *learning* environment for both the developers and the target farmers, therefore promoting ownership of the project between the two parties. This also ensured *fast delivery* of different increments of the product.

4.3.3 Development Milestones

Prior to and during the development, the researchers went through various stages, all of which involved close interaction with farmers. This interaction consisted of three major stages.

Stage 1 (Time t_1) – Requirements Gathering and Context Understanding

During this phase, the researchers sought to know about the farmers, their farming activities, what else they were involved in besides farming, their exposure to ICTs in agriculture and how they were fulfilling their needs, which would later have potential for ICT implementation such as accessing the services of an agriculture extension officer.

In addition, farmers made suggestions on how they thought ICT and specifically mobile phones could assist them in agriculture. Using the feedback, the design of an mAgriculture prototype began, in close consultation with farmers. Details such as their desired platform of interaction (SMS, Voice, Application) were collected as well as their preferred language of interaction with the technology. Out of this information, a prototype was designed and developed after 4 months of requirements gathering and consultation with farmers.

Stage 2 (Time t_2) – Deployment of the Prototype

The first version of the prototype was deployed on SMS, using English as the language of communication. However, with continuous usage, farmers requested for inclusion of Swahili and mother tongue as the means of communication, something that was immediately adopted in the system.

The voice module was eventually introduced in the prototype, using English voice commands available on an English text-to-speech engine. Due to challenges with understanding the English accent in the text-to-speech engine, the voice commands were translated into recorded English using a local (Kenyan) accent that the farmers could understand. After collection feedback from farmers, the voice module was later improved to accommodate Swahili and mother tongue commands, which offered an interactive voice menu for the farmers. This became one of the major changes incorporated into the system among other smaller changes based on the farmers' feedback. The voice module was developed using Voice XML via a voice gateway connected to the mobile service providers through a premium rate service provider. On the other hand, the SMS module was implemented using an SMS gateway, also connected to the mobile service providers through a premium rate service provider.

Stage 3 (Time t_3) – Continuous usage assessment

With continuous review and feedback to and from the farmers, more farmers enrolled into the system upon referral by other farmers, as well as interest with authorities such as local county governments. From the initial 78 users involved in the study, the system grew to over 1700 farmers in a few months.

4.3.4 Sample Screenshots

Sample screen shots from the system are shown in Figure 4.8 and Figure 4.9.

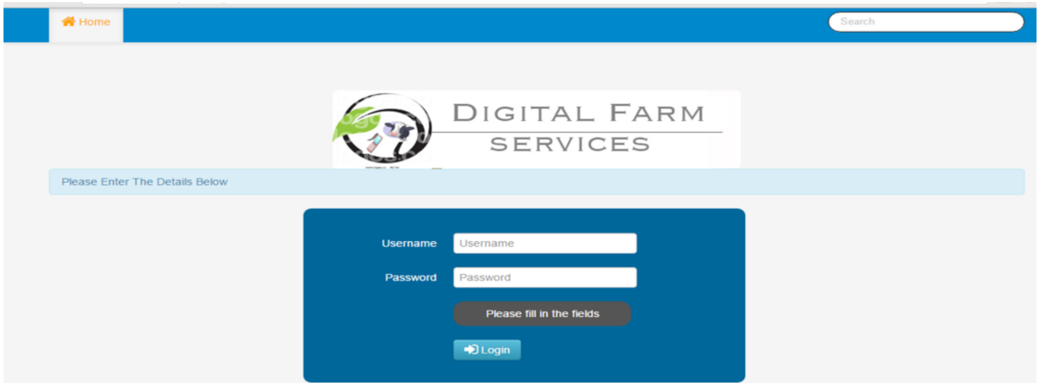


Figure 4.8: DigitalFarm Login Screen

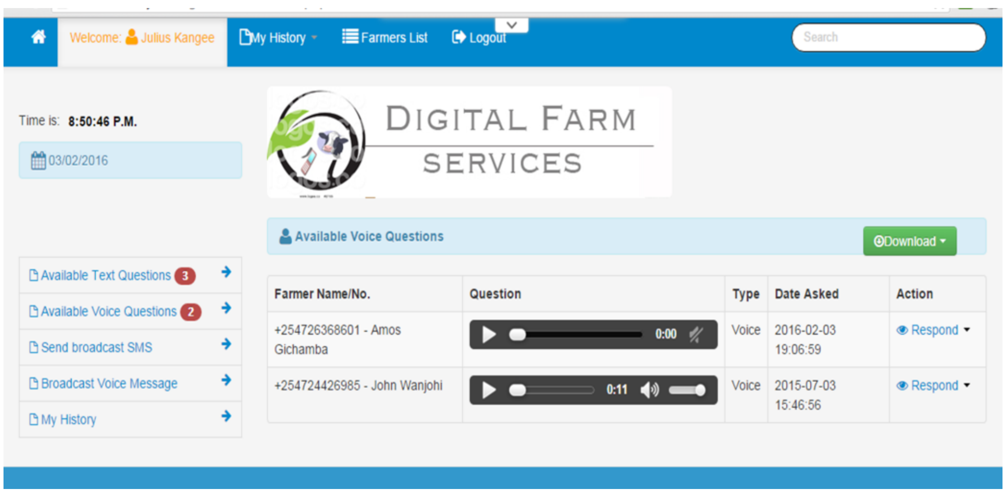


Figure 4.9: Expert Screen to view SMS and Voice questions

More screenshots and sample codes are captured in Appendix C.

4.3.4 Development Tools

Table 4.3: The development tools, platforms and languages used in the development of the prototype

System Component	Development Platforms and Languages	Database	Application Server
Front End Web Interface	HTML5, PHP v6, JavaScript	MySQL	Apache HTTP Server
Back End Web Interface	HTML5, PHP v6, JavaScript		
SMS Module	PHP v6, HTTP SMS Gateway		
Voice Module	PHP v6, Voice XML		

CHAPTER 5: RESULTS AND DISCUSSIONS

5.1 Introduction

This study involved a series of data collection exercises at various stages, for various purposes. To start with, a pre-study was conducted, in order to understand the mAgriculture space in Kenya, explore the existing technologies and establish the penetration of mAgriculture applications among farmers in Kenya. The second phase of data collection of data collection involved the Pre-Prototype phase, which was followed by the Post-Prototype test 1 of the developed mAgriculture platform, *DigitalFarm* as discussed in Chapter 4. The fourth phase of major data collection involved Post-Prototype test 2 results. This chapter elaborates the results of the Pre-Prototype stage, Post-Prototype stage 1 and Post-Prototype stage 2 results. The entire research process towards the realization of the proposed model has been shown on the research road map on Figure 3.1.

5.2 Pre-Prototype Stage Results

The researchers narrowed down on two regions for the Pre-Prototype stage. The two regions were Embu and Kirinyaga. These selected regions were equipped with all the stakeholders that were required in the study, which included extension and livestock officers, expert farmers whose establishments were used as demonstration farms, and groups of dairy farmers who practice dairy farming for commercial purposes. In addition, the ICT infrastructure in these regions was more appropriate for the launch and testing of an mAgriculture platform unlike in the other three regions that had infrastructural constraints. Moreover, the two regions offered better access due to the frequent travels and communication required during the design and testing of the prototype, using the agile approach chosen by the researchers.

In addition, the prototyping process is usually an intensive process that requires a sizeable number of participants in order to achieve meaningful results. The number of participants chosen for the Pre-Prototype stage was considered based on recommendations by previous research in User Centred Design (UCD) and usability studies. In his extensive study on appropriateness of number of participants in usability studies, Faulkner (2003) came up with recommended number of participants to involve during the prototype stage of a product or a service. Table 5.1 shows the results of Faulkner's (2003) research which was based on a large number of studies to establish how various sizes of participants influences the problem discovery level that a study will achieve. This measure shows how meaningful a study is towards informing the design and development of a prototype, which leads to a fully-fledged product or service. This recommended standard has been widely adopted across various industries (Macefield 2009).

Table 5.1: How sizes of participants influence problem discovery level (Faulkner 2003)

No. Users	Minimum % Found	Mean % Found
5	55	85.55
10	82	94.686
15	90	97.050
20	95	98.4
30	97	99.0
40	98	99.6
50	98	100

The benefit of this criterion, in selecting an appropriate number of participants is that it promotes the iterative design processes that are fundamental to a UCD philosophy (Macefield 2009). It also ensures that meaningful findings are achieved with minimal resources even in constrained environments.

44 farmers from Embu, and 34 farmers from Kirinyaga were involved during the Pre-Prototype stage, making a total of 78 participants. To start with, the researchers drilled down further to get more details from the participants concerning their farming profile, capability to use technology, and identified clear needs that could be addressed using technology. The identified needs were established as the features of the prototype.

5.2.1 Pre-Prototype Stage Participants Demographic Details

The 78 farmers chosen for the Pre-Prototype stage practiced both dairy and crop farming. They included 31 female, and 47 male farmers, representing 40% and 60% of the population respectively. Their level of education as shown in Table 5.2 ranged from primary school to university, with university registering the lowest ratio of 10% while high school had the highest ratio of 41%.

Table 5.2: Respondent Gender and Education Level Crosstabulation

		Education Level					Total
		Primary School	High School	College Diploma	University Degree	No Formal Education	
Gender	Male	11	19	11	6	0	47
	Female	7	13	8	2	1	31
Total		18	32	19	8	1	**78**

The age of the respondents involved in the Pre-Prototype stage was spread with both young, middle aged and older respondents being involved. As shown in Table 5.3, the youngest group was within the range of 26 to 35 years, representing the lowest age group ratio at 11.5% while the group aged 56 years and over registered the highest ratio at 37%. This confirmed a previously made observation that the average farmer in Africa is above 60 (Obuya 2015). Moreover, during the FGD sessions, the farmers mentioned that very few of their children have opted to continue with farming as they deem it not lucrative. However, there were instances where some farmers had succeeded to pass over the farming culture to their children.

Table 5.3: Respondent Gender and Age Crosstabulation

		Age				Total
		26-35	36-45	46-55	Over 56	
Gender	Male	3	10	11	23	47
	Female	6	8	11	6	31
Total		9	18	22	29	**78**

The respondents kept both dairy cows and goats as shown in Table 5.4. An average of 96.85% of the farmers kept dairy cows, while an average of 52.65% of the farmers kept dairy goats. Both regions have been one of the few leading in the country in the area of dairy goats keeping.

Table 5.4: Dairy animals kept by the respondents

Region	Cows	Goats
Embu	96.2	46.2
Kirinyaga	97.5	59.1
Average	**96.85**	**52.65**

66% of the total respondents kept dairy animals for other purposes besides selling milk or milk products. Other reasons for keeping dairy animals included to sell later to other farmers, breeding to create pure breeds and sell or retain them, production of manure for farm use and for selling to other farmers and the production of biogas for home use. In addition, majority of the respondents (73.7%) practiced crop farming commercially, besides practicing dairy farming. A smaller percentage reported to be running another business (11.5%) or having been employed (17.3%). This meant that majority of the respondents were full time farmers, relying on their farms as a major source of income.

Majority of the farmers had the technical know-how of using mobile phones during the commencement of the study. As shown in Table 5.5, their skills included using mobile based services such as SIM toolkit applications (e.g. M-Pesa), SMS features, downloadable mobile applications and mobile internet. These observations were important to the researchers as they informed them the capability of the farmers in using various technologies that can be used in the deployment of mAgriculture applications.

Table 5.5: The technical capability of the respondents in using mobile technology

Ability of Respondents to use Mobile Technology	Mobile Technology			
	SIM Toolkit e.g. M-Pesa(%)	SMS(%)	Mobile Application(%)	Mobile Internet(%)
Able to Use Without Assistance	82.5	85.4	68.8	53.3
Neutral	5.9	5.4	12.7	18.3
Cannot Use	9.2	9.2	18.6	28.5

As shown in Table 5.5, the largest number of respondents (85.4%) had the necessary skills to read, write and send SMS messages without assistance. This was closely followed by SIM toolkit applications e.g. M-Pesa and Mobile Network Operator SIM applications where 82.5% of the respondents confirmed that they can operate without assistance. 68.8% had the necessary skills to download and use a mobile application, while 53.3% reported to have the necessary skills to use the internet on a mobile phone. Among the respondents, only 9.2% could not use SIM applications and SMS without assitance, while 18.6% and 28.5% could not use mobile applications and mobile internet respectively.

31.2% of the respondents were already using their mobile phones to request for information related to agriculture. The farmers were using existing mAgriculture applications that they were exposed to, as well as using search engines to find websites that have agriculture-related information via their mobile phones. The majority of the farmers (86.5%) believed that a mobile phone can help them increase their knowledge and skills as dairy farmers.

Table 5.6: Overall needs identified among the respondents and choice of information delivery technology

Identified Need	SMS	Voice	Internet
The need to receive animal feeding tips from experts	74.6	15.3	15.2
The need to know where to market produce	46	31.2	11.6
The need to know the price of milk in the market	41.6	29.5	9.9
Need to ask questions to an expert	51	26	14.8
Need for an animal diagnosis service	39.3	39.4	13
Need to contact an agricultural extension officer	32.6	39.8	9.9
Technology Preference Average	**47.5**	**30.2**	**12.4**

Table 5.6 shows the needs of the farmers, ranging from advisory services from experts to the need for market information for their produce. Majority of the farmers preferred voice and SMS technologies as their first two options. The Internet was the least favorite among the farmers, as it required some knowledge on how to browse online, while at the same time requiring phones with specific features such as data services instead of the basic mobile phone that most farmers owned.

Among the respondents, 79% preferred English as the language of choice for mAgriculture services or information. However, 19.7% of the respondents preferred Swahili as the language of choice for mAgriculture services or information.

5.2.2 Summary of Pre-Prototype Stage Results

The Pre-Prototype stage brought out very critical aspects towards the design and development of an mAgriculture application. The needs identification process lead the researchers to know in advance the kind of problems specific ICTs could address. Also, the respondents' familiarity with different kinds of technology was a key factor to know what kind of platforms would be ideal to be used in delivering the developed innovation.

It was observed that majority of the farmers were comfortable with SMS and SIM toolkit technologies, followed by mobile applications at a lower percentage while mobile internet recorded the lowest percentage. This familiarity and capability to use mobile technology determined the kind of a prototype to be developed. This observation directly coincided with the preferred technologies that the respondents selected for their various needs, as shown in Table 5.6.

The fact that majority of the respondents (86.5%) reported to believe that mobile phones can help them increase their knowledge and skills as dairy farmers showed a positive reception of mAgriculture applications among the participating farmers.

Most of their needs being information and knowledge, the researchers embarked on the design and the development of a platform to address the identified needs. The platform was tailored to address the identified needs, in the farmers context while using a language they understood. The design and development process followed is as explained in Chapter 4.

5.3 Post-Prototype Stage 1 Results

After the design and the deployment of the mAgriculture prototype, *DigitalFarm* as explained in Chapter 4, the researchers observed the usage of the technology by farmers for a period of 3 months. The 78 farmers involved in the previous stage were available for an interview during the Post-Prototype stage 1 assessment.

During this period, farmers were able to give feedback on the system mostly by calling the support line provided for them during the launch of the system.

5.3.1 Post-Prototype Stage 1 Participants Demographic Details

As observed in the Pre-Prototype phases, the farmers practiced both crop and dairy farming. Majority owned both cows and dairy goats. However, a number of farmers only owned dairy cows, while others only owned dairy goats. The farmers practiced commercial crop farming which included bananas, maize, beans, rice, French beans, sweet potatoes, butter nut, tomatoes, Khat(*miraa)*, coffee, passion fruits, tea, coffee, macadamia and bees farming. During the FGD sessions, farmers in Embu and Kirinyaga expressed their interest in doing commercial crop farming in as much as they were focusing on commercial dairy farming.

As shown in Table 5.7 and Table 5.8, the demographic details consisting of gender, education and age remained the same as the previous stage, since this was exactly the same group of respondents.

Table 5.7: Gender and Education Level Crosstabulation

		Education Level					Total
		Primary School	High School	College Diploma	University Degree	No Formal Education	
Gender	Male	11	19	11	6	0	47
	Female	7	13	8	2	1	31
Total		18	32	19	8	1	**78**

As shown in Table 5.7, 23% of the population had reached up to primary education, while 24% had college education. The highest group constituted those who had attained high school education at 41% while only 10% had university education. Among this population only 1% had no formal education.

Table 5.8: Gender and Age Crosstabulation

		Age				Total
		26-35	36-45	46-55	Over 56	
Gender	Male	3	10	11	23	47
	Female	6	8	11	6	31
Total		9	18	22	29	**78**

As shown in Table 5.8 majority of the interviewees were over 56 years at 37% while the lowest group was aged between 26 and 35 years at 11.5%. This indicated that majority of farming was still done by the older generation although the younger generation was progressively embracing farming as well.

As indicated in the pre-study and the Pre-Prototype stages, farmers preferred interactions via the SMS platform, as opposed to the voice platforms. Figure 5.1 shows the interactions recorded on the platform during this 3 month period.

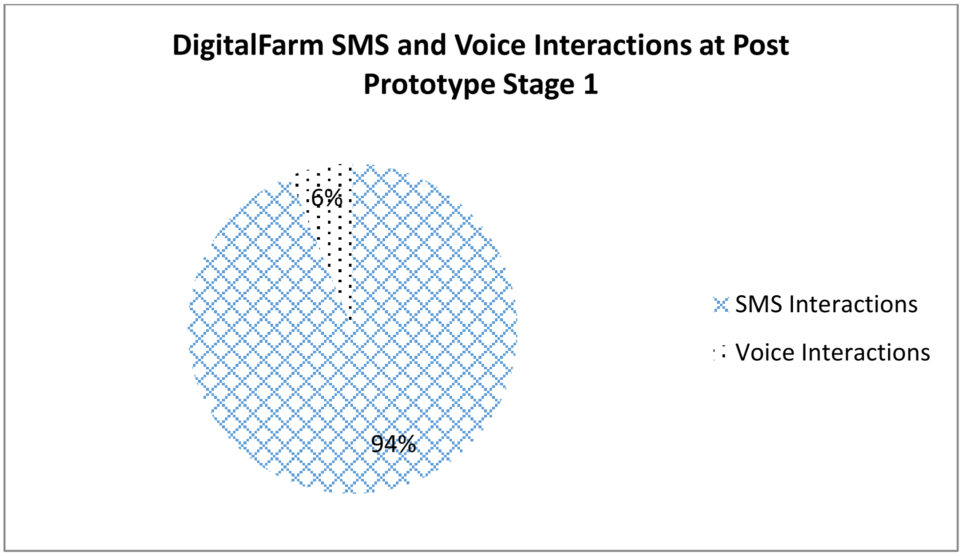


Figure 5.1: SMS and Voice Interactions at Post-Prototype Stage 1

Farmers asked questions based on their areas of farming primarily dairy cow keeping, dairy goats and crops farming. More details about the *DigitalFarm* platform have been discussed in Chapter 4.

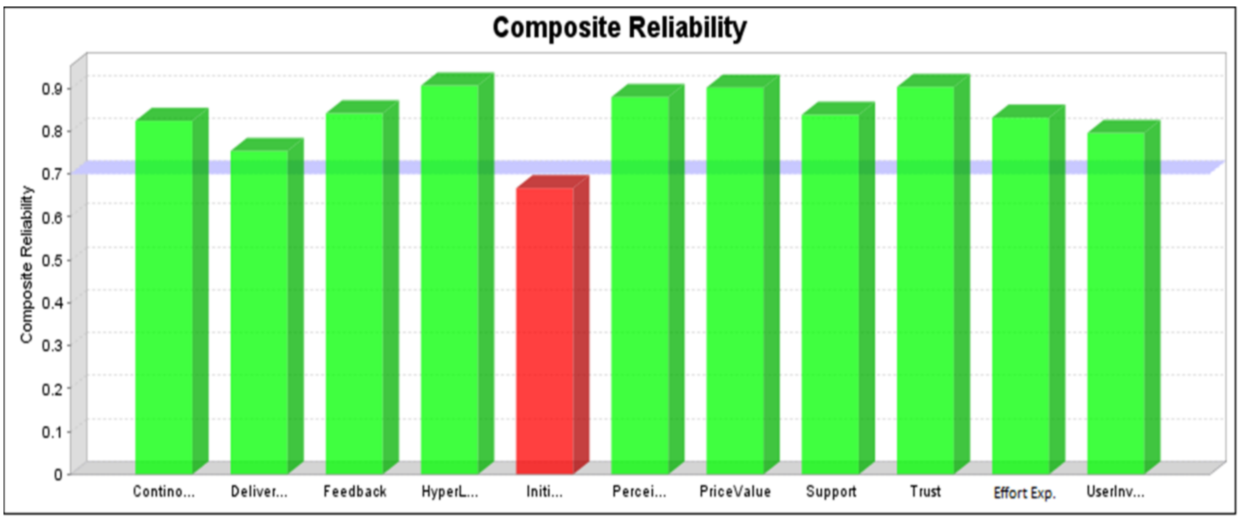
5.3.2 Reliability and Validity Testing in the Post-Prototype Stage 1

To test the reliability and validity of the instruments used in the pre-study exercise, the researchers used the data collected from 78 respondents in the Post-Prototype stage 1 phase.

Reliability Assessment

The purpose of this step was to test internal consistency, whose basis was to ensure that individual characteristics that make up a construct measure the same construct and are highly inter-correlated (Churchill 1979).

Since the approach taken in this research is Partial Least Squares as indicated in the Research Design, the most appropriate reliabilty test technique to accompany this approach was the composite reliability technique. Composite reliability is a preferred alternative to cronbach alpha tests in PLS-based research, especially when using a reflective model (Hair , Hult, Ringle & Sarstedt 2014), which has been used in this study as the path modeling technique. Composite reliability takes into account the individual contribution of each latent factor to each item and each iterm's error and provide much less biased estimate of reliability than alpha tests (Starkweather 2012). However, a Cronbach alpha test on the data produced 0.723, indicating an acceptable level of internal consistency (George & Mallery 2003).



Composite Reliability										
Cont.Usage	Delivery	Feedback	HyperL	InitialAc.	Perceiv.	Price	Supp.	Trust	Eff.E	UserInv.
0.824	0.754	0.841	0.906	0.667	0.880	0.902	0.838	0.903	0.831	0.796

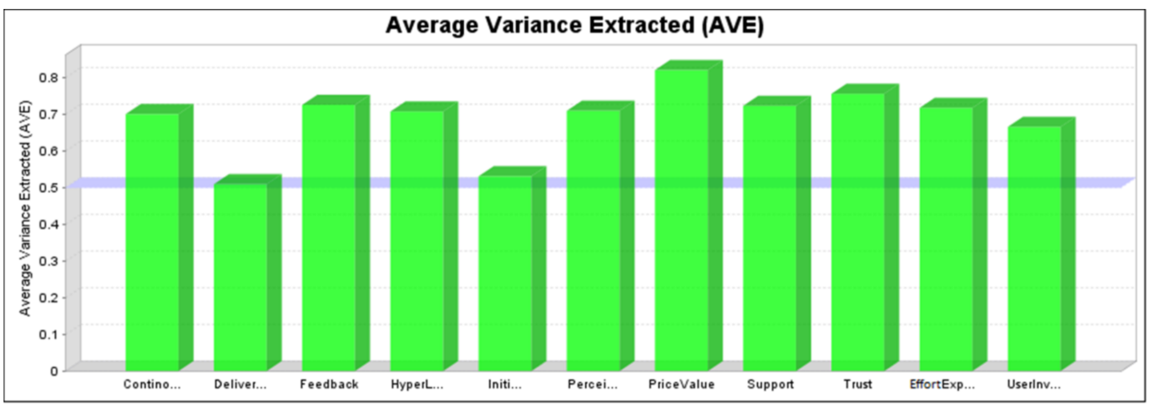
Figure 5.2: Composite Reliability of the Constructs in Post-Prototype Stage 1

Among the measured constructs, Hyperlocalization and Trust both scored the highest values at 0.906 and 0.903 respectively, followed by Perceived Usefulness and Feedback, with scored of

0.880 and 0.841 respectively. While Initial Acceptance and Usage of Technology scored a value below the threshold of 0.7, there was convincing evidence that the farmers were satisfied with the technology, which resulted to continuous usage even beyond the initial acceptance phase.

Convergent Validity Assessment

A convergent validity test is used to assess the construct validity of a measurement procedure (Campbell & DW 1959) which is used to measure a construct. Evidence of convergence is demonstrated using Average Variance Extracted (AVE) co-efficients. This is used to demonstrate that a measure correlates highly with measures of the same construct whose value is the average amount of variance that a construct explains in its indicator variables relative to the overall variance of its indicators (Henseler, Ringle & Sarstedt 2015). In the case of this study, all the constructs attained an AVE co-efficient threshold of 0.5 which is the expected minimum for an adequate model (Chin 1998; Höck & Ringle 2006), with majority attaining a co-efficient of above 0.7 (70%) which is considered good. This indicates that the constructs are well measured by their indicators as provided in the conceptual model.



AVE Co-efficients										
Cont.Usag	Delivery	Feedbac	HyperL	InitialAc.	Perceiv.	Price	Supp.	Trust	Eff.E	UserInv.
0.701	0.510	0.726	0.708	0.532	0.710	0.821	0.724	0.757	0.718	0.666

Figure 5.3: AVE Co-efficients for Post-Prototype Stage 1

Discriminant Validity Assessment

Discriminant validity assessment measures the strength of the relationship between a reflective construct and its own indicators (e.g., in comparison with than any other construct) in the PLS path model (Hair et al. 2014). This assessment specifies that indicators should explain a low proportion of variance from other latent variables (Wang, French & Clay 2015). The dorminant approaches to test discriminant validity for variance-based structural equational modeling such as partial least squares have been the Fornell-Larcker criterion (Fornell & Larcker 1981) and the examinantion of cross-loadings (Hair et. al 2014). Table 5.9 shows the discriminant validity using the Fornell-Larcker criterion.

Table 5.9: Discriminant Validity for Post-Prototype Stage 1 using Fornell-Larcker Criterion

	Usag.	**Deliv.**	**Feed.**	**Hyp.**	**Initi.**	**Perc.**	**Price**	**Supp.**	**Trust**	**Eff.E**	**User.**
Usag.	0.837										
Deliv.	0.294	0.714									
Feed.	0.564	0.533	0.852								
Hyp.	0.130	0.123	0.187	0.841							
Initi.	0.835	0.183	0.610	0.356	0.729						
Perc.	-0.372	-0.414	-0.489	-0.077	-0.258	0.843					
Price	0.838	0.263	0.450	0.074	0.564	-0.439	0.906				
Supp.	0.191	0.140	0.424	0.790	0.411	-0.129	0.090	0.851			
Trust	0.414	0.303	0.259	0.355	0.372	-0.206	0.390	0.133	0.870		
Eff.E	0.387	0.672	0.509	0.286	0.276	-0.458	0.393	0.232	0.563	0.847	
User.	0.296	0.105	0.250	0.619	0.404	-0.142	0.246	0.525	0.208	0.376	0.816

The values shown in Table 5.9 indicate that the model shows good discriminant validity due to the fact that for each of the constructs, 91% of the calculated square roots of AVE are higher than correlations against the other latent constructs present in the model.

In a simulation study done by Henseler, Ringle, & Sarstedt, 2015 they criticized the Fornell-Larcker approach as not to reliably check the lack of discriminant validity. The authors proposed an alternative approach that has received acceptance among scholars. This approach uses multitrait-multimethod matrix, to assess discriminant validity. The approach is called heterotrait-monotrait ratio of correlations (HTMT). In this study, the researchers also used the HTMT approach to assess discriminant validity as shown on Table 5.10 due to the shortcomings highlighted concerning the Fornell-Larcker approach.

Table 5.10: Discriminant Validity for Post-Prototype Stage 1 using HTMT approach

	Usag.	Deliv.	Feed.	Hyp.	Initi.	Perc.	Price	Supp.	Trust	Eff.E	User.
Usag.											
Deliv.	0.565										
Feed.	0.918	0.928									
Hyp.	0.169	0.283	0.227								
Initi.	2.188	0.528	0.220	1.396							
Perc.	0.511	0.701	0.722	0.095	0.626						
Price	1.274	0.446	0.692	0.111	1.315	0.518					
Supp.	0.277	0.490	0.525	1.024	1.656	0.224	0.112				
Trust	0.572	0.486	0.362	0.383	0.957	0.225	0.468	0.244			
Eff.E	0.516	1.107	0.823	0.381	0.610	0.574	0.467	0.439	0.807		
User.	0.490	0.497	0.432	0.896	1.647	0.179	0.403	0.827	0.300	0.433	

HTMT is a geometric mean of the correlations of indicators across constructs, which measures different phenomena (heterotrait-heteromethod correlations) divided by the correlations of indicators within the same construct (monotrait-heteromethod correlations) (Garson 2016). In HTMT, discriminant validity is considered to be established between two constructs of a reflective model if the HTMT value is below 0.9 (Garson 2016). Majority (80%) of the measurements qualified for discriminant validity under this criteria.

5.3.3 Post-Prototype Stage 1 Path Model

Using the data gathered in prototype stage 1, a reflective path model was generated using SmartPLS. In a reflective model (as opposed to a formative model), the indicators are a representative set of items which all reflect the latent variable they are measuring (Garson 2016), thus assuming that the factor is the reality, and measured variables are a sample of all possible indicators of that reality. Figure 5.8 shows the Post-Prototype stage 1 model, with the measured indicator variables represented by the rectangles, and the factors (latent variables) represented by ellipses.

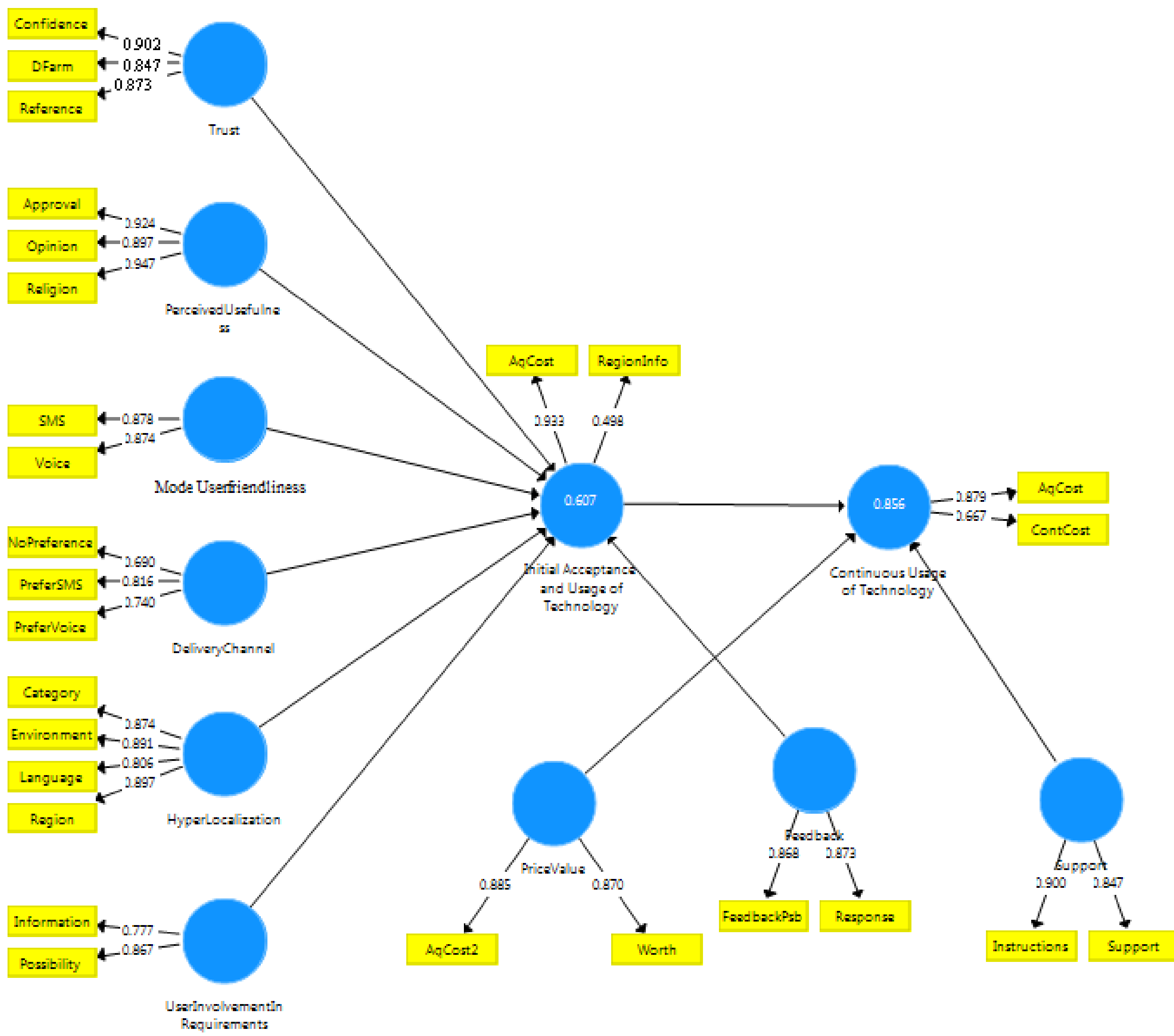


Figure 5.4: Post-Prototype Stage 1 Path Model

The model contains nine exogenous latent variables and two endogenous latent variables. In this case, *Initial Acceptance and Usage of Technology* is a mediating variable between the nine exogenous latent variables on one hand, and *Continuous Usage of Technology* on the other hand.

As shown in Figure 5.4, all the indicators loaded into their latent variables with highly positive values. The overall values for each of the indicators onto its equivalent latent variable are shown in Table 5.11. The outer measurement model loadings range from 0 to 1 in SmartPLS. The loadings are considered a form of item reliability coefficients for reflective models, meaning that the larger the loadings, the stronger and more reliable a model is (Garson 2016).

Table 5.11: Post-Prototype Stage 1 model measurement loadings

Indicator	Cont.Us.	Deliv.	Feedb	Hyper	Initial	Perceiv	Price	Supp.	Trust	Eff.E	UserIn.
#1	0.879	0.690	0.868	0.874	0.933	0.924	0.885	0.900	0.902	0.878	0.777
#2	0.667	0.816	0.873	0.891	0.498	0.897	0.870	0.847	0.847	0.874	0.867
#3		0.740		0.806		0.947			0.873		
#4				0.897							

Majority (89%) of the values were above the loading of 0.70, with only three out of the twenty seven indicators scoring below 0.70.

Path coefficients in the model are shown by the arrows between the exogenous latent variables and the endogenous variable. Path coefficients range from -1 to +1, with weights close to 1 reflecting the strongest paths, and weights closest to 0 reflecting the weakest paths in the model. Path coefficients extracted from SmartPLS for the model shown in Figure 5.4, demonstrates that User involvement in requirements gathering has the highest effect on Initial Acceptance and Usage of Technology. Table 5.12 shows the full list of path coefficients as extracted from the model.

Table 5.12: Post-Prototype Stage 1 Path coefficients

	Delivery	Feedback	HyperL	Perceiv.	Price	Supp	Trust	Eff.E	UserI
InitialAcc.	0.096	-0.046	0.322	-0.060	-0.093	0.085	0.091	-0.162	0.641

The value shown inside the ellipses (Figure 5.4) representing the endogenous variables *Initial Acceptance and Usage of Technology* and *Continuous Usage of Technology* are called R-square in PLS-based modelling. R-square also known as the coefficient of determination is the overall effect size measure for a structural model (Garson 2016). The R-square values of 0.607 and 0.856 imply that about 60.7% of the variance in *Initial Acceptance and Usage of Technology* and about 85.6% of the variance in *Continuous Usage of Technology* is explained by the model respectively. R-square values are only shown for endogenous variables.

In this study, the researchers used boostrapping to calculate the significance of the PLS coefficients. Figure 5.5 shows the results of the PLS boostrapping algorithm on the post prototyping stage 1 data set. Table 5.13 shows the full results of the bootstrapped significance for path coefficients.

Table 5.13: Bootstrapped Significance for Path Coefficients

Delivery	Feedback	HyperL	Perceiv.	Initial.Ac	Price	Supp.	Trust	Eff.E	UserInv.
0.871	5.015	0.374	0.042	5.226	5.121	1.606	2.964	1.736	1.854

From the figures shown in Table 5.13, it was evident that *Price Value* followed by *Feedback* had the highest significance on *Initial Acceptance and Usage of the Technology*, while *Initial Acceptance and Usage of Technology* had a high significance on *Continuous Usage of the Technology*.

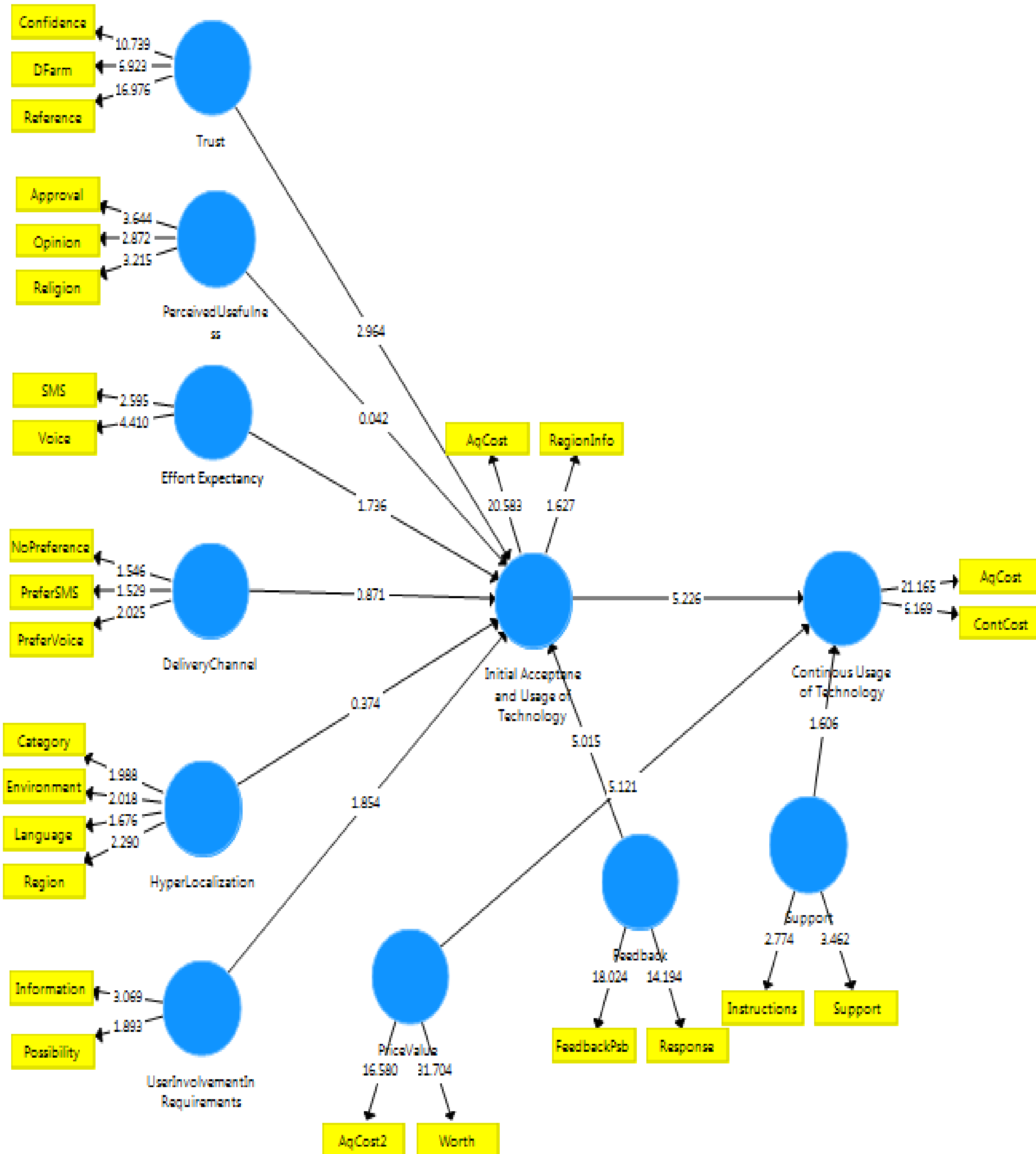


Figure 5.5: Post-Prototype Stage 1 Bootstrapped Model

5.3.4 Post-Prototype Stage 1 Results Overview

Having used the Post-Prototype stage 1 data to draw the path and the bootstrapped model, the researchers used the drawn observations to evaluate the originally laid out hypotheses, concerning the various aspects of the study. The researchers used t-values as a guide in the rejection or acceptance of hypothesis as the recommended approach for reflective models. All t-values above 1.96 are significant to the 0.05 level and is the default cut-off of considering a result significant (Garson 2016).

The nine constructs appearing on the path model in Figure 5.4 had been drawn from four categories of construct groupings in the conceptual model (Figure 2.15) namely Human aspects (Trust and Perceived Usefulness), the Technology aspects (Effort Expectancy and Delivery Channel), the Need aspects (User Involvement in Requirements Gathering and Hyper Localization of content and context) and Cost and Sustainability aspects (Price Value, Support and Feedback).

In the Human aspects category, Trust and Perceived Usefulness have positive significant effect, and positive non-significant effect on the initial acquisition and usage of technology, with t-values 2.964 and 0.042 respectively. Also, Effort Expectancy and Delivery Channel in the Technology aspects demonstrated positive non-significant effect with t-values of 1.736 and 0.871 respectively. Need aspects also demonstrated positive non-significant effect on Initial Acceptance and Usage of Technology with User Involvement in requirements gathering scoring a t-value of 1.854 and Hyperlocalization scoring a t-value of 0.374. In the Cost and Sustainability aspects, Trust and Feedback both scored positive significant t-values of 5.015 and 5.121 respectively, while Support scored a positive non-significant t-value of 1.606. However, it was important to note that the Initial Acceptance and Usage of Technology had a positive significant effect on the Continuous usage of the technology with a t-value score of 5.226.

Based on the discussion above, Table 5.12 shows the originally drawn hypotheses and their status with respect to the Post-Prototype stage 1 results.

Table 5.14: Post-Prototype Stage 1 Hypothesis

Hi	**Factor**	**Hypothesis**	**Outcome**
H1	Tr → IAT	Tr has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H2	PU → IAT	PU has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H3	EE → IAT	EE has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H4	DC → IAT	DC has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H5	HL → IAT	HL has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H6	UIRG → IAT	UIRG has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H7	PV → IAT	PV has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H8	Sp → IAT	Sp has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H9	Fb → IAT	Fb has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H10	IAUT → CUT	Initial Acceptance and Usage of Technology has a positive significant influence on Continuous Usage of Technology	**Accept**

5.4 Post-Prototype Stage 2 Results

After the first phase of the Post-Prototype evaluation, the researchers observed the usage of the technology by farmers for another period of 3 months. Even though there were additional farmers on the platform, only 78 farmers who were in the Post-Prototype stage 1 were considered for an interview during the Post-Prototype stage 2 assessment. Out of the previous 78 farmers, 72 were available for the interview.

5.4.1 Post-Prototype Stage 2 Participants Demographic Details

The interviewed farmers constituted 62.5% male and 37.5% female, which just a slight difference from the previous ratio of 60.3% male and 39.7% female. The same farming activities were reported, similar to the Post-Prototype stage 1.

As shown in Table 5.15, the respondents represented the different age groups as previously shown in the Post-Prototype stage 1. The elderly age group (Over 56 years) still had the majority of respondents and were 100% represented by the same group of farmers, similar to the younger generation (26-35 years) who were 100% represented by the same individuals present in the Post-Prototype stage 1 assessment.

Table 5.15: Gender and Age Crosstabulation

		Age				Total
		26-35	36-45	46-55	Over 56	
Gender	Male	3	9	10	23	45
	Female	6	7	8	6	27
Total		9	16	18	29	**72**

Similar to what was demonstrated during the Post-Prototype stage 1 assessment, there was continuous dominance of SMS interactions between the farmers and experts as opposed to voice interactions. However, there was a considerable increase of the voice interactions from 6% to 32%. This was due to the fact that an additional language (*Kikuyu)* was added to the Interactive Voice Platform. This addressed the concern raised by farmers during the FGD sessions, with regards to language barrier as inhibiting factor in the usage of mobile technology. Figure 5.6 shows the interactions on the *DigitalFarm* platform for the Post-Prototype stage 2 period, which was 3 months after the Post-Prototype stage 1 assessment.

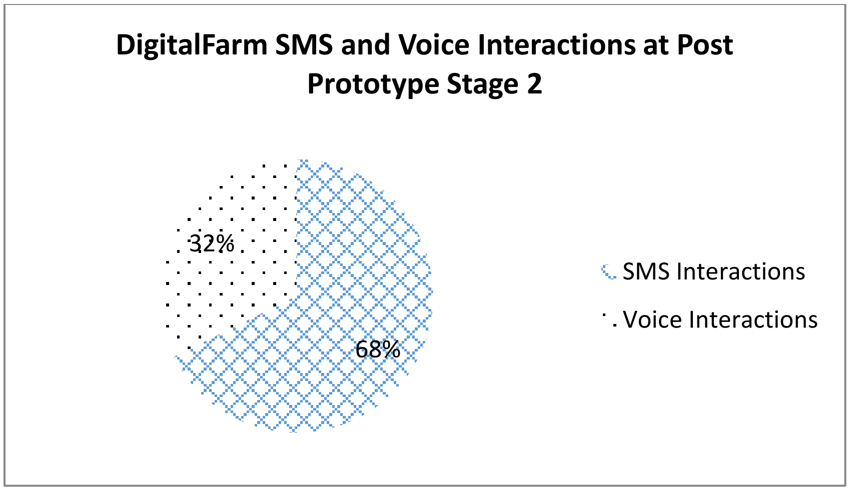


Figure 5.6: SMS and Voice Interactions at Post-Prototype Stage 2

A set of questions similar to what featured in Post-Prototype stage 1 featured in this stage. Farmers were interested to know more based on their areas of farming. They kept dairy cows, farmed crops and wanted to know more concerning general advisory questions, diagnosis and where to market their produce.

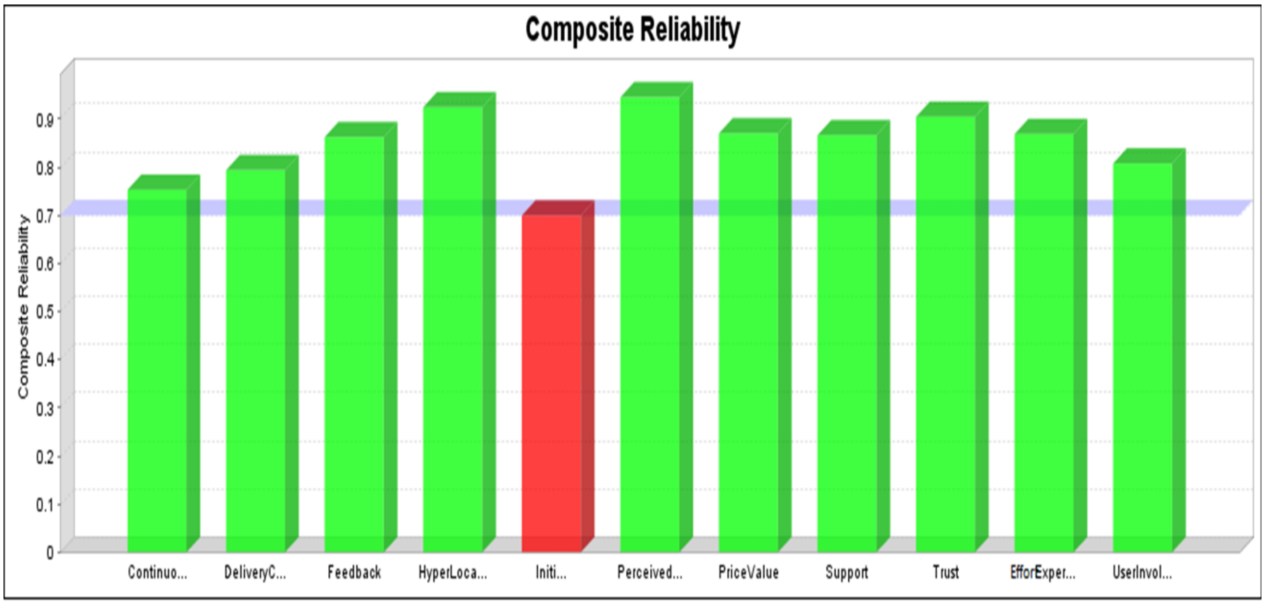
5.4.2 Reliability and Validity Testing in the Post-Prototype Stage 2

To test the reliability and validity of the instruments used in the pre-study exercise, the researchers used the data collected from 72 respondents in the Post-Prototype stage 2 phase.

Reliability Assessment

The researchers conducted reliability tests to test for internal consistency, whose basis is to ensure that individual characteristics that make up a construct measure the same construct and are highly inter-correlated (Churchill 1979).

In PLS-based research, the recommended approach to test reliability is the Composite reliability tests as opposed to the more traditional Cronbach Alpha (Hair et. al 2014). Composite reliability is acquired by measuring the internal consistency of constructs, and is regarded as the degree to which a set of indicators are internally consistent, the extent to which the research instrument gives same results on repeated tests. An overall Cronbach alpha test on the Post-Prototype stage 2 data produced 0.861, indicating a good level of internal consistency (George & Mallery 2003).



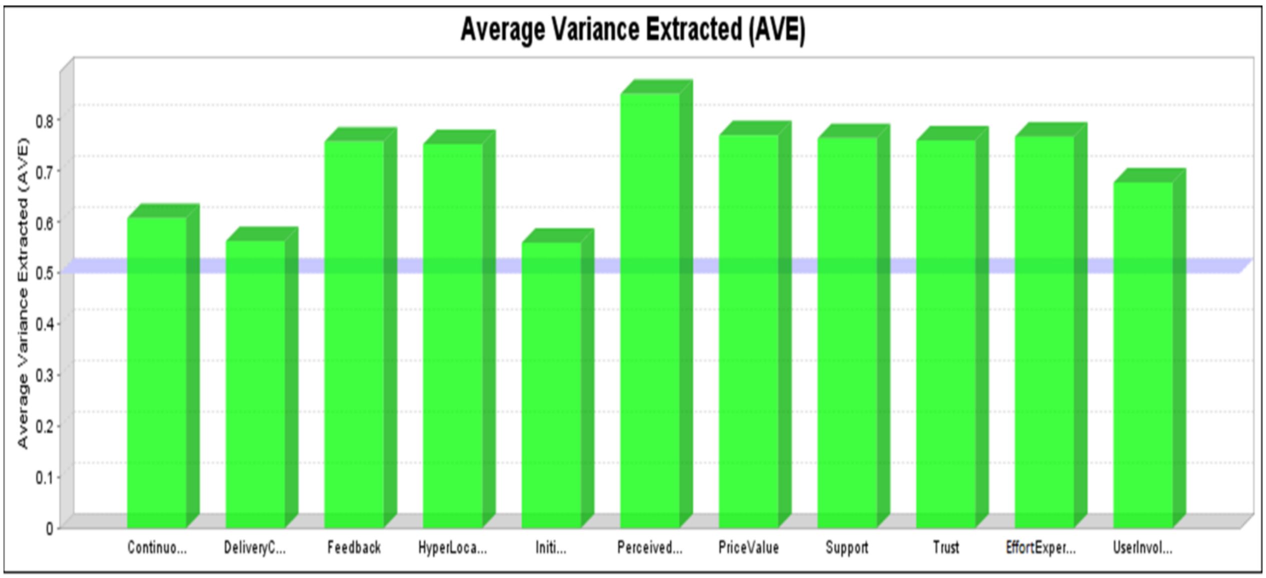
Composite Reliability										
Cont.Usage	Delivery	Feedback	HyperL	InitialAc.	Perceiv.	Price	Supp.	Trust	EE	UserInv.
0.753	0.794	0.862	0.924	0.669	0.945	0.870	0.866	0.905	0.869	0.808

Figure 5.7: Composite Reliability of the Constructs in Post-Prototype Stage 2

As shown in Figure 5.7, all the constructs scored composite reliability values of above 0.75 apart from Initial Acceptance of Technology which scored 0.669, slightly below the required minimum value of 0.7. Percived Usefulness and Hyperlocalization scored the highest values at 0.945 and 0.924 respectively, followed by Trust and Price Value, with scores of 0.905 and 0.870 respectively.

Convergent Validity Assessment

As explained in Post-Prototype stage 1, evidence of convergence is demonstrated using AVE co-efficients. During Post-Prototype stage 2 assessment, all the constructs attained an AVE co-efficient threshold of 0.5 which is the expected minimum for an adequate model(Chin 1998; Höck & Ringle 2006). The overall AVE coefficients indicate that generally the constructs were well measured by their indicators as provided in the model.



AVE Co-efficients										
Cont.Usage	Delivery	Feedback	HyperL	InitialAc.	Perceiv.	Price	Supp.	Trust	EE	UserInv.
0.608	0.563	0.758	0.753	0.560	0.851	0.770	0.764	0.760	0.768	0.678

Figure 5.8: AVE Co-efficients for Post-Prototype Stage 2

Discriminant Validity Assessment

As previously mentioned, discriminant validity ensures that a reflective construct has the strongest relationships with its own indicators in the PLS path model (Hair et al. 2014). In PLS-based studies, the Fornell-Larcker criterion(Fornell & Larcker 1981) and the examination of cross-loadings(Hair, et. al 2014) have been used. The two approaches were challenged on their ability to detect discriminant validity and instead an alternative method called heterotrait-monotrait ratio of correlations (HTMT) was proposed (Henseler et al. 2015). The researchers used both approaches in this study as shown in Table 5.16 and Table 5.17.

Table 5.16: Discriminant Validity for Post-Prototype Stage 2 using Fornell-Larcker Criterion

	Usag.	**Deliv.**	**Feed.**	**Hyp.**	**Initi.**	**Perc.**	**Price**	**Supp.**	**Trust**	**Eff.E**	**User.**
Usag.	0.780										
Deliv.	0.498	0.750									
Feed.	0.587	0.552	0.871								
Hyp.	0.198	0.084	0.123	0.868							
Initi.	0.836	0.384	0.580	0.426	0.748						
Perc.	-0.232	-0.389	-0.233	0.076	-0.043	0.923					
Price	0.704	0.466	0.355	0.115	0.433	-0.305	0.878				
Supp.	0.354	0.254	0.383	0.720	0.608	0.014	0.105	0.874			
Trust	0.432	0.423	0.086	0.305	0.338	-0.111	0.524	0.145	0.872		
Eff.E	0.387	0.640	0.378	0.269	0.212	-0.345	0.464	0.190	0.663	0.876	
User.	0.191	0.016	-0.098	0.496	0.264	0.006	0.242	0.244	0.349	0.137	0.823

Table 5.16 indicate that the model shows good discriminant validity due to the fact that for each of the constructs, 91% of the calculated square root of AVE is higher than correlations against the other latent constructs in the model.

Table 5.17: Discriminant Validity for Post-Prototype Stage 2 using HTMT approach

	Usag.	Deliv.	Feed.	Hyp.	Initi.	Perc.	Price	Supp.	Trust	Eff.E	User.
Usag.											
Deliv.	1.015										
Feed.	1.061	0.878									
Hyp.	0.275	0.177	0.223								
Initi.	2.005	0.765	1.079	1.117							
Perc.	0.431	0.503	0.289	0.088	0.262						
Price	1.510	0.685	0.515	0.156	0.975	0.378					
Supp.	0.740	0.395	0.572	0.865	1.593	0.128	0.225				
Trust	0.825	0.560	0.138	0.351	0.748	0.145	0.665	0.234			
EE	0.848	0.979	0.551	0.345	0.468	0.428	0.662	0.297	0.885		
User.	0.441	0.247	0.172	0.735	0.927	0.076	0.371	0.391	0.527	0.234	

In the HTMT approach, discriminant validity is considered to be established between two constructs of a reflective model if the HTMT value is below 0.9 (Garson 2016). Majority (80%) of the constructs qualified for discriminant validity under this criteria.

5.4.3 Post-Prototype Stage 2 Path Model

Using the data gathered in prototype stage 2, a reflective path model was generated using SmartPLS. Figure 5.9 shows the Post-Prototype stage 2 model, with the measured indicator (measured) variables represented by the rectangles, and the factors (latent variables) represented by ellipses.

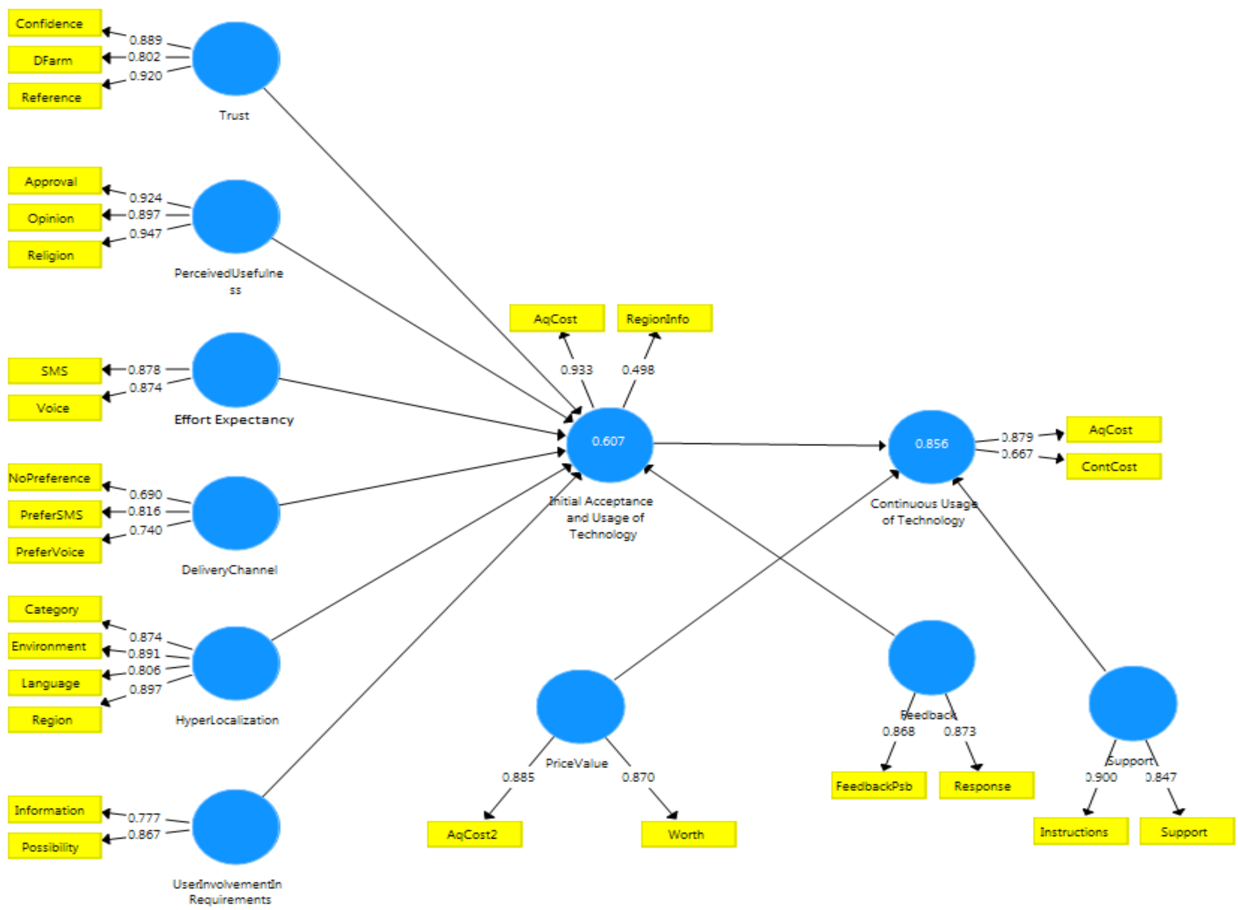


Figure 5.9: Post-Prototype Stage 2 Path Model

As shown in Figure 5.9, the endogenous latent variable *Initial Acceptance and Usage of Technology* is a mediating variable between the nine exogenous latent variables on one hand, and the endogenous latent variable *Continuous Usage of Technology* on the other. All the indicators loaded into their latent variables, majority of whom had highly positive values. The overall values for each of the indicators onto its equivalent latent variable are shown in Table 5.18, ranging from 0 to 1. The larger the loadings, the stronger and more reliable a model is (Garson 2016).

Table 5.18: Post-Prototype Stage 2 model measurement loadings

Indicator	Cont.Us.	Deliv.	Feedb	Hyper	Initial	Perceiv	Price	Supp.	Trust	EE	UserIn.
#1	0.879	0.690	0.868	0.874	0.933	0.924	0.885	0.900	0.889	0.878	0.777
#2	0.667	0.816	0.873	0.891	0.498	0.897	0.870	0.847	0.802	0.874	0.867
#3		0.740		0.806		0.947			0.920		
#4				0.897							

89% of the values were above the loading of 0.74, signifying good reliability of the model.

Path coefficients, shown by the arrows between the exogenous latent variables and the endogenous variable signify the strong and the weak paths (ranging from -1 to +1). In Figure 5.9, the model demonstrates that User involvement in requirements gathering has the highest effect on Initial Acceptance and Usage of Technology. The complete list of path coefficients extracted from the model is shown in Table 5.19.

Table 5.19: Post-Prototype Stage 2 Path coefficients

	Delivery	Feedback	HyperL	Perceiv.	Price	Supp.	Trust	EE	UserInv.
InitialAcc.	0.155	0.620	0.289	0.018	0.392	-0.145	0.420	-0.485	0.099

The strongest paths signified that Feedback and Price Value had the strongest influence towards the Initial Acceptance and Usage of Technology, as had been previously observed.

The R-square (coefficient of determination) values of 0.662 and 0.849 derived at this stage from the model imply that about 66.2% of the variance in *Initial Acceptance and Usage of Technology* and about 84.9% of the variance in *Continuous Usage of Technology* is explained by the model respectively.

The researchers also used boostrapping in this stage to calculate the significance of the PLS coefficients. Figure 5.10 shows the results of the PLS boostrapping algorighthm on the post prototyping stage 2 data set, while Table 5.20 shows the results of the bootstrapped significance for path coefficients as calculated by SmartPLS using 5000 subsamples, recommended for confirmatory purposes (Garson 2016).

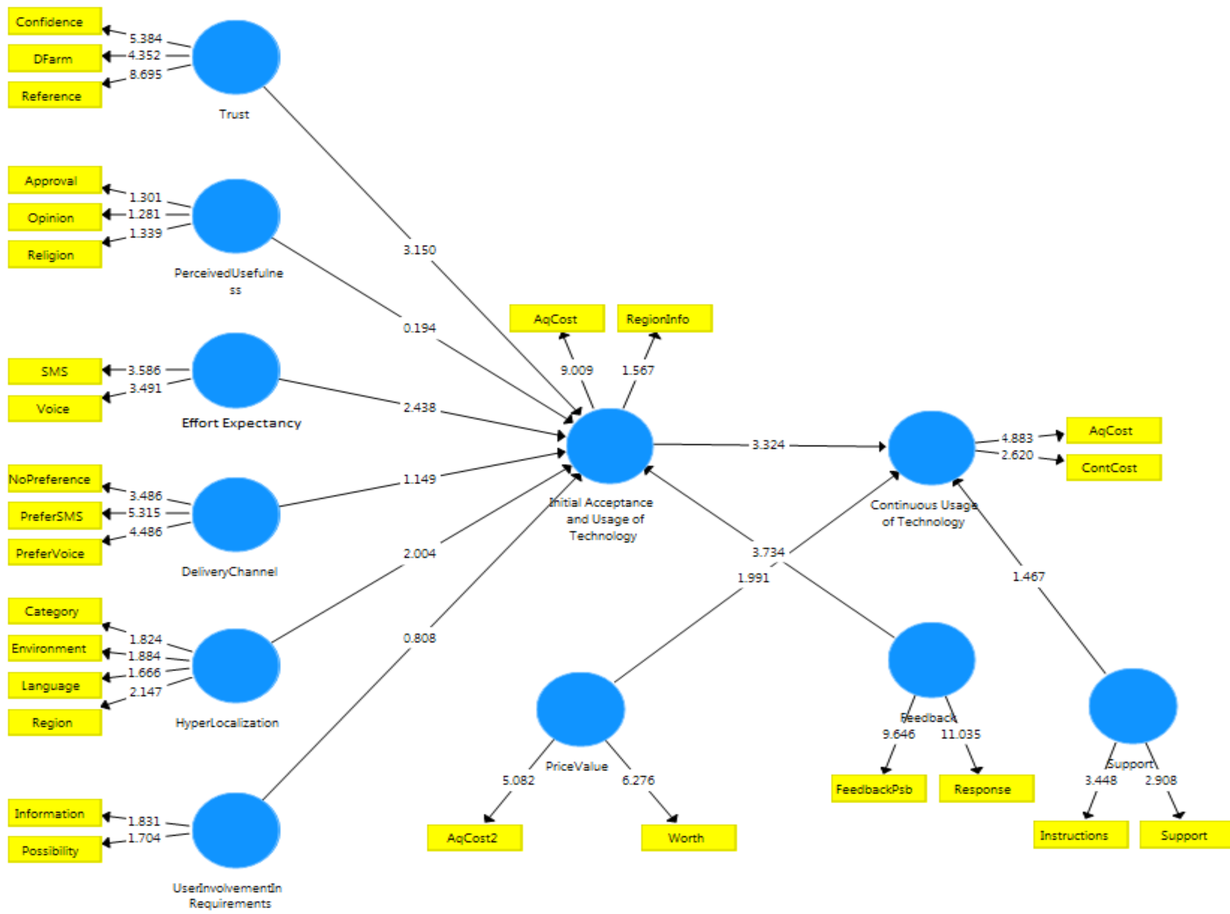


Figure 5.10: Post-Prototype Stage 2 Bootstrapped Model

Table 5.20: Post-Prototype Stage 2 Bootstrapped Significance for Path Coefficients

Delive	Feedbac	Hyper	Initial	Perceiv	Price	Supp	Trus	EE	UserInv.
1.149	3.734	2.004	3.324	0.194	1.991	1.467	3.150	2.438	0.808

As shown in Table 5.20, *Feedback* had the highest significance on *Initial Acceptance and Usage of the Technology*. *Trust* continued to have a strong significance on the usage of the technology.

5.4.4 Post-Prototype Stage 2 Results Overview

The researchers used t-values generated in the bootstrapped model as a guide in the rejection or acceptance of hypothesis as the recommended approach for reflective models. The significance of the various items constituting the conceptual model in Figure 2.15 were evaluated bearing in mind that t-values above 1.96 are significant to the 0.05 level and is the default cut-off used to consider if a result is significant (Garson 2016).

In the Human aspects category, Trust and Perceived Usefulness have positive significant effect, and positive non-significant effect on the initial acquisition and usage of technology, with t-values 3.150 and 0.194 respectively. Unlike in Post-Prototype stage 1 assessment, Effort Expectancy demonstrated a positive significant effect with a t-value of 2.438, while the counterpart item Delivery Channel in the Technology aspects demonstrated positive non-significant effect with t-values of 1.149. Hyperlocalization in the Need aspects also demonstrated a positive significant effect on Initial Acceptance and Usage of Technology scoring a t-value of 2.004, while User Involvement in requirements gathering within the same category demonstrated a positive non-significant effect with a t-value score of 0.808. In the Cost and Sustainability aspects, Price Value and Feedback both scored positive significant t-values of 1.991 and 3.734 respectively, while Support scored a positive non-significant t-value of 1.467. However, it was important to note that the Initial Acceptance and Usage of Technology had a positive significant effect on the Continuous usage of the technology with a t-value score of 3.324.

The significance of the various measurement items in Post-Prototype stage 2 was consistent with Post-Prototype stage 1 observations. However, it was important to note that two additional constructs (Hperlocalization and Effort Expectancy) had a positive significant effect, with more usage of the technology. In addition, cost and sustainability aspects (Price and Feeback) continued to be important and critical beyond the initial acceptance and usage of the technology, and become more critical in the continuous usage of the technology phase.

Based on the discussion above, Table 5.19 shows the originally drawn hypotheses and their status with respect to the Post-Prototype stage 2 results.

Table 5.21: Post-Prototype Stage 2 Hypothesis

Hi	**Model Path**	**Hypothesis**	**Outcome**
H1	Tr → IAT	Tr has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H2	PU → IAT	PU has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H3	EE → IAT	EE has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H4	DC → IAT	DC has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H5	HL → IAT	HL has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H6	UIRG → IAT	UIRG has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H7	PV → IAT	PV has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H8	Sp → IAT	Sp has a positive significant influence on Initial Acceptance and Usage of Technology	Reject
H9	Fb → IAT	Fb has a positive significant influence on Initial Acceptance and Usage of Technology	**Accept**
H10	IAUT → CUT	Initial Acceptance and Usage of Technology has a positive significant influence on Continuous Usage of Technology (CUT)	**Accept**

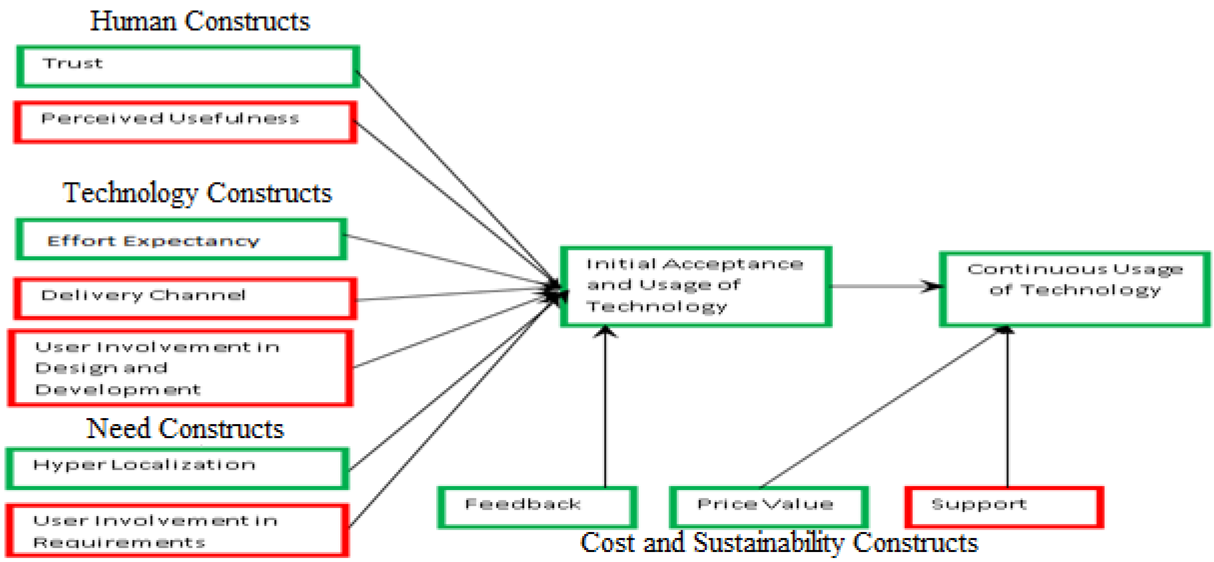


Figure 5.11: Research Conceptual Model with highlights of dropped and retained constructs

Figure 5.11 shows the research conceptual model, with the retained constructs in green border, and the dropped constructs in red border. Figure 5.12 shows the derived conceptual model, constituting of the retained constructs.

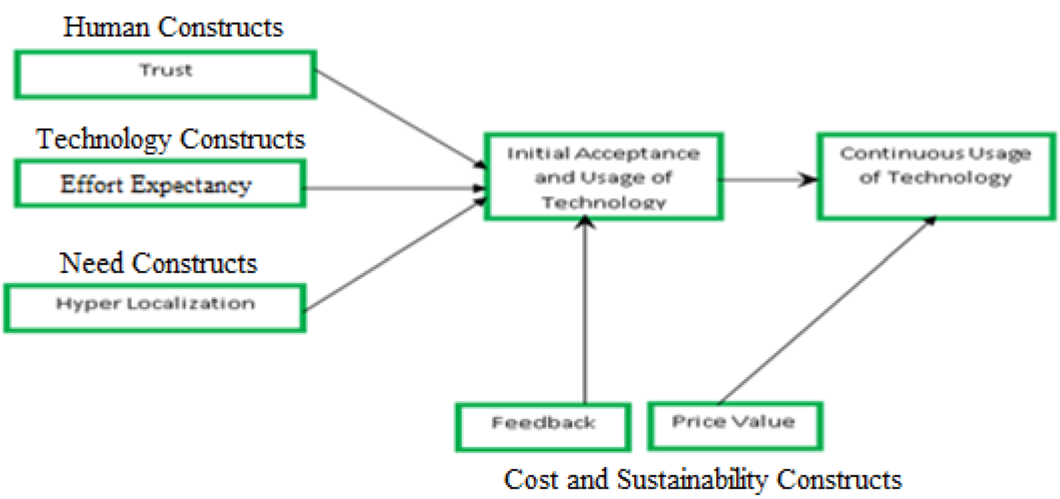


Figure 5.12: Derived mAgriculture Design and Implementation Model

Table 5.22 shows the change in significance loadings of the retained constructs in the model between Post-Prototype Stage 1 and Stage 2 assessments.

Table 5.22 Significance Loadings of Retained Constructs

Construct	Stage 1	Stage 2	Change (%)
Trust	2.964	3.150	+ 6.28
Effort Expectancy	1.736	2.438	+40.44
Hyperlocalization	0.374	2.004	+435.83
Feedback	5.015	3.734	-25.54
Price Value	5.121	1.991	-61.12

Over the usage of the system, the Trust of the users with the systems grew as they got to appreciate it more. Also, the user friendly aspects of SMS and Voice interfaces experience a positive change. Hyperlocalization experienced a drastic positive change of a 435% between Stage 1 and Stage 2. This was due to frequent customization and personalization of farmer needs in the system, based on their category of farming, their language of communication, environment, and their specific region. On the other hand, Feedback experienced a reduction of 25%. This was attributed to the fact that users had continually given a lot of feedback during the first stage of deployment, and therefore the importance of this aspect reduced with further usage. In addition, the importance of Price Value became less significant with continuous usage, as the users realized the worth of the system, the concern of price became less important.

5.5 Discussion on the Retained Constructs

After two cycles of improving the model, all the constructs achieved a positive effect on the Initial Acquisition and Usage of Technology, although not all had a positive significant effect. The constructs Trust, Effort Expectancy, Hyperlocalization, Price Value and Feedback achieved a positive significant effect on the Initial Acceptance and Usage of Technology, while the Initial Acceptance and Usage of Technology achieved a positive significant effect on the Continuous Usage of Technology.

i) Trust

In this study, the aspects of Trust that were investigated included determining the level of confidence farmers had with the technology, whether they felt that the system was useful to them, and if they would refer it to other farmers. From the research, it was evident that the aspect of the trustworthiness of a technology is key factor among the groups of farmers that were interviewed, as supported by the positive significance towards Initial Acceptance and Usage of Technology. Some of the farmers had prior experiences with other mAgriculture applications, which provided misleading information and therefore were sceptical about accepting other technologies. Given that the word of mouth is a powerful tool that shapes opinions and perspectives in the African culture, lack of trust in a technology may lead to total non-acceptance by the target groups due to the experience of a few members. In addition, since most of the interviewed farmers rely on agriculture as their main livelihood, anything that might lead to misfortunes in their flock or crop yield would easily be rejected. Trust barriers of a technology may be reduced by involving the local community agriculture experts who are known to the farmers (Loucky 2012). Previous research has confirmed the importance of Trust in the initial adoption of technology (Kim, et. al 2009; Quelch & Klein 1996; Disabatino 2000). In addition, high levels of trust have been found to encourage people to use technology (Hoffman et. al 1999) while aspects such as unreliability and poor service lead to lose of trust and eventual withdrawal from using the technology (Sarker & Wells 2003).

ii) Effort Expectancy

It was evident that users were most comfortable using the interaction mode that they usually use for normal communication e.g. SMS or Voice. The simplicity in the mode of interaction (SMS commands and Voice menus) was a key factor in motivating the farmers to use the system. The continuous improvement of the user experience based on the feedback provided, promoted the system’s ease of use. In addition, the involvement of the users in the preprototyping stage lead to a better understanding of their level of exposure to mAgriculture applications, and their preferences in terms of interacting with various system interfaces. Mobile-based services with poor user experience hinder the target users from using them (Xiaoguang 2011). An observation of the existing mAgriculture applications revealed that mobile applications that did not meet basic user experience requirements such as user friendliness formed a majority that did not move from pilot stage to sustainability stage. The critical importance of this aspect in mAgriculture applications was supported by the positive significance Effort Expectancy had towards the Initial Acceptance and Usage of Technology. It has been previously proven that Effort Expectancy has been a key factor towards initial acceptance, leading to the continuous usage of a technology (Venkatesh & Bala 2008; Venkatesh, Thong & Xu 2012).

iii) Hyperlocalization

In this study, the researchers focused on observing the effect of providing highly localized information which was specific to a user's language, region, environment and category of information. During the pre-study, farmers reported to have had experience with mAgriculture applications which do not consider critical aspects such as their farming interests (category of farming e.g. dairy or crop farming), their region (giving advise based on locally available materials, feeds etc) or language (providing information in a language which the farmer has difficulty to understand). When farmers felt their farming activities, region (or area), environment, and language were considered in an mAgriculture service, they were more receptive in accepting an mAgriculture application, and subsequently continued using the technology. This was more critical to rural regions where consumer education and literacy levels are low, including limited sources of credible expert advice besides the local knowledge. Previous research has demonstrated the importance of localizing information as per the needs of the farmers (Lokanathan

2010; McNamara 2009; Mittal et. al 2010), while considering the relevance to local information and language (World Bank 2012).

iv) Feedback

A mobile help line was available for the system users to call in case of any issue, as well as a mechanism to report any issue via SMS. However, the most useful means of feedback collection was during the face-to-face prototype and Post-Prototype assessments. The system users felt accommodated in decisions concerning the features available in the system and how they were presented to them. The feedback received enhanced initial acceptance, which led to the continuous usage of the system. The feedback received ranged included suggestions on improvement of features, message content among others. Appendix B shows sample feedback received from the users.

Previous work has regarded appropriate feedback mechanisms as a critical component for mobile-based services in development (World Bank 2012; InfoDev 2011). This has been seen to promote the ownership of a system by users (Qiang et. al. 2012).

v) Price Value

It was observed that most farmers were keen on the price elements of a technology before its initial acquisition and continuous usage. Farmers who had prior experience with mAgriculture applications were quick to inquire about the initial pricing model, and if there would be any changes to pricing in future (after the pilot). Over 95% of the mAgriculture applications that were studied by the researchers had no cost implication for the users during their launch, but then introduced cost aspects during the scaling stage. This has led to the downfall of many mAgriculture applications, as the farmers felt cheated while majority felt that they were not getting value for their money (Qiang et. al 2012).

Bearing in mind that profit margins for farmers was not very high, their desire was to keep the cost of production and animal maintenance very low, which included the cost of input (animal nutrients, fertilizers, seeds, drugs and veterinary services) and other value chain aspects such as transport to the market. Any additional cost to the cost of production has to be very worth the money they are spending on. It would then be very critical for the farmer to see the value for the money they spend on any mAgriculture technology, for it not to be an additional budget that eats into their small margin profits. Previous work in in technology acceptance models (Venkatesh et al. 2012; Kleijnen et. al 2004) has proved the importance of cost elements in the initial acceptance of an innovation. In addition, it has also been a key determinant of the continuous usage of a technology (Aker 2011; De Silva H. & Ratnadiwakara 2010).

vi) Initial Acceptance and Usage of Technology towards Continuous Usage of Technology

It is expected that the Initial Acceptance and Usage of Technology would lead to the continuous usage of that technology. However, this is not always the case due to some factors that mostly relate to the initial acceptance stage. Previous research has shown that only a small percentage of mobile based applications go beyond the pilot phase. In a comprehensive study done by the World Bank that involved 92 mobile-based systems for rural development and agriculture in various parts of the world, only 16% of the systems reached the sustainability stage (Heike 2012).

The researchers observed that continuous usage of the technology was determined by key aspects such as ensuring quality is maintained, the users have proper feedback mechanisms to provide to the service provider, and the price aspect is maintained at a level that is affordable to the users, and at the same time, where they feel the amount they are spending for this technology is worth their money.

5.6 Discussion on the Dropped Constructs

After two cycles of improving the model, the constructs discussed below achieved a positive non-significant effect on the Initial Acceptance and Usage of Technology.

i) Perceived Usefulness

In this study the construct had a positive non-significant effect on the Initial Acceptance and Usage of Technology. The researchers recognized the impact of Perceived Usefulness in determining whether or not target users will use a system, even though it did not attain the threshold required to be considered positively significant for this study. In rural communities, it has been found that people are more likely to adopt a technology, not because of the personal belief it might help them, but because someone else has referred it to them. In most cases, the beginning of adoption is filled with curiosity, and not necessarily the individual belief that the system is going to help the user perform their work in a better way. In some instances, cultural aspects are stronger determinants to adopting a technology than the perceived usefulness of the technology itself (Biljon & Kotze 2008; Hofstede 1995; Hofstede 2001). This perspective was supported in this research, especially based on the strong positive significance demonstrated by the Trust construct, which also considered the impact of referrals from other farmers towards the acceptance of using an mAgriculture technology. During the pre-study, it was evident that farmers had attempted to use other mAgriculture platforms based on referrals by influential people in their society and not necessarily because they thought the mAgriculture platform was useful to them. This construct has been researched under different mobile for development contexts such as mobile banking (Omwansa 2012), mobile health (Pynoo et. al 2013) and mobile agriculture with different profiles of users (Orwa 2012).

ii) Delivery Channel

During the pre-study, the researchers observed that users were specific about their choice of technology, which was primarily based on their preferred communication mode during normal mobile communication, or previous experience with other mobile-based services such as mobile money, mobile banking and social media applications. This was supported in the research by the fact that the Delivery Channel achieved a positive attitude with regards to the Initial Acceptance and Usage of a Technology, even though it did not score the required threshold for positive significance.

After the needs assessment and commencement of the system design in the prototype and Post-Prototype stages, the researchers settled on using two commonly used modes of communication: SMS and Voice. These two were a preferred choice of interaction from the farmers, and also based on the fact that majority owned basic and feature phones, which comfortably support these two communication channels. The vast majority of mobile agriculture platforms are build on simple easy-to-use technologies, with SMS and voice providing the easiest access and lowest barriers to entry for users (Loucky 2012). These two channels are the most commonly used means of communication, by almost 100% of subscribers in all mobile networks in Kenya (CA 2015). They may therefore not capture a distinctive difference in significance of usage, as opposed to if other channels of communication were also observed. This construct can be further tested by incorporating divert modes of information delivery such as using installable mobile applications or mobile web applications. The delivery channel has been found to be a key element in the acceptance of technology (Microsoft 2008; Microsoft 2009; Wasserman 2010), although its significance is largely on individual basis and may not be generalized.

iii) User Involvement in Requirements Gathering

In this study, users had the opportunity to express their needs, experiences with similar technologies, and their choice of interaction with the system among other requirements gathering aspects. The needs were refined in the pre-study and pre prototyping stages, with the researchers focusing on the top priority needs, and putting the other needs aside for future consideration in the improvement of *DigitalFarm*, the mAgriculture platform.

This construct demonstrated positive effect on the Initial Acceptance and Usage of the Technology, although it did achieve the required threshold to be considered significant. However, in multiple development studies related to mobile-based services for development in Agriculture, Health and Education, involving the users in requirements gathering is always a key component towards the success of the technology (Manning-Thomas 2009; ACDI/VOCA 2011). This phenomenon may be further investigated for mAgriculture services based on measurement parameters that have been successful in other domains. Previous research has demonstrated the importance of involving users during requirements collection, with various significance levels recorded (Sommerville 2015; ISO 9241-210 2015; Hoffman 2008).

iv) Support

The users of *DigitalFarm* were given the initial training of the complete system. They were also provided with a helpline to call or send an SMS in case of further inquiries or any other issues related to the system. It was observed that identifying the provision of support with a person rather than an institution promoted continuous usage of the technology. Farmers and extension experts were also comfortable communicating in Swahili or their mother tongue when seeking explanations to various features of the system.

Although the Support construct demonstrated a positive effect towards the Initial Acceptance and Usage of the Technology, it did not achieve the required threshold to be considered positively significant. It would be important to note that farmers create their own support mechanisms amongst themselves, which mostly involves peer farmers that are more experienced with technology, and peer farmers who are more educated and regarded to be elite in the society such as teachers. In the pre-study phase, it was observed that some farmers who had exposure to mAgriculture applications did not know how to read or write (compose text messages), and instead relied on their school going children or grandchildren to read messages for them or ask any questions. While support and training from the solutions vendor/innovator is critical, this phenomenon may be further investigated while considering the informal support mechanisms that arise around the ecosystem of a mobile-based innovation.

In usual information systems usage and in research, support has been an important aspect of continuous usage of technology (Pfitzer & Krishnaswamy 2007) at different levels of significance depending on the type of systems in question and other factors such as competing products and the experience of users.

5.7 Qualitative Analysis and Results

Qualitative data was gathered through interviews, observations and from the system data gathered in the research exercise. The qualitative Data Analysis process by Seidel (1998) provided the analysis guidelines of the collected qualitative data.

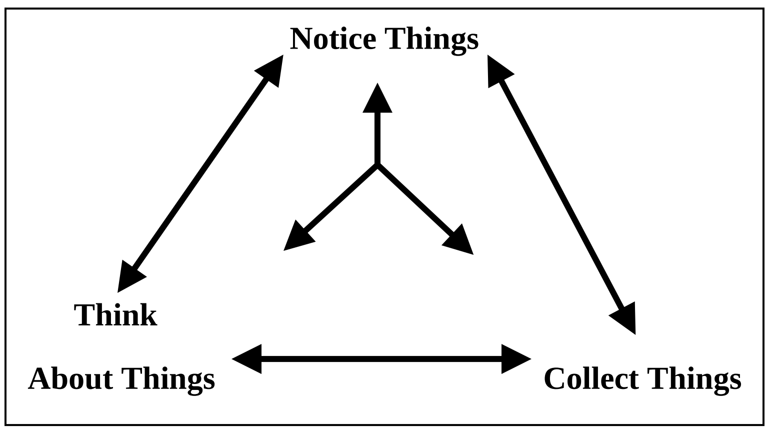


Figure 5.13: Qualitative Data Analysis Process (Seidel 1998)

The Seidel (1998) model consists of three phases namely noticing, collecting and thinking about the phenomena in question. The three phases are cyclical, as you think about your observations and interactions, you notice other aspects and collect them into the analysis. Noticing leads to the coding of data into various themes where the researchers labels the collected information into thematic ideas that were examined together. The identified themes were consistent in the data collection cycles, thus confirming the importance of the identified themes and the consistency of the famers' view concerning the identified themes.

The different variety of participants in the study brought out important aspects that don't come out in most technology adoption and use studies. These include the impact of community opinion leaders, family values, cultural influences within the family, and at the community level, community traits and their influence on technology. For rural communities, the influence of opinion leaders is key towards the adoption of a technology. The opinion leaders who influence technology adoption are teachers, clergy men or women, local politicians and administrators such as the chief. In the areas where the prototype was tested, farmers with demonstration farms paused as trendsetters in terms of farming and they largely influenced the choices of other farmers including the choice of technologies they should adopt. The peer influence among farmers was also a key factor, with members of farmer groups and other social set ups such as churches and investment groups (*chamas*) influencing each other on the usage of the technology.

Table 5.23 shows themes that were acquired from the study qualitatively through discussions with farmers and as observations by the researchers.

Table 5.23 Qualitative themes obtained from the research

Theme	**Matching Construct**	**Kirinyaga**	**Embu**	**Deduction**
Information Delivery Channel	Delivery Channel	*I would like to ask questions in mother tongue through voice* *I would like to receive information on email*	*SMS is satisfactory* *Give written information to study every month*	Farmers would wish to use their usual and most preferable means of communication to interact with mAgric apps
Cost	Price Value	*The service is not expensive* *Will asking questions be free always*	*The service is affordable* *Are there any likely payments to be introduced in future?*	The cost of DigitalFarm was affordable to farmers. They were worried if the service will continue to be free. They cited other instances when they start using a service for free then after a while it is charged.

Language and Information Structure	Hyperlocalization	*The information should always be in Kiswahili* *The information is scanty and better understanding is required*	*Give the information in Kiswahili so that we get it clearly* *Up to date information should be sent to farmers*	Farmers wanted to interact with DigitalFarm in the language they use for usual communication
Face to Face Interaction	Support Feedback	*We would like face to face visits to the farm by Digital Farm team/experts* *Visit the farmers frequently*	*Make face to face visit to farmers to strengthen Digital Farm* *Make face to face visits to the farm for first-hand experience on issues facing farmers*	Technology should not entirely replace face to face interactions. It is still important to put a face to the people behind the technology and get to interact in a more intimate manner than technology would allow
Feedback Mechanism	Feedback	*We would like to give feedback concerning the system*	*How can we give feedback concerning the system*	Farmers want to be part of the continuous improvement of the system by giving their feedback

Market	A catalyst to Initial Acceptance and Usage & Continuous Usage of Technology	*We want updates on daily market prices of various crops especially horticulture, livestock and livestock products* *Need for information on local animal feeds processing machine for low cost livestock feeds*	*Need for information on the prevailing market prices for farm produce* *Need for information on value addition and marketing*	Marketing of produce is an issue of big concern. mAgric apps may find a way to incorporate some marketing aspects
Response Time and Frequency	A catalyst to Initial Acceptance and Usage & Continuous Usage of Technology	*The response time is slow* *Increase the frequency of sending messages*	*Improve on the frequency of SMS sent*	Majority of farmers want immediate response to their queries and frequency of advisory messages
Trust and Satisfaction	Trust	*Thanks for the support, God bless you* *Information given by Digital Farm is satisfactory.*	*Good job. Continue with the good work* *Good work and thanks for the support.*	Majority of farmers were happy with DigitalFarm and were satisfied with the services offered

Farming Category-specific information	Hyperlocalization	*Information on how to serve the cows, what drugs to give, areas to observe to know the health of the cow. To preserve cow feeds. The best minerals to give* *Need for information on birds layering e.g. local chicken*	*Information on Maize farming. Poultry Keeping. Banana Farming. Goat keeping*	Farmers want information which is specific to their areas of farming

Table 5.12 shows are a close relationship between the qualitative aspects picked by the researchers and the measured constructs. This signifies the importance and positive significance of the identified themes towards the initial acceptance and usage of a technology, as well as the continuous usage of the technology.

CHAPTER 6: CONTRIBUTIONS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This study explored in details the mAgriculture space in Kenya, aiming to provide useful insights to application developers, researchers, and other practitioners in the mAgriculture ecosystem. Through a pre-study exercise, the researchers was able to understand mAgriculture in specific regions in Kenya, including the existing technologies, key stakeholders and the experiences of farmers and other involved stakeholders in using those technologies. This resulted in a rich discussion on the existing mAgriculture innovations, and the establishment of key challenges affecting mAgriculture applications in Kenya, leading to the development of a model to guide the design and implementation of mAgriculture applications. The model was validated using *DigitalFarm*, an mAgriculture prototype that focused on the provision of extension services to farmers by the use of SMS and Voice interfaces. In this concluding chapter, the researchers focuses on the key highlights towards the attainment of the set objectives, achievements and contributions made in this research, and the recommendations for further research.

6.2 Attainment of the Objectives

The primary aim of this research was to inform mobile application developers, researchers and other practitioners in the mAgriculture domain, in the design, development and implementation of mAgriculture applications. The research was able to achieve the set objectives as discussed below:-

i) To investigate the challenges facing the usage of mAgriculture applications.
ii) To establish the factors that lead to successful or unsuccessful design, development and implementation of mAgriculture applications.
iii) To model the identified factors and challenges into a perspective that will guide the design, development and implementation of mAgriculture applications.

iv) To validate the model using a user-centric mAgriculture prototype for dairy farmers which is informed by the developed model.

a) Challenges facing the usage of mAgriculture applications in Kenya

The researchers embarked on a pre-study exercise that involved 143 farmers from five different regions in Kenya namely Wajir, Marsabit, Isiolo, Embu and Kirinyaga. The pre-study aimed at understanding the mAgriculture domain in Kenya among different communities, the exposure to mAgriculture applications by dairy farmers and the challenges farmers face when using mAgriculture applications. From the interaction with farmers, the researchers was able to identify the challenges facing the usage of mAgriculture applications in Kenya. From this exercise, the key challenges below were identified:-

i) Lack of involvement by the target users on the ground during the determination of needs, design and development
ii) Unfavourable pricing models to the farmer
iii) Poor support after deployment of the innovation
iv) Lack of feedback mechanisms
v) Non-localized content in terms of language, region of farming and category of farming

Further to these, the researchers identified the various challenges during each stage of an mAgriculture innovation life span that includes Needs and Analysis, Proof of Concept, Large Scale Implementation and Widespread Adoption.

An exploration of mAgriculture applications in Kenya and other developing countries also gave a deeper insight on the challenges affecting the usage of mAgriculture applications in different contexts of usage. The researchers reported on comprehensive studies done on mAgriculture applications by researchers in renown institutions such as the World Bank(2012) and Harvard Business School (Loucky 2012).

Besides the insights borrowed from the pre-study and literature, the researchers also interviewed 28 e-extension officers. This was a group of extension officers that had been trained by the government on using ICT tools (mobile and web platforms) to advise farmers. The officers provided key lessons and challenges that they were facing when using mobile based systems in advising farmers as explained in section 3.3.2 of this work.

Challenges raided by e-extension officers include:-

i) Technical and detailed language on the platform
ii) Lack of internet bundles to access the online platform
iii) Lack of internet access in some regions of the country, thus making it difficult to access information
iv) Poor usability of the e-extension platform
v) Lack of information on some crops and animals farmers are inquiring about
vi) Following up farmers
vii) Illiteracy among farmers
viii) Lack of electric power in remote areas making it difficult for the e-extension officer to frequently access information
ix) Poor mobile network coverage in some regions of the country

b) Factors that lead to the successful or unsuccessful design, development and implementation of mAgriculture applications

An investigation on the design and implementation techniques that was followed in the process of coming up with various mAgriculture applications provided useful evidence on what approaches resulted in the successful or unsuccessful design and implementation of mAgriculture applications. In addition, the researchers explored existing design, development and implementation standards applicable for mobile-based systems (Microsoft 2008; Basole 2005; Wang & Waiman 2004).

The development process of *DigitalFarm* was paramount in identifying the factors leading to the successful or unsuccessful design of mAgriculture applications. The activities in the Pre-Prototype, Post-Prototype stage 1 and Post-Prototype stage 2 included design and implementation steps that involved participation by farmers and other stakeholders, such as agriculture extension officers. During the design and implementation process, farmers provided useful insights that were critical in the design and implementation of *DigitalFarm*. This ensured that the target users were involved throughout the entire process as explained in Chapter 4.
As identified in the modelling process, the factors that lead to successful mAgriculture applications development include Trust, Effort Expectancy, Hyperlocalization of content, language, region and environment, and Price Value.

c) Components of a design, development and implementation model for mAgriculture applications

The rich information acquired in the pre-study phase and during the exploration of literature led to the formation of a design and implementation model for mAgriculture applications. The model was composed of key aspects identified to be critical in mAgriculture, and were categorized into human aspects, technology aspects, need aspects, and cost and sustainability aspects. Each of these aspects had items of measurements which guided the kind of questions that were required to gather data for the same.

The model went through a refinement process, while the various aspects were investigated for their role towards the acceptance and continuous usage of an mAgriculture technology. The PLS-SEM process was applied, and measures of path-coefficients significance were used to indicate what was critical and non-critical in the initial acceptance of an mAgriculture technology, as well as the continuous usage of an mAgriculture technology. The model was validated using an mAgriculture prototype.

d) **Validation of the model using a user-centric mAgriculture prototype for dairy farmers which is informed by model.**

Following the interactions with farmers and extension experts, the *DigitalFarm* system was designed and developed as elaborated in Chapter 4. The users were involved in the needs collection, design and development, and also trained on how to use the final system, and given the opportunity to critic it and suggest any improvements on it. Three cycles of data collection were made, while measuring the user's responses against the constructs identified to be of key importance in the conceptual model. The data collection stages allowed for periods of observation on the usage of the system, as well as improving the system as per the feedback received from the users.

The key items that stood out to be of positive significance were Trust, Effort Expectancy, Hyperlocalization, Feedback and Price Value.

6.3 Research Contributions

This study resulted to theoretical contributions that will form the foundation of further research in mAgriculture, as well as practical contributions that provide actionable guidelines in the design and development of mAgriculture applications in developing countries.

In addition, the research identified important aspects of mAgriculture through a pre-study exercise and was able to confirm their importance in mAgriculture by testing the model and obtaining a positive outcome. This created new relationships that can be considered by researchers when building theories around initial adoption of technology and continuous usage. While majority of technology adoption and usage theories focus on an organizational set up of users, this study involved the participation of a different demographic of users during theory development. The demographic consisted of rural farmers, most of whom have basic education and are not operating in an organizational set up.

Moreover, most of the existing information system theories have been derived from systems that have been introduced to the users without their involvement in pre-deployment activities and sensitization. This study however, involved users in all stages of design, development, and deployment of the technology.

As show in Figure 6.1, the constructs in the final model were able to highlight key aspects that should be considered during the Design and Implementation of mAgriculture applications.

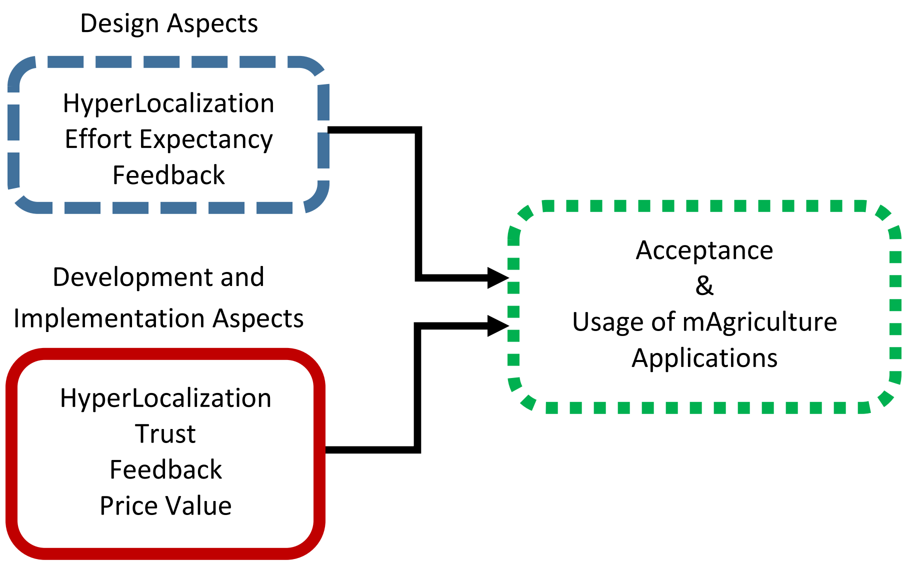


Figure 6.1: The Design, Development and Implementation aspects of the derived research model

The key theoretical contribution from this study was the development of a group of the determinants of initial acceptance, and the use of a technology and continuous use of the technology. The above characteristics touching on behavioural aspects of the farmers, their culture, attitude and behaviour towards technology were key ingredients in building the research model, besides what other researchers have concluded as widely cited in this research work.

The framework developed by Whetten (1989) to assess research model contributions was used as a guideline in discussing the key contributions made in this research.

i) Does the research make significant value-added contribution to current thinking?

The research took into consideration the previous work that has been done in the design and development of mobile-based systems. Different design and development models, models investigating the initial acquisition and usage of technology, as well as the experiences of farmers with mobile technology provided in-depth insights into the current approaches that have been used. This study incorporated some aspects that had not been considered in other models addressing the design and implementation of mAgriculture applications, such as the consideration of Delivery Channel and Hyperlocalization as key aspects in determining the initial acceptance and usage of a technology. The new model is a key contribution that can be used in the design of mAgriculture applications, as well as replicated in other M4D domains, for similar audiences such as mHealth and mLearning.

ii) Will the study change the practice of design and implementation of mAgriculture applications among farmers in developing countries?

The results of this study will be of substantial benefit to the community of mAgriculture application developers, researchers, content providers and other practitioners in mAgriculture. The information gathered on the impact of the model towards the acceptance and usage of technology is evidence that practitioners can expect success in the usage of mAgriculture applications when they apply the specified components of the model. In addition, discoveries made during the pre-study exercise and the interactions with farmers during prototyping provided guidelines to be followed in the user-centred design and implementation of mAgriculture applications. The research and the success of the prototype also brings out the importance of collaborative efforts towards the design of applications among all the target users, application developers, content providers, government agencies and technology infrastructure providers.

iii) Are the underlying logic and supporting evidence compelling?

A progressive step-by-step process was followed throughout the study. The pre-study done at the commencement of this research led to a deep understanding of the needs and challenges facing farmers, readiness of farmers for mAgriculture applications, and exposed key lessons from existing mAgriculture innovations. The research objectives and questions were then developed, to address a key problem that was identified in the mAgriculture domain. This was followed by a comprehensive and analytical literature review, which explored the deployments of mAgriculture applications in developing countries, the challenges of mAgriculture innovations, readiness for mAgriculture applications among dairy farmers in Kenya, mobile software engineering design and development models, user-centred design, and the initial acceptance and usage of mobile-based technologies. The rich information gathered from the pre-study and the extensive literature review led to the development of the research conceptual model, from which research instruments were derived.

The identified model components were factored in during the design and development of *DigitalFarm*. In addition, three cycles of data collection and continuous feedback was done on the system, leading the validation of the research model and the identification of key factors that affect the initial acceptance and usage of mAgriculture applications, as well the continuous usage of mAgriculture applications. This was done using the PLS predictive modelling technique, which inculcates a rigorous step-wise process, proven beyond doubt in numerous research studies.

iv) How well does the research convey completeness and thoroughness?

The research road map in Figure 3.1, shows the process followed in this study. The progressive execution of the research phases ensured a coherent logical flow that borrowed from one stage to another. The data collected in the study was subjected to relevant reliability and validity tests, cleaning and coding before analysis. In addition, the results of the study showed consistency for similar components in other studies, while the perceptions identified in the pre-study as critical factors in determining the initial acceptance and usage of the technology were supported by the derived research model. Moreover, acceptable and sound research procedures were followed throughout the study.

v) Is the thesis well written and does it flow logically?

The composition and documentation of the research was done according to conventional and proven structures, while upholding the required logical flow of thoughts, ideas, existing knowledge, and new discoveries. The organization of the study began with an account of background information and problem identification, followed by research objectives and questions. The next chapter consists of an extensive literature review, covering key areas important to the research study such as ICT innovations in Agriculture, mobile software design and development models, user-centred design, and a discussion on research models related to initial acceptance and continuous usage of technology. This consequently led to the derivation of the research conceptual model. This chapter is followed by the methodology, with details of the research road map and design. An exposition of the design and development of *DigitalFarm* system was done, which was followed by a thorough discussion of the results and findings, and then major contributions and recommendations were highlighted.

vi) Why now? Is the topic of interest to scholars and practitioners in this area?

ICT, specifically mobile technology has recorded exponential penetration in the developing countries, providing opportunities for application in areas of economic empowerment, consequently leading to improved life standards. Moreover, agriculture has continued to be the key economic activity for Kenya, contributing the highest to the GDP (Arndt, et al. 2016), a characteristic that is similar in other African countries. The impact of ICT in fostering agriculture cannot be ignored, given the teething challenges and needs in agriculture within developing countries. As identified in the pre-study and literature review exercises of this study, there are numerous endeavours of developing ICT solutions for agriculture that have been both successful and unsuccessful. Moreover, there is also a new focus on ICT4Ag in developing countries as an area for research and practice, given the numerous international conferences and forums on this subject (AGRF, 2016). This is with the realization that ICT is a tool that can transform agriculture as a key economic sector in developing countries such as Kenya.

vii) Who else including academic readers are interested in this topic?

This topic is of interest to mAgriculture application developers, ICT4D, M4D and ICT4Ag researchers, policy makers, government agencies that deal with agriculture and national and international development agencies that support agriculture development.

For each of the identified groups, the research has made the following contributions:-

a) mAgriculture application developers

The key lessons in the user-centred design and development techniques for mAgriculture applications shall be useful to application developers. The challenges facing the usage of mAgriculture applications and lessons learnt on existing mAgriculture applications provide very useful information to this audience. In addition, the steps followed in the design and development of *DigitalFarm* is a wealth of knowledge for practice to application developers. The development of Web, SMS, and Voice-based subsystems demonstrated how various communication channels can be used to accommodate different kinds of users, while taking into consideration their capabilities and the kind of technology which is affordable to them.

b) ICT4Ag Researchers

The research model, the methodology followed, and the scientific approach of deriving the model, forms a resource to ICT4Ag researchers. The research model components provides a theoretical foundation that can be used for further research, or in the investigation of other sectors in relation to mobile-based systems. In addition, the use of PLS-SEM approach shows how to apply sound research techniques in modelling a research phenomenon.

c) Policy Makers and Government agencies

The access of technology infrastructure in some parts of developing countries such as Kenya is still a challenge. The outcomes of this research as pertains to the full potential of mAgriculture applications, will benefit policy makers to support ICT infrastructure growth, to enable more farmers and other agriculture practitioners benefit from the full potential of mAgriculture applications. On the other hand, government agencies and bodies such as the Ministry of Agriculture and Ministry of ICT may support the ecosystem of mAgriculture applications by setting up nation-wide initiatives that involve the usage of mobile-based systems among farmers and other practitioners in agriculture.

The research findings can be used as considerations in deploying ICT4Ag initiatives in developing countries. In addition, governments can find directly applicable ways to use technology in the promotion of important sectors of the economy. Moreover, a competitive environment in the mobile telecommunications sector needs to be encouraged in order to lower costs at the benefit of farmers.

d) Development Agencies

Organizations that fund areas of economic growth such as agriculture should consider supporting mAgriculture initiatives, given the potential of agricultural transformation that they have. As shown in the research process, there are numerous needs and challenges among farmers that can be addressed using mAgriculture applications as an intervention.

In addition to the above theoretical contributions, the research also made key best-practical contributions in the development of mobile-based systems, by demonstrating the creation of *DigitalFarm*. The development process detailed in Chapter 4 may be applied in other areas such as health, education, finance, transport, etc in the development of applications that target communities in developing countries. The steps and techniques followed not only propel the initial adoption and continuous usage of a technology, but has also impacts the user's decision making process, which is a key measurement metric in mobile for development projects.

6.4 Research Conclusions

Mobile-based innovations have been identified as potential drivers towards a transformation of agriculture in developing countries such as Kenya. The high penetration of mobile technology and the great economic impact by agriculture calls for a maximization of available technologies that can enhance various activities in the agriculture value chain. It is therefore of paramount importance that best practices for maximum success of mAgriculture applications are adhered to, in all stages of the solution development.

This study demonstrated key aspects that should be considered for successful design and development of mAgriculture applications. The findings made are of importance to the various stakeholders in mAgriculture, and can be extended to other areas focusing on the design and development of M4D innovations.

The process followed in the design and development of *DigitalFarm* provides a guideline to mAgriculture application developers. The application of critical components to be considered such as Trust, Effort Expectancy, Hyperlocalization, Price Value and Feedback validated the developed research model. This validated the importance of the developed research model components towards the design and development of mAgriculture applications. Moreover, the research demonstrated how the least educated in the society can be accommodated in mobile-based systems, by the use of voice-based interfaces. In addition, the research demonstrated the use of PLS-SEM, in developing a sound argument with theoretical and technical contributions.

6.5 Limitations and Recommendations for further study

This study had several limitations to it. To start with, the focus was domain specific, and only addressed mAgriculture, and therefore the derived model may not be confirmed to work in other domains. Secondly, the group of respondents were primarily rural smallholder dairy farmers, with uniform characteristics such as environments of operation and general level of education. The study may therefore not fully represent the views of farmers with differing characteristics, or in different areas of operation e.g. pastoralists or large scale farmers. Thirdly, the study was done in an environment that did not have cultural diversity among the respondents, and varied socio-economic status. Majority of the farmers shared the same cultural values, and belonged to the same socio-economic class.

The researchers recommend further investigation on several areas. Firstly, the model can be investigated within other M4D domains apart from agriculture, such as health and education. The prototype may also be tested in other domains, especially for advisory or learning purposes. Secondly, the research may be done with varied groups of farmers, such as large scale farmers and pastoralists, in order to cater for a wide array of farmers' personal characteristics and settings. Thirdly, the constructs may be further investigated, with a wider array of measurement items. For example, constructs such as Delivery Channel, User Involvement in Requirements Gathering and Perceived Usefulness were expected to have positive significance, based on the opinions shared during the pre-study and the review of existing literature. A keen focus on the items of measurement for these constructs, may probably yield different results. Fourthly, the researchers recommend that the dropped constructs be studied with a different group of users to see if there is any variability with the aspects relating to initial acceptance and continuous usage of a technology.

Finally, the researchers also recommends that the effect of the proposed model constructs to Initial Acceptance and Use of Technology be moderated by certain aspects such as the user's experience, gender, age and social class.

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APPENDIX A: Questionnaires

A1: Pre-Study Questionnaire

MOBILE-AGRICULTURE RESEARCH QUESTIONNAIRE
RESEARCHER: AMOS GICHAMBA, PhD Computer Science Student
University of Nairobi

Thank you for agreeing to participate in this research.

In this research, our purpose is to find out how we can best develop mobile-based programs that will improve your farming experience, leading to better yields in your areas of farming such as dairy farming.

The information you will give us will be treated with utmost confidentiality and your personal information such as names will not be used in other contexts or associated with anything you say or take part in during the research process

A: GENERAL DEMOGRAPHIC DATA

1.

Region/Area of Respondent
Residential Area:____

2. Respondent gender: MALE ☐ FEMALE ☐

3. Other Occupation apart from farming: ____

4. Highest Education Level

Primary School	High School	College	University	No Formal Education	Other

5. Indicate your age bracket.

16 -25	26-35	36-45	46-55	Over 56

6. What activities do you do as a dairy farmer?

Activity	**Challenge**	**What can be done / Proposed Solution**
Buying farm inputs		

Receiving advise from Agric		

7. Apart from the challenges noted above, are there any other challenges that you encounter as a dairy farmer?

Challenge	**What can be done / Proposed Solution**

8. Is there an Agriculture extension officer in your region? Yes ( ) No ( )
9. If you answered Yes to the above question, do you get advise from the agriculture extension officer in your region? Yes ( ) No ( )
10. If you answered No to the above question, Why?

I don't know how to find him/her	
I don't find their advise useful	
Other reasons: Specify	

B: GENERAL MOBILE PHONE SERVICE AND DEVICE INFORMATION

11. Do you own a mobile phone? Yes ( ) No ( )

12. If your answer is yes to the question above , what is the make of your cell phone?

Manuf.	Nokia	Motorola	Huawei	Ericsson	iPhone	Samsung	Techno	Others (…………….)
Model								

13. Do you use mobile phone programs such as games, social network applications, communication applications e.g. chat? Yes( ) No( )

14. Who is your Mobile Service Provider? **Safaricom** ( ) **Airtel** ( ) **Orange** ( ) **Yu**( ) **Other**( ) Please specify……………………………………..

15. Do you use the mobile payment system provided by your Mobile Service Provider? Yes( ) No( )

16. If you answered Yes to the question above, which mobile money service do you use?
☐ M-Pesa ☐ Airtel Money ☐ Orange Money ☐ Yu Cash

17. What is the frequency of failure of your mobile service provider's network?

Daily	Once per week	Once per two weeks	Once per month	Hardly fails

C: USAGE OF M-AGRICULTURE APPLICATIONS

18. Have you ever used any mobile agriculture application? Yes( ) No( )

19. Do you use your mobile phone to request for information or services related to agriculture? Yes ( ) No ( )

20. If your answer to the question above is Yes, Specify the service/information you request____

21. As a dairy farmer, in which ways would you like to use your mobile phone to enhance your farming?

____

____

D: OPPORTUNITY TO USE PHONES

22. Which services would you like to receive from your mobile phone?
Receiving information on farm input ☐

Contacting the Veterinary Officer ☐

Contacting the Agriculture Ext. Officer ☐

Finding market for produce ☐

23. What other things would you want to do if you were informed you could be able to achieve them with a phone?

____

____

24. How do you normally achieve those things at the moment without a phone?

____

____

25. What is your preferred language?

LANGUAGE	Writing	Reading	Speaking
Kiswahili			
English			
Mother Tongue:			

A2: E-Extension Experts Questionnaire (Administered via Google Forms)

9/20/2016 E-Extension Survey: iKilimo Case Study

E-Extension Survey: iKilimo Case Study

Thank you for agreeing to participate in this research.
In this research, our purpose is to find out how we can best develop mobile-based programs that will improve the farming experience of farmers, leading to better yields in various areas of farming such as dairy farming.
The information you will give us will be treated with utmost confidentiality and your personal information such as names will not be used in other contexts or associated with anything you say or take part in during the research process
AMOS GICHAMBA, PhD Computer Science Student
University of Nairobi

* Required

1. **Name (Optional)**

____

2. **Mobile Number (Optional)**

____

3. **District** *

____

4. **For how long have you used iKilimo?** *
Mark only one oval.
   - ◯ Less than 2 Months
   - ◯ 3 Months - 6 Months
   - ◯ 6 Months - 11 Months
   - ◯ 1 Year

5. **Which modules do you frequently use on iKilimo?** *
Check all that apply.
   - ☐ Animal Production
   - ☐ Farm Equipment
   - ☐ Food Processing
   - ☐ Plant Production
   - ☐ Marketing

6. **Select the iKilimo platforms you have used** *
Check all that apply.

- [ ] Web Access (Via Computer)
- [ ] Web Access (Via Phone)
- [ ] Android Application
- [ ] SMS Service

7. **Which iKilimo platform do you prefer the most?** *
Mark only one oval.

- ( ) Web Access (Via Computer)
- ( ) Web Access (Via Phone)
- ( ) Android Application
- ( ) SMS Service
- ( ) The platform doesn't matter to me

8. **Briefly explain your reasons for selecting the above answer** *

9. **iKilimo is user friendly** *
Mark only one oval.

- ( ) Strongly Disagree
- ( ) Disagree
- ( ) Neutral
- ( ) Agree
- ( ) Strongly Agree

10. **I can easily navigate iKilimo** *
Mark only one oval.

- ( ) Strongly Disagree
- ( ) Disagree
- ( ) Neutral
- ( ) Agree
- ( ) Strongly Agree

11. **I can easily remember previous steps to do a task in iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

12. **How can the interactivity of iKilimo be improved to make its usage easier for you?** *

____

13. **What challenges do you have while using iKilimo?** *

____

14. **Do you think iKilimo is easy to use by the common mwananchi? Why or Why Not?** *

____

15. **I was consulted during the design of iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

16. **I enjoy using iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

17. **At times I find myself opening iKilimo without the aim of achieving something specific** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

18. **The time you would spend accessing information on Dairy breeds on the iKilimo platform (Access the feature and estimate your time)** *

Mark only one oval.

- 2 Mins or Less
- 3 - 5 Mins
- 6 - 10 Mins
- 11 - 15 Mins
- Over 15 Mins

19. **What content can be added on iKilimo animal production section in order to suite your needs?** *

____

20. **The content provided on iKilimo suites my needs** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

21. **I find the functionality of the application helpful to me** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

22. **iKilimo is outstanding** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

23. **My religious beliefs would influence whether or not I can use iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

24. **Approval from an administrator e.g. a chief would determine whether I will use iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

25. **The opinion of a community elder would influence if I should use iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

26. **I find it easy to get iKilimo to do what I want it to do** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

27. **Interacting with iKilimo does not require a lot of my mental effort** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

28. **iKilimo is worth the amount of money I am spending on it(e.g. on data bundles)**

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

29. **The use of iKilimo has become a habit to me** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

30. **I must use iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

31. **I intend to continue using iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

32. **I would recommend other people to use iKilimo** *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

33. **Have you used another application/program similar to iKilimo?** *

Mark only one oval.

- Yes
- No

34. **If you answered Yes to the question above, indicate the application/program you have used** *

____

35. **What do you like about the other application/program you have used apart from iKilimo?** *

36. **What don't you like about the other application/program you have used apart from iKilimo?** *

A3: Pre-Prototype Questionnaire

MOBILE-AGRICULTURE RESEARCH QUESTIONNAIRE
RESEARCHER: AMOS GICHAMBA, PhD Computer Science Student
University of Nairobi

Thank you for agreeing to participate in this research.

In this research, our purpose is to find out how we can best develop mobile-based programs that will improve your farming experience, leading to better yields in your areas of farming such as dairy farming.

The information you will give us will be treated with utmost confidentiality and your personal information such as names will not be used in other contexts or associated with anything you say or take part in during the research process

A: GENERAL DEMOGRAPHIC DATA

1.

First Name: ______________________ Mobile No: __________________________________

County : _______________________________ Residential Area: ______________________________

2. Respondent gender: MALE ☐ FEMALE ☐

3. Tick your highest education level

Primary School	High School	College/Diploma	University / Degree	No Formal Education	Other
☐	☐	☐	☐	☐	☐

4. Tick your age bracket below

16 -25	26-35	36-45	46-55	Over 56
☐	☐	☐	☐	☐

5. Which ***dairy*** animals have you currently kept?

Animal	No. of Animals
Cow	
Goats	
Camel	

6. Do you keep the dairy livestock for the purpose of selling milk only?
Yes ☐ No ☐

7. If you answered No to Question 6, what other purpose do you keeping the animals?
To Sell Later ☐ Sign of Wealth ☐ Dowry ☐ Other: __________________

8. On average how many ***liters*** of milk do you get from the animals daily?

	0.5 – 2	3-5	5-9	10-19	15-19	20 - 29	30 and Over
Cow							
Goat							
Camel							

9. Is selling of milk your main source of income?
Yes ☐ No ☐

10. What are your other sources of income?

Employment	Crop Farming	Business	Casual Laborer	Other (indicate below)
☐	☐	☐	☐	______________

B: GENERAL MOBILE PHONE SERVICE AND DEVICE INFORMATION

11. Do you own a mobile phone? Yes ☐ No ☐

12. If your answer is yes question 11, what is the make of your cell phone?

Manuf.	Nokia	Motorola	Huawei	Ericsson	iPhone	Samsung	Techno	Others (…………….)
Model								

13. Do you use mobile phone programs such as games and mobile money e.g. M-Pesa?
Yes ☐ No ☐

14. I have the necessary skills to use a mobile phone to read, write and send SMS messages

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

C: USAGE OF M-AGRICULTURE SERVICES

15. Do you use your mobile phone to request for information or services related to agriculture?
Yes ☐ No ☐

16. If your answer to question 14 is Yes, Specify the service or information you receive____

17. As a dairy farmer, I believe that a mobile phone can help me achieve more productivity

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

18. As a dairy farmer, I believe that a mobile phone can help me increase my knowledge and skills

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

D: OPPORTUNITY TO USE PHONES

19. As a dairy farmer, which services or information would you like to receive via your mobile phone? (See example services / information that can be offered below)

Information / Service	**How would you like to receive that information/ service.**		
	SMS	Internet / Website	Receive a Call
Animal Feeding Tips From Experts			
Ask questions to an expert			
Receive responses from an expert			
Where to find market for my produce			
Price of produce e.g. milk in the market			
Contacting agriculture extension officer			
Animal Diagnosis Service			
Others:			

20. What is your preferred language for the information / service you have selected?
Swahili ☐ English ☐ Mother Tongue (Specify)_____________

A4: Post-Prototype Stage 1 and Stage 2 Questionnaire

MOBILE-AGRICULTURE RESEARCH QUESTIONNAIRE
RESEARCHER: AMOS GICHAMBA, PhD Computer Science Student
University of Nairobi

Thank you for agreeing to participate in this research.

In this research, our purpose is to find out how we can best develop mobile-based programs that will improve your farming experience, leading to better yields in your areas of farming such as dairy farming.

The information you will give us will be treated with utmost confidentiality and your personal information such as names will not be used in other contexts or associated with anything you say or take part in during the research process

A: GENERAL DEMOGRAPHIC DATA

First Name: ______________________ Mobile No: ________________________________

County : _____________________________ Ward: ____________________________

1. Respondent gender: MALE ☐ FEMALE ☐

2. Tick your highest education level

Primary School	High School	College/Diploma	University / Degree	No Formal Education	Other
☐	☐	☐	☐	☐	☐

3. Tick your age bracket below

16 -25	26-35	36-45	46-55	Over 56
☐	☐	☐	☐	☐

4. Which ***dairy*** animals have you currently kept?

Animal	No. of Animals
Cow	
Goats	

5. Which crops do you farm for commercial (selling) purposes?

Crop	[√] Tick all that apply
None	
Bananas	
Maize	
Beans	
Rice	
French Beans	
Sweet Potatoes	
Arrow Roots	
Water Melons	
Butternut	
Tomatoes	
Other	

B: **DIGITAL FARM SERVICE SURVEY**

Part 1:

6. The delivery channel (SMS, Voice, etc) would influence whether I should use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

7. I prefer to send an SMS instead of Calling on *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

8. I prefer to Call instead of sending an SMS on *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

9. Calling or sending an SMS does not matter to me as long as I get the information or service I need

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 2:

10. The content I receive from *DigitalFarm* is useful to me

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

11. The *DigitalFarm* SMS service is user friendly

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

12. The *DigitalFarm* Voice service is user friendly

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

13. *DigitalFarm* is good for me

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

14. I was asked to give feedback concerning *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 3:

15. I have full confidence in *DigitalFarm* and that is why I accepted to use it

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

16. I would refer *DigitalFarm* to other farmers

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 4:

17. My religious beliefs would influence whether I would use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

18. Approval from an administrator e.g. a chief would influence whether I would *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

19. The opinion of a community elder would influence if I should use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 5:

20. I was asked to specify which information/services I would like to receive from *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

21. The possibility of getting information/services that I am interested in influenced my decision to use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 6:

22. The possibility of getting information which is specific to my region, my category of farming and use of my preferred language influenced my decision to use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

23. The information and services I receive from *DigitalFarm* are specific to my region

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

24. The information and services I receive from *DigitalFarm* are specific to my category of farming/agriculture

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

25. The information and services I receive from *DigitalFarm* is provided in my preferred language

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

26. I feel that my operating/working environment has been considered by *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 7:

27. I considered the cost of acquisition and continuous cost before accepting to use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

28. The cost of acquiring *DigitalFarm* is affordable to me

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

29. The continuous cost of using *DigitalFarm* is affordable to me

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

30. *DigitalFarm* is worth the amount of money I am spending on it

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 8:

31. I considered the possibility of giving feedback before accepting to use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

32. I know how to give feedback concerning *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

33. I feel that the feedback I give is usually acted upon

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

34. The response to my feedback will determine whether or not I will continue using *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 9:

35. I considered the possibility of getting Support before accepting to use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

36. I was given instructions on how to use *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

37. I receive continuous support while using *DigitalFarm*

Strongly Disagree [ ]	Disagree [ ]	Neutral [ ]	Agree [ ]	Strongly Agree [ ]

Part 10:

38. Apart from the current advice given on the *DigitalFarm* system, what other service or information would you like to receive?

____

____

A5: Focus Group Discussion guide used in the Pre-Study

A Model for the Design, Development and Implementation of mAgriculture Applications

Researcher: Amos Gichamba, University of Nairobi

Discussion Preparation

The participating members to settle down.
Where required, the interpreter to be on stand-by with their copy of FGD guide with necessary notes to emphasize on the discussion points.

Introduction (15 Minutes)

Calling the group to attention by the group leader.
Introduction of the researcher by the group leader and an overview purpose for the group discussion.
Introduction of the researcher by self and a detailed purpose of the group discussion.

Actual Discussion (45 Mins)

- *Researcher to give a brief intro on technology and generate a conversation among the group on various ways they use technology, specifically mobile phones.*

Questions to prompt after intro

a) *What technology do you have access to, either owned by you, either at home, workplace, community centres, etc?*
b) *How do you use your mobile phone in relation to your farming activities?*
c) *How else would you like to use your mobile phone as a farmer?*
d) *Are there circumstances you require help when using your phone? If so, which ones?*
e) *What kind of challenges do you face in your usage/ownership of a mobile phone?*
f) *Do you have any challenges using your mobile phone services/features?*
g) *On average, how much do you spend on expenses related to your mobile phone ownership e.g. purchase of airtime, charging, etc? How much do you spend on farming-related activities (refer to (b) above)? Would you pay for the services quoted in (c) above?*

APPENDIX B: Sample feedback from the system users

Add a feature to the system to help farmers detect counterfeit products
Provide Information on where to source livestock breeds e.g. rabbits, improved poultry, dairy cows and where to market the livestock
Please send messages more frequently
Give written information to study every month; Visit the farmers frequently; Advise on how to improve the farming systems
Provide updates on daily market prices of various crops especially horticulture, livestock and livestock products
Give written information to study every month; Visit the farmers frequently; Advise on how to improve the farming systems
Provide more information on value-addition and marketing farm produce
How to/where can I get polythene tank type for rain water harvesting? Give NGOs information that support dairy farming and upgrading. God bless you for the support you have offered
Some of the information is scanty and summarized
Provide a list of suppliers who give genuine seeds for crops and cattle dip sprays.
My SMS replies are not being delivered
Come up with projects that help farmers learn from them to understand more
Make face to face visit to farmers to strengthen DigitalFarm
Thanks for the support, God bless you

APPENDIX C: DigitalFarm Sample Screenshots and Source Code

C1: Web Interface Screenshots

Figure C1.1: Voice Questions Dashboard

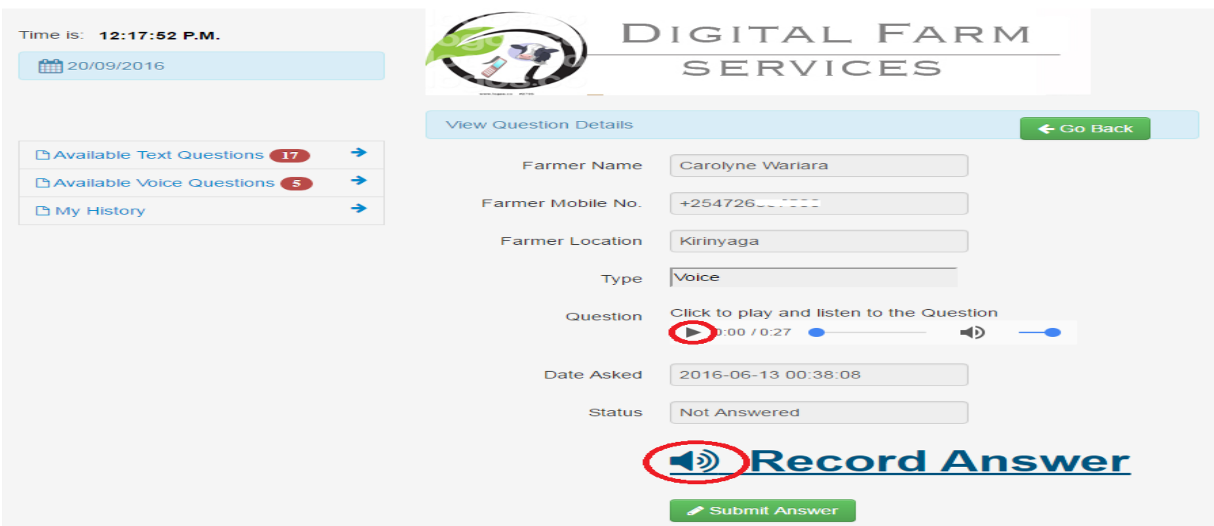


Figure C1.2: Responding to a Voice Question

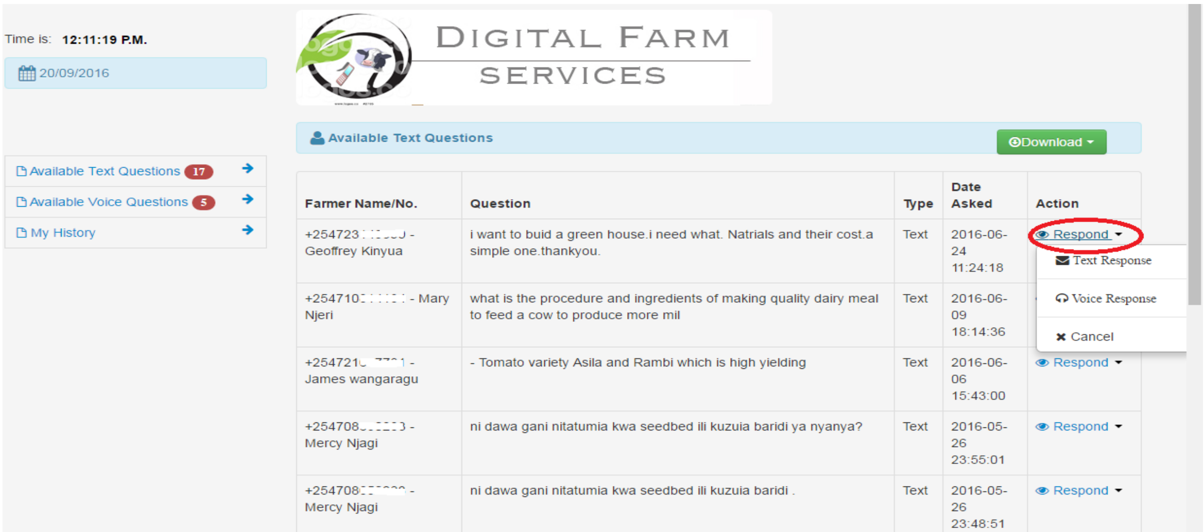


Figure C1.3: Text Questions Dashboard

C2: Voice System Code Snippets

```
//A function to make the voice response
function respond($text)
{
  $response  = '<?xml version="1.0" encoding="UTF-8"?>';
  $response .= '<Response>';
  $response .= '<Say voice="woman" playBeep="false">'.$text.'</Say>';
  $response .= '</Response>';
 return $response;
}

//A function to play the welcome message
function playAudio()
{
  $response  = '<?xml version="1.0" encoding="UTF-8"?>';
  $response .= '<Response>';
  $response .= '<Play url="host/digitalfarm/voice/audio/welcome_eng.wav" />';
  $response .= '</Response>';

 return $response;
}

//A function to play audio and prompt for input using a beep
function respondAndBeep($text)
{
  $response  = '<?xml version="1.0" encoding="UTF-8"?>';
  $response .= '<Response>';
  $response .= '<Say voice="woman" playBeep="true">'.$text.'</Say>';
  $response .= '</Response>';

 return $response;
}
```

C3: SMS System Code Snippets

```php
<?php
  $sms = "Dear $fname,you have successfully registered on Digital Farm Services.Send your questions to 20414 via SMS starting with the word Farmer, o
  }
  }
  else
  {
  $sms = "Registration Failed.Please register for FREE by sending your name and county to 20414 starting with the words Farmer Register e.g. Farmer R
  }
}
else
{
 $farmerid = "";
 $sender = "DigitalFarm";
 $county_id = getFarmerCounty($from);
        $user = getCountyAPIUsername($county_id);
        $pass = getCountyAPIPassword($county_id);
 $sms = "Dear $farmername,your message has been received."; //Acknowledge recepit of an incoming SMS
 // SMS message to the experts of the county

 $sms2 = "A new question has come in from a farmer, kindly login to respond.";
 }
 else
 {
```

APPENDIX D: Research Permit and Authorization Letter

NACOSTI

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471, 2241349, 310571, 2219420
Fax: +254-20-318245, 318249
Email: secretary@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/15/7732/8620**

Date:
15th December, 2015

Amos Njihia Gichamba
Africa Nazarene University
P.O. Box 53067-00200
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"A model for the design and deployment of magriculture applications: The case of dairy farming in Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Embu and Kirinyaga Counties** for a period ending **14th December, 2016.**

You are advised to report to **the County Commissioners and the County Directors of Education, Embu and Kirinyaga Counties** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

DR. M. K. RUGUTT, PhD, HSC.
DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Embu County.

The County Director of Education
Embu County.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

APPENDIX E: Pre-Study Results

Introduction

The pre-study involved 143 dairy farmers from five different regions of Kenya namely Wajir, Marsabit, Isiolo, Embu and Kirinyaga. The major objective of the pre-study was to carry out a needs assessment exercise among dairy livestock keepers, establish the penetration of mobile technology among different groups of farmers, establish the exposure of mAgriculture technologies among farmers and challenges in their usage, identification of affordable preferably farmer-owned technologies that meets the needs of farmers. The diversity of regions provided a rich variety of respondents borrowed from commercial dairy farming, non-commercial traditional dairy farming, high production and low production regions.

Pre-Study Participants Demographic Details

The pre-study involved participants of varied backgrounds, including pastoralist farmers, small scale farmers, and medium scale farmers.

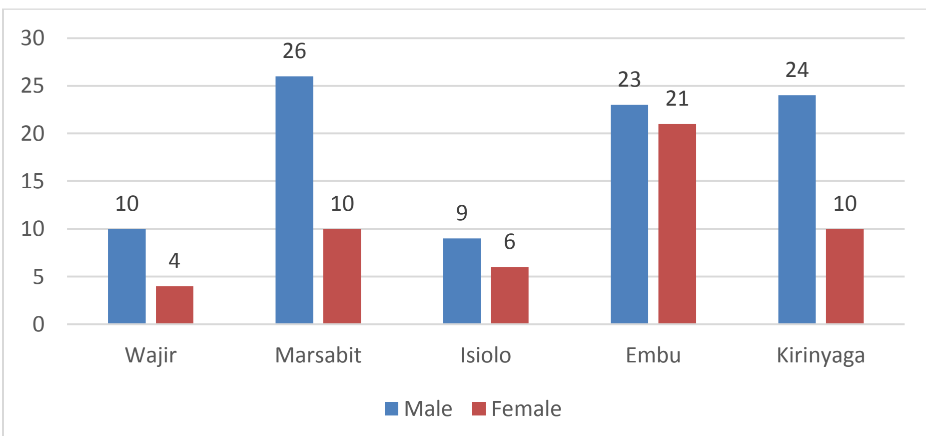


Figure E1: Number of participants involved in the pre-study

From Figure E1, there were more men interviewed in all the regions than women. This reflects on the groups of farmers interviewed and does not necessarily mean that men are more involved in farming than women. On the contrary, women are nearly as much involved in farming as men are as they comprise around 43% of the agriculture labour force globally and in developing countries (FAO 2011). This fact was evident in Embu where the number of women involved in dairy farming was almost equal to the number of men at 48% and 52% respectively.

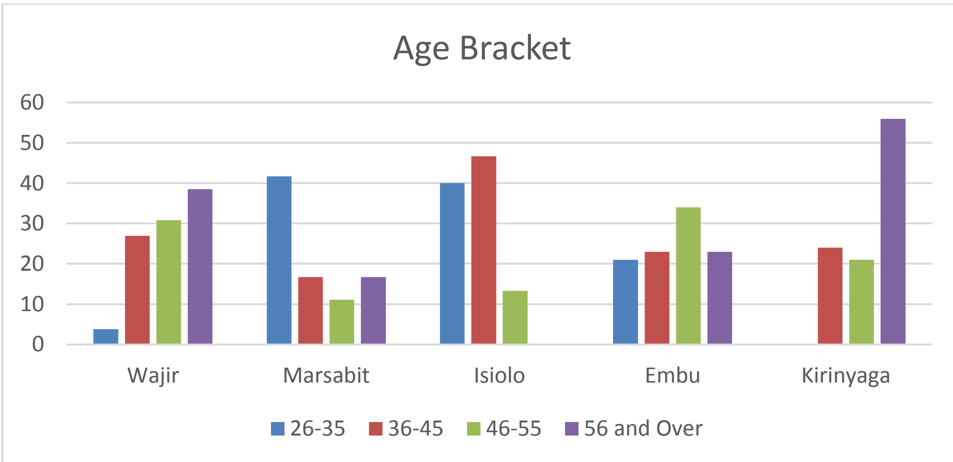


Figure E2: Age bracket distributions of pre-study respondents

The age of the respondents generally varied from 26 years to over 56 years, in some cases there were farmers aged 70 years. In majority of the areas, there was participation of both the old and the young in farming, although the middle aged and older generation seemed to dominate compared to the younger generation.

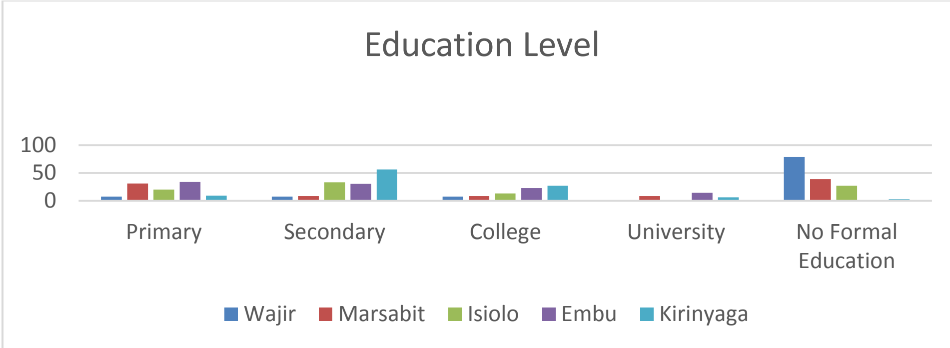


Figure E3: Level of education distribution among the pre-study respondents

In some regions such as Wajir and Marsabit there were cases of farmers who did not have any formal education. This was supported by the Kenya National Adult Literacy survey which ranked the North Eastern region as having the lowest literacy level in Kenya at 9.1% (KNBS 2006). However in Embu and Kirinyaga, most of the interviewed farmers had basic education and a substantial number with college education(24%) and university education (10%). The two latter regions did not record any cases of farmers who did not have any kind of education.

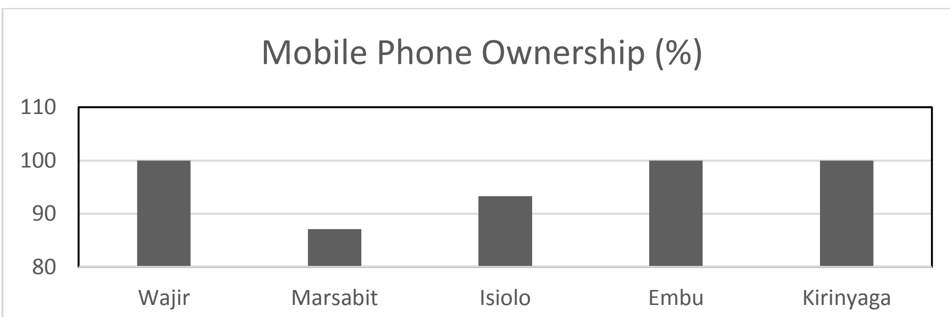


Figure E4: Mobile phone ownership among the pre-study respondents

In the regions of Wajir, Embu and Kirinyaga, there was 100% ownership of mobile phones among the interviewed farmers. The lowest mobile phone ownership rate was recorded in Marsabit at 87%. During the pre-study period, it was evident that this region was not well covered by mobile telecommunication infrastructure due to its sparsely populated nature and vastness. However, there were signal hot spots every couple of tens of kilometers, meaning communities had to access these spots in order to to make use of mobile communication services such as voice calls, SMS or mobile money.

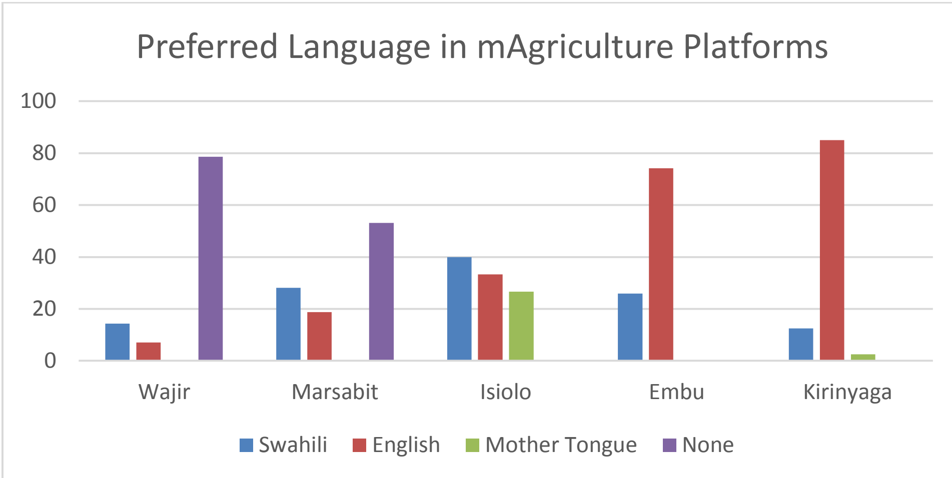


Figure E5: Preferred language in mAgriculture platforms

Farmers were also asked to specify which language they preferred when reading content in an mAgriculture platform. A substantial number of farmers in Marsabit(53.1%) and Wajir(78.6%) indicated they did not have a language of choice due to their inability to read. However, these specific farmers who could not read owned mobile phones and they could make and receive phone calls.

Focus Group Discussions

Part of the pre-study activities involved a Focus group discussion with the farmers at this initial stage of the study. In Marsabit and Wajir, FGDs were conducted in groups of men and women separately. This is due to cultural practices that restrict men and women sitting together in public to discuss a matter. This gave out interesting perspectives on the perception of males and females in pastoralist communities with regards to agriculture and use of technology. For instance, while some of the women claimed they owned mobile phones, it was discovered that actually the mobile phones were in the custody of their husband, and the device was shared across the family. In Embu, Isiolo and Kirinyaga, FGDs were conducted in groups of both men and women.

As indicated on the phone ownership on Figure E4, majority of the farmers owned mobile phones. However, only very few had access to computers or any other kind of computing equipment.

In relation to farming activities, farmers were using their mobile phones to support their agriculture lifestyle by calling experts in regions where they are available, ordering for inputs from agro vets or seeking veterinary services for their livestock. There was limited exposure to mAgriculture applications among the groups of farmers in the five regions. However, the farmers appreciated the potential of the mobile phone and expressed needs that can be met via mobile-based services.

Majority of the farmers could operate their mobile phones without assistance. Only in a few instances in Wajir and Marsabit where literacy levels were low that some farmers would seek assistance from their school-going children in operating their mobile phones due to their inability to read English or Swahili. Besides the challenges of usage due to literacy levels, the telecommunication infrastructure in Wajir and Marsabit was poor in most regions due to the sparsely population nature of these two regions. Good mobile network signals would be found tens of kilometers apart.

From the discussions with farmers, majority of them used minimal resources in operating their mobile phones. Purchase of airtime ranged from KES 5 to KES 50, with some repeatedly using the airtime lending services offered by mobile service providers. In other instances, farmers had to pay between KES 10 and KES 20 to charge their mobile phones due to lack of electricity in homes. This was mostly experienced in Wajir, Marsabit and Isiolo. It was good to note that majority of the farmers in all regions expressed their interest in paying for services that would ensure their yields increase and revenue from agriculture.

The findings of the FGD sessions were a key input towards the identification of needs among farmers, understading the challenges on the ground with regards to using the technology, and their experience with mobile-based agricultural services. These lessons were used as a key input into the model for the design, development and implementation of mAgriculture applications.

Summary of Pre-study Results

During the pre-study, it was discovered that farmers of different backgrounds had various needs that could be tackled using technology. Most of the identified needs related to lack of information on various aspects concerning agriculture. Primarily, the farmers interviewed during the pre-study expressed the need to make contact with extension officers allocated to the different regions for the purpose of getting advice on various issues to do with their dairy livestock and crop farming activities. It was also discovered that the farmers had the capacity to use technology, specifically mobile phones given the high number of recorded phone ownership among the farmers in the different regions. They reported ability to use services such as sending and receiving SMS messages, mobile money operations and operating basic mobile phone applications. Majority of the farmers practiced other economic activities besides keeping dairy livestock such as keeping a business or being employed. In addition, despite keeping livestock for the purpose of selling milk, farmers also kept livestock to sell after a period of time, as a sign of wealth and for dowry purposes especially among the pastoralist communities.

APPENDIX F: OPERATIONALIZATION OF THE MODEL

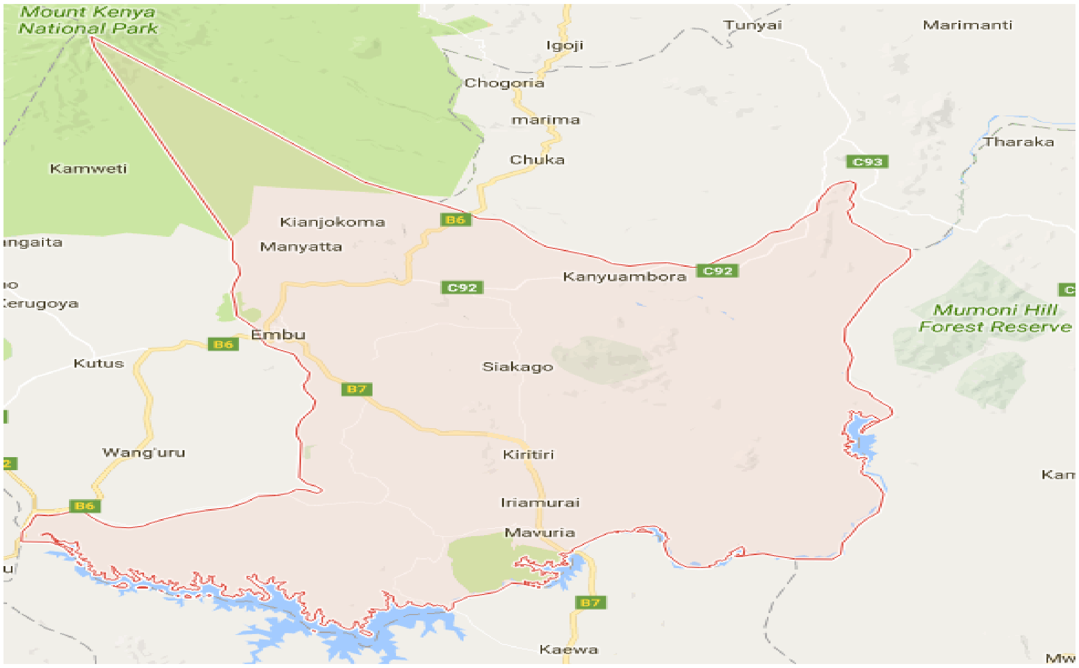
Table F1 shows the operationalization of the derived model, from an application, design, and development and implementation perspective of each of the retained constructs.

Table F1: Operationalization of the derived model for the design, development and implementation of mAgriculture applications

Construct	Application	Design	Development and Implementation
Trust	Instilling confidence among farmers and creating ownership in the Design and Development process	Keen focus on farmers needs e.g. choices of menu options	Implementation of specific needs as desired by the user
Effort Expectancy	Being in the user's shows and developing a service which is easy to use	Iterative design to accommodate easiness of use; Design of user friendly interfaces ; mock / paper prototyping	Implementation of interfaces as designed and envisioned during mock prototyping; Focus on user friendliness and ease of service (3 step process to task completion)
Hyperlocalization	Localizing information based on region, category of farming, language of the farmer	Design of various interfaces for different groups of users	Implementation to accommodate the variety of users in terms of language, region, content and environment
Price Value	Considerations of all possible cost aspects from acquisition, running cost and value for money	Lowering cost of entry; minimal running cost; light platform for low bandwidth consumption (web portal)	Implementation of a cost effective pricing that favors the farmer, ensures continuous usage and value for money
Feedback	Provision of feedback mechanisms and responsiveness of feedback	Providing an easy feedback mechanism within the system; considering preferable feedback channels	Implementation of effective feedback mechanisms/ channels; modalities and ways of implementing feedback to enhance user satisfaction

APPENDIX G: RESEARCH AREA MAP

EMBU COUNTY



KIRINYAGA COUNTY