UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

A FRAMEWORK FOR ADOPTION OF WIRELESS SENSOR NETWORKS IN WEATHER FORECASTING IN KENYA

By

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DECLARATION

STUDENT

I, the undersigned, declare that this project is my original work and that it has not been presented in any other university or institution for academic credit.

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This research project has been submitted for examination with my approval as university supervisor.

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DEDICATION

This research project is dedicated to my beloved husband Felix Musau and my dear children Perpetual, Nehema and Laura

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Foremost, my utmost gratitude goes to the Lord Almighty for blessing me with the capability to take this task and accomplish it well thank you God.

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ABSTRACT

Wireless Sensor Networks has been prospected as powerful solutions for many applications, such as surveillance, tracking, locating, weather forecasting etc. Weather forecasting is to predict the state of the atmosphere at some future time and the weather conditions that may be expected. Weather forecasting is the single most important practical reason for the existence of meteorology as a science. It is obvious that knowing the future of the weather can be important for individuals and organizations. Accurate weather forecasts can tell a farmer the best time to plant, an airport control tower what information to send to planes that are landing and taking off, and residents of a coastal region when a hurricane might strike among others. The purpose of this study was to investigate the challenges of the current weather practice in Kenya with a view to address them by adopting WSNs technology. The study found that the current weather forecasting practices in Kenya were not satisfactory. This indicated that there was need for adoption of WSNs in weather forecasting in Kenya. The study found that KMD faced various external challenges which affects weather forecasting in KMD. The study also found that there was need to adopt WSNs in the weather forecasting practices in Kenya. On the benefit of wireless sensor network, the study revealed that the various benefits of WSNs were; Sensing accuracy, large area coverage, minimal human interaction, sensor nodes can be deployed in harsh environments that make the sensor networks more effective, fault tolerance, connectivity and dynamic sensor scheduling. The study concluded that the various challenges faced by the KMD in weather forecasting were; poor coverage by weather stations, high cost of procuring, installation and maintenance of AWS, lack of technical knowledge required for installation, operation and maintenance of otherwise complex AWS has slowed the impact of AWS, insecurity of the instruments, ineffective information dissemination and non-user centered weather forecast information. The study established that the possible solutions to improve current challenges of weather forecast by KMD were adoption of WSNs in the weather forecasting practices in Kenya and dissemination of the information, purchase of new equipment for weather forecasting and training of the staff of WSNs in weather forecasting.

TABLE OF CONTENTS

LIST OF THE TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BEAMS	British East African Meteorological Service
EAC	East African Community
EAMD	East African Meteorological Department
EDR	Energy Discharge Rate
FFSS	Forest-Fires Surveillance System
GSM	Global system for mobile communication
ICAO	International Civil Aviation Organization
ICT	Information communication technology
IDT	Innovation diffusion theory
IMO	International Meteorological Organization
IT	Information Technology
KMD	Kenya Meteorological Department
MAC	Medium Access Control
PCA	Principal Component Analysis
PEOU	Perceived Ease of Use
PhD	Doctor of Philosophy
PU	Perceived Usefulness
RFID	Radio-frequency identification
SPSS	Statistical Package for Social Science
TAM	Technology acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
TWIN	Taipei Weather Science Learning Network
UN	United Nations
US	United States
WMO	World Meteorological Organization
WSNs	Wireless Sensor Networks

CHAPTER ONE

INTRODUCTION

1.1 Background

With the increasing development in microelectronics and wireless networks in the recent few years, the deployment of a large number of small, self-powered and inexpensive devices, in a wide range of daily life applications is becoming more and more feasible. Environmental monitoring, battlefield and harsh areas surveillance, healthcare and agriculture applications are only few examples amongst others (Bulusu *et al.*, 2001; Schwiebert *et al.*, 2001). Commonly, Wireless Sensor Networks (WSNs) are used to monitor the occurring of specific events such as: fire, flooding, air condition change or hazardous material leak. An important issue in such event-based sensor applications is how to report the events as quickly and as efficiently as possible, while taking into consideration the multi-hop fashion the transmission is commonly performed (Sohrabi *et al.*, 2000; Min *et al.*, 2010). Actually, since the detection range of sensors often overlap; numerous nodes usually detect the same event. This leads to a high-energy waste due to the transmission of redundant packets.

To solve this problem, one of the most essential paradigms for routing in WSNs is data aggregation (Intanagonwiwat *et al.*, 2000), whose benefits have been proved theoretically (Krishnamachari *et al.*, 2002) and experimentally (Heidemann *et al.*, 2001). Since data aggregation is usually performed at cluster heads, an efficient-clustering scheme is highly desirable. Many clustering algorithms have been proposed in the literature and an interesting survey on clustering algorithms is done by Abbasi and Younis (2007). Some of these algorithms such as linked cluster algorithm (Baker *et al.*, 1984) and random competition-based clustering (Xu and Gerla, 2002) are designed to support the mobility of some of the network components. In fact, it is shown that the use of mobile nodes has a boosting effect on energy saving (Somasundra *et al.*, 2006), on the lifetime of the network (Marta and Cardei, 2009; Yang *et al.*, 2010), on the coverage (Wang *et al.*, 2009a) and thus the global performance of the network.

Radio-frequency identification (RFID) tags are small electronic devices that can identify products from a distance without any physical contact. Implementation of RFID technology has been a challenge especially for small to medium sized enterprises (Ao *et al.*, 2010). Currently barcodes are the predominant method of identifying products in the food supply chain. WSNs can combine both the RFID tags and the data logger's technologies and present many advantages for data collection compared with traditional solutions. WSNs have been prospected as powerful solutions for many applications, such as surveillance, tracking, locating, weather forecasting etc (Schwiebert *et al.*, 2001).

WSNs are built up with a number of small spatially dispersed sensor nodes, each with limited processing capacity and memory, which transmit data in digital form to a base station (Akyildiz *et al.*, 2002). The sensors are mobile and can record and store data until they come again in range of the base station and transmit the stored data. WSNs systems can be equipped with various types of sensors, such as temperature, humidity and volatile compound detection to monitor different environments (Shen *et al.*, 2004). The base station collects data from multiple sensors and sends it via a mobile network such as GSM to a central server. Rapid development of WSNs during recent years has resulted in the availability of low cost, low power, multifunctional sensors (Ruiz-Garcia *et al.*, 2009). These new developments in WSNs open the possibility of having a battery driven base station, following the products throughout the whole supply chain.

Weather forecasting is to predict the state of the atmosphere at some future time and the weather conditions that may be expected. Weather forecasting is the single most important practical reason for the existence of meteorology as a science. It is obvious that knowing the future of the weather can be important for individuals and organizations. Accurate weather forecasts can tell a farmer the best time to plant, an airport control tower what information to send to planes that are landing and taking off, and residents of a coastal region when a hurricane might strike among others.

According to Estrin, et al. (2001), mobile computing, grid computing, recent advancements in wireless technologies and electronics have enabled the development of low cost, low-power, multifunctional sensor nodes that are small in size and communicate undeterred in short distances. WSNs is a combination of a number of sensor nodes connected via wireless communications. Wireless technologies have made it possible to integrate sensing, signal processing and wireless communication in one integrated circuit (http://www.utdallas.edu/~gshashi/survey.pdf). Sensors can monitor temperature, pressure, humidity, soil makeup, vehicular movement, noise levels, lighting conditions, the presence or absence of certain kinds of objects or substances, mechanical stress levels on attached objects, and other properties Estrin, et al. (1999),WSNs mechanism may be magnetic, thermal, visual or infrared, Akyildiz, et al. (2002), when sensor nodes are networked, could build up the part of larger systems, providing data, as well as performing and controlling multitude of tasks and functions e.g. surveillance, target tracking etc

The World Meteorological Organization (WMO) is a specialized agency of the United Nations. WMO has a membership of 189 member states and territories (since 4th December, 2009). WMO became the specialized agency of the United Nations for meteorology (weather and climate), operational hydrology and related geophysical sciences in 1951. The organization provides the framework for such international cooperation. Since its establishment, WMO has played a unique and powerful role in contributing to the safety and welfare of humanity.

WMO promotes cooperation in the establishment of networks for making meteorological, climatological, hydrological and geophysical observations, as well as the exchange, processing and standardization of related data, and assists technology transfer, training and research. It also fosters collaboration between the National Meteorological and Hydrological Services of its Members and furthers the application of meteorology to public weather services, agriculture, aviation, shipping, the environment, water issues and the mitigation of the impacts of natural disasters.

The Kenya Meteorological Department was established with key function of provision of meteorological and climatological services to various users that include agriculture, forestry, water resources management, civil aviation, military aviation and public sector;
Organization and administration of surface and upper air meteorological observations; Maintenance of an efficient telecommunications system for rapid collection and dissemination of meteorological information; Co-ordination of research in meteorology and climatology; Evolvement of suitable training programmes in all fields of meteorology and other related scientific subjects.

1.2 Statement of the Problem

The Kenya Meteorological Department has provided regular weather forecasts since the 60s. KMD plays a major role because it let the general public know what to expect. Weather forecasts are crucial in our day to day life; the output is used in decision making by decision makers at organizational levels as well as by individuals. Currently the Government of Kenya implements using macro-in fractures based on expensive weather stations of which are sparsely deployed in form of relatively small number of fixed locations to provide climate maps for droughts and other natural disasters prediction. KMD runs 3 main types of stations that are currently managed by the Climatological Section of the Department. The KMD has been faced with a number of challenges in the weather forecasting practices, these weaknesses exist particularly in the application of meteorological information in the decision-making processes of the climate-sensitive sectors. These weaknesses include: lack of awareness of the vulnerable groups on impacts of climate change and the adaptation strategies meant to create resilience; no instrumentation in some areas prone to formation of weather phenomena such as fog that hampers the transport sector; dissemination of meteorological information not sourced from KMD by some media houses; limited contact with the end users of the climate information; according to the Ministry of Health Malaria Prevention Strategy 2005-2010, forewarning of malaria epidemics is still a challenge and lack of sufficient capacity to generate tailor-made products to meet the demands of the diverse users (EAC Report, 2008). One of the recommendations of the EAC report (2008) was that KMD requires funds to acquire, install and maintain the relevant observation and display instruments in areas prone to formation of fog that endangers road users, this shows that there need for KMD to adopt WSNs in weather forecasting practice in Kenya as this will help in alleviating the current challenges faced by KMD in their current weather forecasting practices, this study sought to fill the existing research gap by conducting a study to develop a framework for adoption of WSNs in weather forecasting practices , specifically the study sought to examine the challenges faced by KMD in their current weather practices , to determine factors influencing the adoption of WSNs in weather forecasting practices by KMD and to determine the benefits of adopting WSNs by KMD.

1.3 Purpose of the Study

The purpose of this study was to investigate the challenges of the current weather practice in Kenya with a view to address them using WSNs technology adoption.

1.4 Research Objectives

i. To examine the challenges faced by KMD in their current weather practices.
ii. To determine factors influencing the adoption of WSNs by KMD.
iii. To determine the benefits of adopting WSNs in weather forecasting practices by KMD.
iv. To develop a framework for adoption of WSNs in the weather forecasting practices by KMD.

1.5 Research Questions

i. What are the challenges faced by KMD in their current weather forecasting practices?
ii. What are the factors influencing the adoption of WSNs by KMD?
iii. What are the benefits of adopting WSNs in weather forecasting practices by KMD?

1.6 Assumptions of the Study

The study assumed that the intended respondents were available and in a position to respond to the questionnaires and interview questions used during data collection. The study further assumed that respondents were aware of existence of other technologies e.g. WSNs.

1.7 Definition of Terms

Sensor: It is an electronic device used to measure a physical quantity such as temperature, pressure or loudness and convert it into an electronic signal of some kind (e.g. a voltage)

Technology Adoption: refers to the stage in which a technology is selected for use by an individual or an organization.

Weather Forecast: It is predicting how the present state of the atmosphere will change with time

Weather: the state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity, pressure etc.

Wireless Sensor Networks: Refers to network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions e.g. temperatures, sound vibration, pressure, motion or Pollutants at different locations.

Wireless: It is a term used to describe telecommunications in which electromagnetic waves (rather than some form of wire) carry the signal over part or the entire communication path.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Framework

The adoption of new technologies has been studied through different theoretical frameworks, which include the Diffusion of Innovation Theory; Rogers (1995), the Theory of Reasoned Action; Fishbein and Ajzen, (1975), Technology Acceptance; Model, Davis, (1989) among others.

2.1.1 Theory of Reasoned Action

The Theory of Reasoned Action (TRA) was proposed by Fishbein and Ajzen (1975) to explain and predict the people’s behavior in a specific situation. TRA is a well-known model in the social psychology domain. According to TRA a person’s actual behavior is driven by the intention to perform the behavior. Individual’s attitude toward the behavior and subjective norms are the ‘loading factors’ toward behavioral intention. Attitude is a person’s positive or negative feeling, and tendency towards an idea, behavior. Subjective norm is defined as an individual's perception of whether people important to the individual think the behavior should be performed.

The Theory of reasoned action is a more general theory than TAM, and has been applied to explain behavior beyond the adoption of technology. However, when applied to adoption behavior, the model includes four general concepts - behavioral attitudes, subjective norms, intention to use and actual use. The inclusion of subjective norm represents an important addition when compared to TAM. In TRA, subjective norm is composed of the user's perception of how others think she should behave, and her motivation to comply with the expectations of these referents, Fishbein and Ajzen, (1975). TRA has been applied in its original form to explain the adoption of ICT-applications, Liker and Sindi (1997), but typically TRA is used as a basis for modifying the TAM-model with subjective norm as suggested above, Venkatesh and Morris, (2000). The theory of reasoned action is more general than other theories of technology adoption and therefore it’s very hard to use it alone in the adoption of WSNs as it will not explain how individual reason in the adoption of

WSNs in the KMD. When applied to adoption behavior, the model includes four general concepts - behavioral attitudes, subjective norms, intention to use and actual use of wireless sensor network.

2.1.2 Theory of Planned Behavior

The theory of planned behavior was proposed as an extension of the theory of reasoned action to account for conditions where individuals do not have complete control over their behavior. Ajzen (1985). However, this theory also included determinants of the behavioral attitude and subjective norm. Models based upon TPB have been applied to the explanation of different types of behavior, but when applied to the adoption of ICT systems or services, the model contains five concepts - behavioral attitudes, subjective norm, behavioral control, intention to use and actual use. The components of behavioral attitude and subjective norm are the same in TPB as in TRA. In addition, the model includes behavioral control as a perceived construct. Perceived behavioral control reflects the internal and external constraints on behavior, and is directly related to both intention to use and actual use. Consequently, actual use is a weighted function of intention to use and perceived behavioral control. TPB has been applied to explain the adoption of such diverse systems as spreadsheets Mathieson (1991), computer resource centers Taylor $Todd(1995), and recently, electronic commerce services Battacherjee (2000). This theory of planned behaviour account for conditions where individuals do not have complete control over their behavior, this theory on its own cannot be used in the adoption of WSNs as it only explain the planned behaviour of individuals in the adoption of WSNs and it doesn’t account for the reasoning aspect of the individual in the adoption of WSNs. This theory only accounts for the planned behavioral aspect in the adoption of WSNs the KMD department while ignoring the other aspect in the adoption WSNs.

2.1.3 The Technology Acceptance Model

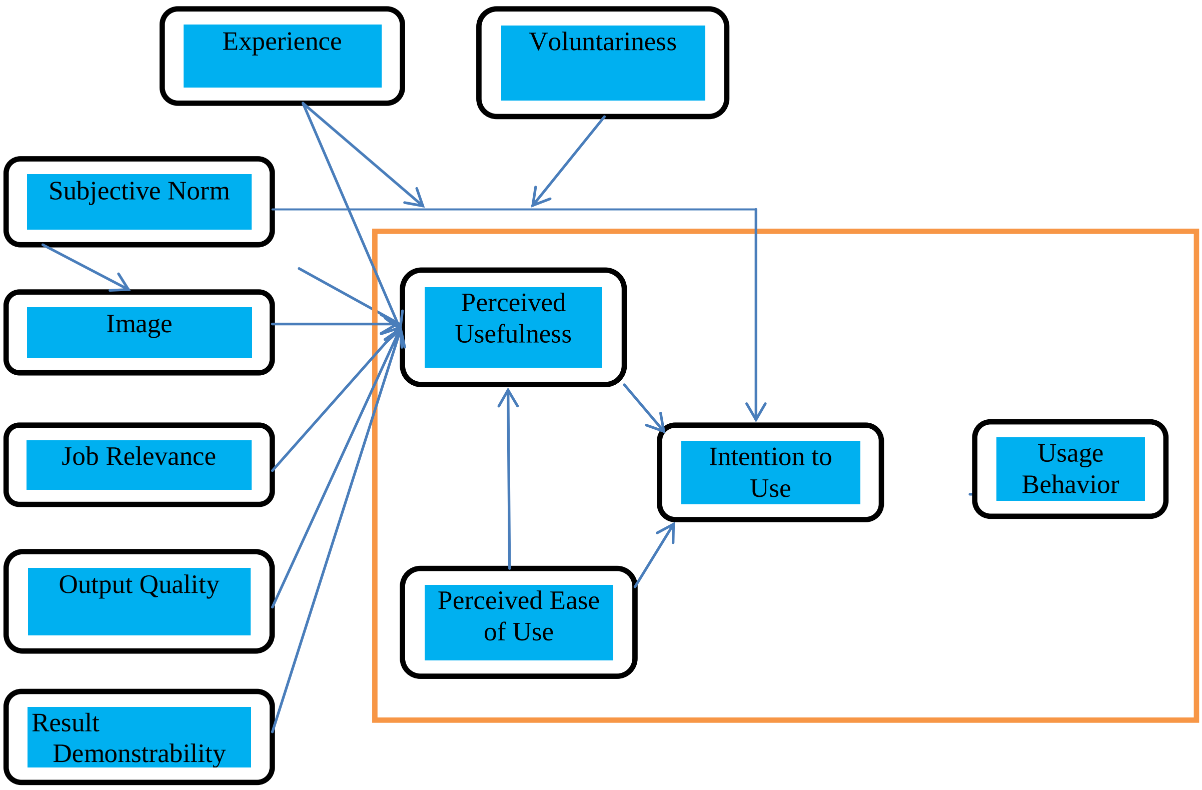
Technology acceptance model (TAM) has been widely used by information technology (IT) researchers to gain a better understanding of IT adoption and its use in organizations. It has been used in very different settings, e.g. to test the acceptance of: computer technology (Davis *et al.*, 1989), online shopping (Gefen *et al.*, 2000a), mobile computing (Wu *et al.*, 2007), e-commerce (Pavlou, 2003), and e-Government services (Carter and Bélanger, 2005).

The theoretical foundation for TAM is based on Fishbein and Ajzen's theory of reasoned action (TRA) (Fishbein and Ajzen, 1975). Davis *et al.*, (1989), the TAM proposed that two particular beliefs are the main drivers for technology acceptance: perceived usefulness ("the degree to which a person believes that using a particular system would enhance his or her job performance") and perceived ease of use ("the degree to which a person believes that using a particular system would be free of physical and mental efforts). Perceived usefulness and perceived ease of use influences one's attitude towards system usage, which influences one's behavioural intention to use a system, which, in turn, determines actual system usage (Davis *et al.*, 1989). However, the external variables that impact the perceived usefulness and perceived ease of use are not completely explored in the TAM. Davis *et al.* (1989) also found that attitude did not fully mediate perceived usefulness and perceived ease of use. Based on these findings, therefore, a more parsimonious TAM was suggested which removed the attitude towards usage construct from the model (Carter and Bélanger, 2005). Technology acceptance model cannot be used on its own on the adoption of WSNs as it only give the various aspect as to why people accept certain technology but fails to explain the behavioral aspect and the reasoning behind the adoption of technology, there is need to include other aspect of adoption of technology like behavioral and reasoning aspect in the adoption of new technologies like WSNs.

2.1.4 The Extended Technology Acceptance Model

Venkatesh and Davis (2000) proposed an extension of TAM (TAM2) by adding more important determinants of perceived usefulness that is, subjective norm, image, job relevant, output quality, result demonstrability, and perceived ease of use – and two moderators – that is, experience and voluntariness (Venkatesh and Davis, 2000). In addition to this, in the TAM2, it omits attitude toward using because of weak predictors of either behavioural intention to use or actual system usage (Venkatesh and Davis, 2000; Wu *et al.*, 2007).

Venkatesh and Davis, (2000), TAM2 consists of social influence and cognitive instrumental processes as the determinants of perceived usefulness. The social determinants are subjective norm ("the degree to which an individual perceives that most people who are important to him think he should or should not use the system"), and image ("the degree to which an individual perceives that use of an innovation will enhance his or her status in his or her social system"). The cognitive determinants are: job relevance ("the degree to which an individual believes that the target system is applicable to his or her job"), output quality ("the degree to which an individual believes that the system performs his or her job tasks well"), and result demonstrability ("the degree to which an individual believes that the results of using a system are tangible, observable, and communicable") (Venkatesh and Davis, 2000; Venkatesh and Bola, 2008). Experience and voluntariness were included as moderating factors of subjective norm (Venkatesh and Davis, 2000). The theory of technology acceptance model only explains why people accept and adopt new technology ignoring the psychological aspect which leads to the adoption of technology; though it explains the experience and voluntariness were included as moderating factors of subjective norm.

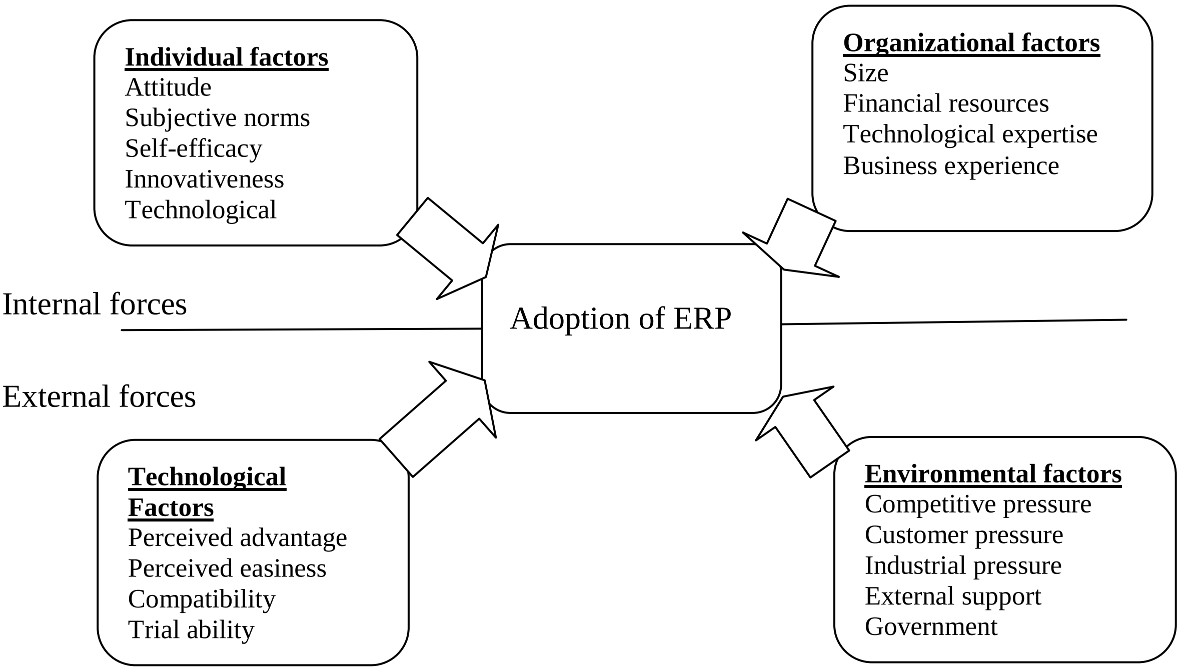


Source, Roger, (2003)

Figure 2.1: Extended Technology Acceptance Model

2.1.5 Innovation Diffusion Theory

The Innovation diffusion theory (IDT) is another model also grounded in social psychology. Since 1940's the social scientists coin the terms diffusion and diffusion theory (Rogers, 1983). This theory provides a framework with which we can make predictions for the time period that is necessary for a technology to be accepted. Constructs are the characteristics of the new technology, the communication networks and the characteristics of the adopters. We can see innovation diffusion as a set of four basic elements: the innovation, the time, the communication process and the social system. Here, the concept of a new idea is passed from one member of a social system to another. Moore and Benbasat (1991) redefined a number of constructs for use to examine individual technology acceptance such as relative advantage, ease of use, image, compatibility and results demonstrability.



Source, Roger (2003)

Figure 2.2: Model for adoption of ERP

According to diffusion of innovation, the likelihood that an innovation will be adopted depends partly on its attributes. The following have attributes are considered in diffusion of innovation: relative advantage, compatibility, complexity, observability, and trialability. Basically these attributes are economic in the sense that they relate to how much effort must be expended in adopting compared with the benefits of adopting, especially compared with the costs and benefits of not adopting.

Relative advantage is the degree to which an innovation is perceived as being superior to its precursor, which is either the previous way of doing things (if there is no current way), the current way of doing things, or doing nothing. The superiority of an innovation is not only measured in economic terms but also may also be expressed in terms of enhanced personal status or other benefit terms. The higher the perceived relative advantage, the higher the rate of adoption, all other factors being equal Note that perceived relative advantage of an innovation involves both perception (evaluation) of the proposed innovation as well as perceptions of other candidates and the status quo. It is not uniquely tied to objective characteristics of the innovation although, of course, perceptions usually, but not always, are influenced by objective reality. Also, relative advantage must take into account "relative advantage for *what?*" What is the task to which the innovation is being put into operation?

Compatibility is the degree to which an innovation is perceived to be consistent with existing social cultural values, needs, and past experiences of potential adopters. Compatibility is positively correlated with the rate of adoption. In developing countries, cellular telephony is directly compatible with the need for mobility for the urban poor, who often do not have the luxury of long-term fixed addresses and whose lifestyles dictate that they are often in transit and do not have access to fixed lines.

Complexity is the degree to which an innovation is perceived as being difficult to understand and use. This attribute correlates negatively with the rate of adoption.

Observability is the degree to which the results of an innovation are visible to others. In some innovation, it is easy for others to see the results of adoptions from those who have already adopted the technology. However, this is not the case with all innovations. Moore and Benbasat (1991) split observability into two: *result demonstrability* (the ability to demonstrate that positive results have occurred for the user) and *visibility* (the ability to share those demonstrations with others). Observability is positively correlated with the rate of adoption. To the extent that something has to be explained in complicated ways to others (complexity), it becomes less "observable," too. Language and culture might also affect observability for text-oriented technologies. Abstract or ambiguous innovations are generally difficult to observe and therefore diffuse slowly. Rogers gives safe sex as an example of innovations with low observability due to its ambiguity.

Trialability is the degree to which an innovation may be experimented with on a limited basis before adoption without undue cost. Trialability is sometimes linked to divisibility of an innovation (Niederman, 1998). Trialability/divisibility is "the degree to which an innovation can be adopted in phases, with each phase potentially leading to a greater adoption" (Niederman, 1998, p153). Trialability might also be influenced by cultural values, the task and its associated stresses, and even social influence (particularly where others might be observing the trials). Innovations that can be tried in pieces are inherently more trial able than those for which the entire technology has to be mastered before any use can be made. In these latter cases, the "trials" are often simply unproductive and unconvincing play-acting or marketing.

Moore and Benbasat (1991) added *voluntariness* of use and *image* to Rogers' five attributes. An innovation is most likely to be adopted if individuals perceive that the adoption enhances their images within the social system. Rogers includes this concept under perceived relative advantage. Voluntariness of use is defined as "the degree to which use of innovation is perceived as being voluntary or of free will.

2.1.6 Analysis of the Frameworks

Theory of Reasoned Action	**Theory of Planned Behavior**	**The technology acceptance model**	**The extended technology acceptance model**	**Innovation Diffusion Theory**	**Proposed framework**
Attitude	behavioral attitude	behavioral attitude	subjective norm	Relative advantage	Relative advantage
Subjective norm	subjective norm	subjective norm	image, job relevant	Compatibility	Compatibility
intention to use	Perceived behavioral control	perceived usefulness	output quality	Complexity	subjective norm,
actual use		Perceived behavioral control	result demonstrability	Observability	Observability
			perceived ease of use	Trialability	Trialability
				voluntariness and image	voluntariness and image
					actual use (adoption of WSNs)

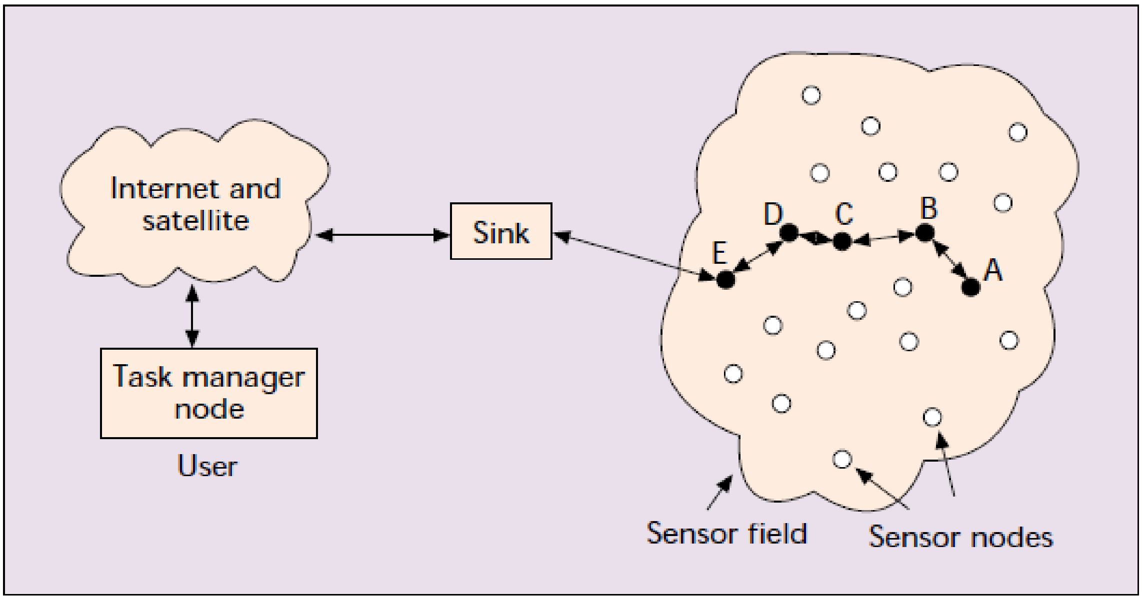
The theory of reason action can be used in the adoption of WSNs, though it lack some important aspect that are crucial in the adoption of WSNs, these include construct like benefits of adoption it only deal with the social psychology aspects as to why people adopt technology. The theory of planned behaviors, the role of subjective norm in TPB when compared to TAM is however somewhat unclear. This theory only explains the behavioral aspect though it doesn't explain why people adopt technology. The theory of technology acceptance model only explains why people accept and adopt new technology ignoring the psychological aspect which leads to the adoption of technology. The theory of extended technology acceptance model only explains why people accept and adopt new technology ignoring the psychological aspect which leads to the adoption of technology; though it explains the experience and voluntariness were included as moderating factors of subjective norm. The proposed framework will incorporate the major aspect of the other entire model.

2.2 Overview of Wireless Sensor Networks

Advances in sensor technology (in terms of size, power consumption, wireless communication and manufacturing costs) have enabled the prospect of deploying large quantities of sensor nodes to form WSNs. These networks are created by distributing large quantities of usually small, inexpensive sensor nodes over a geographical region of interest with a view to collect data relating to one or more variables. These nodes are primarily equipped with the means to sense, process and communicate data to other nodes and ultimately to a remote user(s). Sensor nodes may cooperate with their neighbours (within communication range) to form an *ad hoc* network. WSNs topologies are generally dynamic and decentralized. Sensor nodes can also have mobility capabilities which enable them to physically relocate with relation to neighbouring nodes and the environment in which they are situated. WSNs have a wide range of applications including military, environmental monitoring, health, home, space exploration, chemical processing, and disaster relief (Akyildiz *et al.*, 2002).

A proactive method of efficiently balancing the sensor nodes energy discharge rate (EDR) is to place nodes and assign tasks such that coverage holes are never formed in the WSNs. This method may give an optimal solution but this approach to deployment is impractical for WSNs, as the network designer would require a comprehensive knowledge of the application environment (Ganeriwal *et al.*, 2004). Generally when considering the application environment this information is unavailable. Many of the foreseen applications are within regions where human intervention is not always possible. In such situations deployment is random and the network designer has limited influence over the exact node placement.

Sensor Networks Communication Architecture - The sensor nodes are usually scattered in a *sensor field* as shown in Fig. 2.3. Each of these scattered sensor nodes has the capabilities to collect data and route data back to the *sink*. The sink may communicate with the *task manager node* via Internet or satellite.



Source (Karl and Willing, 2005)

Figure 2.3: Sensor Nodes Scattered In a Sensor Field

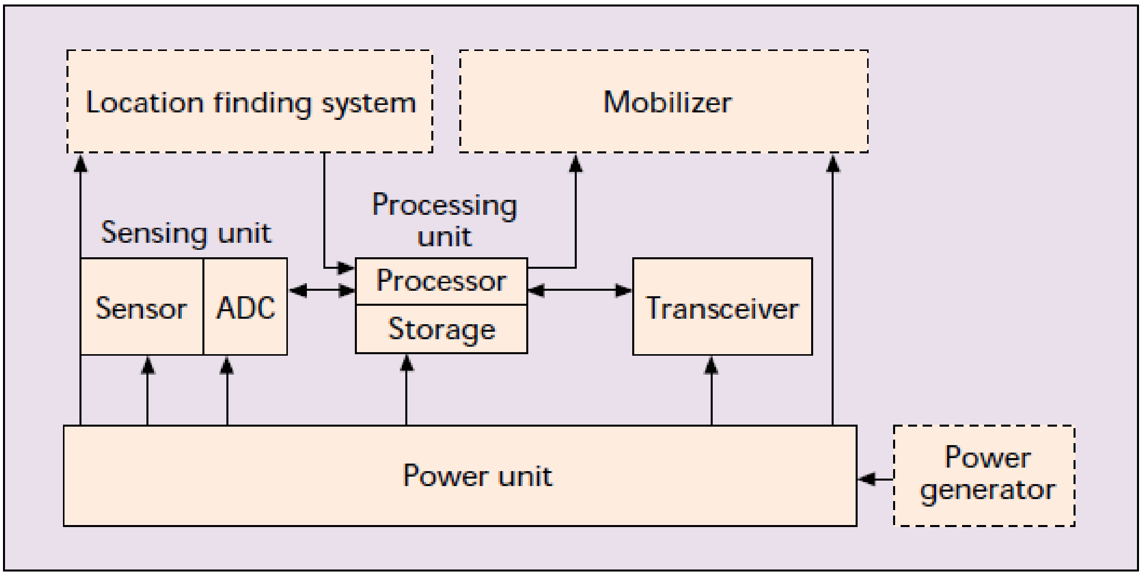
2.2.1 Factors Influencing Sensor Network Design

Reliability/ Fault Tolerance- It is the ability to sustain sensor network functionalities without any interruption due to sensor node failures. Some sensor nodes may fail or be blocked due to lack of power, or have physical damage or environmental interference. These failures of sensor nodes should not affect the overall task of the sensor network.

Scalability — it is the number of sensor nodes deployed in studying a phenomenon which may be on the order of hundreds or thousands. Depending on the application, the number may reach an extreme value of millions.

Production Costs — Sensor networks consist of a large number of sensor nodes, the cost of a single node is very important to justify the overall cost of the network. If the cost of the network is more expensive than deploying traditional sensors, the sensor network is not cost-justified. As a result, the cost of each sensor node has to be kept low. The state-of-the-art technology allows a Bluetooth radio system to be less than US$10; the cost of a sensor node should be much less than US$1 in order for the sensor network to be feasible.

Hardware Constraints — a sensor node is made up of four basic components, as shown in Fig. 2.4: a *sensing unit*, a *processing unit*, a *transceiver unit*, and a *power unit*. They may also have additional application-dependent components such as a *location finding system*, *power generator*, and *mobilize*.



Source Mainwaring, et al . (2002)

Figure 2.4: Components of Sensor Node

Sensor Network Topology — Hundreds to several thousands of nodes are deployed throughout the sensor field. They are deployed within tens of feet of each other. The node densities may be as high as 20 nodes/m3. (Shih *et al.*, 2001)

Environment — Sensor nodes are densely deployed either very close or directly inside the phenomenon to be observed. Therefore, they usually work unattended in remote geographic areas.

2.3 Benefits for Wireless Sensor Networks

Al-Sakib and Humayun (2006) noted WSNs benefits; Sensing accuracy**:** The utilization of a larger number and variety of sensor nodes provides potential for greater accuracy in the information gathered as compared to that obtained from a single sensor. Area coverage: This implies that fast and efficient sensor network could span a greater geographical area without adverse impact on the overall network cost. Minimal human interaction***:*** Having minimum human interaction makes the possibility of having less interruption of the system. Operability in harsh environments***:*** Sensor nodes can be deployed in harsh environments that make the sensor networks more effective**.** Fault tolerance: Device redundancy and consequently information redundancy can be utilized to ensure a level of fault tolerance in individual sensors. Connectivity**:** Multiple sensor networks may be connected through sink nodes, along with existing wired networks (e.g. Internet). The clustering of networks enables each individual network to focus on specific areas or events and share only relevant information. Dynamic sensor scheduling**:** Implying some scheduling scheme, sensor network is capable of setting priority for data transmission.

2.4 Sensor Network Applications Areas

The applications of WSNs typically involve some kind of monitoring, tracking and controlling. WSNs come in handy in habit monitoring, object tracking, nuclear reactor control, fire detection, flood detection and traffic monitoring

2.4.1 Events Reporting

An event can be defined as an exceptional change in the environment parameters such as temperature, light, humidity, etc. According to the event characteristics, the occurrence of the event should be quickly and reliably conveyed to the sink node for decision making.

Bouabdallah and Bouabdallah (2008) analyzed the impact of the number of selected reporting nodes on WSNs performance (energy consumption and reporting time). They proved that using only a small number of sensor nodes to report the event occurrence rather than all the nodes in the event area reduces considerably the energy consumption and improves the network lifetime. They also showed that when only one reporting node is activated, the maximal network lifetime is achieved. This joins our work since in our approach only one cluster head is elected to report the event which leads to high-energy savings.

Shih, *et al.* (2008) focused on both event detection and tracking. They tackled the event boundary determination issue in critical scenarios such as fire or pollution by a hazardous gas. For this purpose, they propose a dynamic role assignment for sensor nodes so that the event can be tracked. Nevertheless, their approach is evaluated from one perspective only the accuracy of the edge of the event of interest. They actually fail to analyze some important performance metrics such as energy consumption or delay.

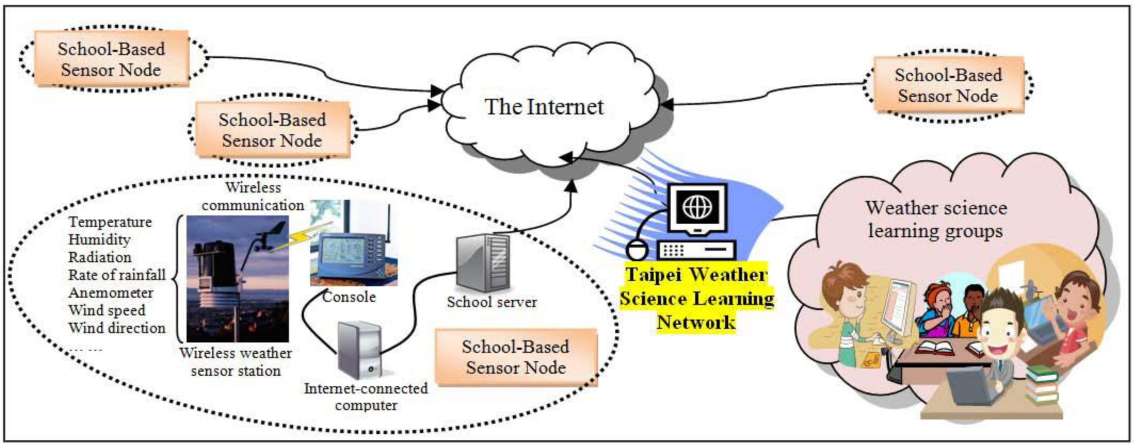
As mentioned before, in order to minimize energy consumption, many energy-efficient medium access control (MAC) and routing protocols have been proposed in the literature. These protocols aim to schedule the activity inside the network by switching off the nodes when they are not sending or receiving. To do so, Lazarou *et al.* (2007) propose a cluster-based MAC scheme for event-driven sensing applications where sensor nodes forward data to the cluster head only if significant events occur. Their aim is to reduce the energy dissipation due to idle listening and collisions. According to their simulations, their proposed protocol performs well in terms of energy saving in comparison with the conventional time division multiple access (TDMA) scheme and the energy-efficient TDMA. Basically, the state-of-the-art techniques used for events reporting focus only on using static sinks. In our paper, we extend them to take into account mobile sinks as well.

2.4.2 Environmental Applications of Wireless Sensor Networks

Fire Detection in South Korea; According to Son, et al (2006) Forest-Fires Surveillance System (FFSS) was developed to prevent forest fires in the South Korean Mountains and to have an early fire-alarm in real time. The system senses environment state such as temperature, humidity, smoke and determines forest-fires risk-level. Early detection of heat is possible and this allows for the provision of an early alarm in real time when the forest-fire occurs, alerting people to extinguish forest-fires before it grows.

Flood Detection in the US; An ALERT system for flood detection and prevention was deployed in the US, rainfalls, water level and weather sensors were used in that system to detect, predict and hence prevent floods. The sensors would supply information to a centralized database system in a pre-defined way (Coulson, 2006).

City-Wide Wireless Weather Sensor Network in Taipei ; Chang, et al (2010) developed the project to analyze the effectiveness of a city-wide wireless weather sensor network and Taipei Weather Science Learning Network (TWIN), in facilitating elementary and junior high students' study of weather science. TWIN provided a distributed wireless weather sensor network throughout Taipei and promoted weather science learning activities for students. The network, composed of sixty school-based weather sensor nodes and a centralized weather data Archive server, the sixty weather sensor nodes were connected by a centralized archive server. The weather data from the area around the weather sensor node were collected every five minutes and wirelessly transferred to the TWIN server. This provided students with current weather data at specific locations in the city. Figure 2.5 shows the distributed architecture of TWIN. Taipei Weather Science Learning Network Architecture



Source: Chang, et. al. (2010)

Figure 2.5: Taipei Weather Science Learning Network Architecture

The TWIN website is open to the public users who are interested in using the data for Taipei City weather science learning can freely access the database. The website provides not only the current weather status at a particular weather sensor node, but also the past data for all nodes and for elapsed-time periods of five minutes, an hour, a week, or a month.

Health Applications; The small size and light-weight structure of sensor nodes provides much functionality in the health sector including: tracking and monitoring doctors and patients; drug administration and tele-monitoring of human physiological data (Akyildiz et al. 2002).

Commercial Applications; Some of the commercial applications of WSNs include: burglary detection and monitoring; vehicle tracking and detection; interactive museums; environmental control in the buildings; robot control and guidance in automatic manufacturing environments; factory process control and automation; smart structures with sensor nodes embedded inside (Akyildiz et al. 2002)

Military Applications; Dense deployment of low cost disposable sensor nodes makes WSNs concept beneficial for battle fields. Some of the military application areas include; monitoring friendly forces, equipment and ammunition; battlefield surveillance; exploration of opposing forces and terrain; targeting; battle damage assessment and nuclear, biological and chemical attack detection

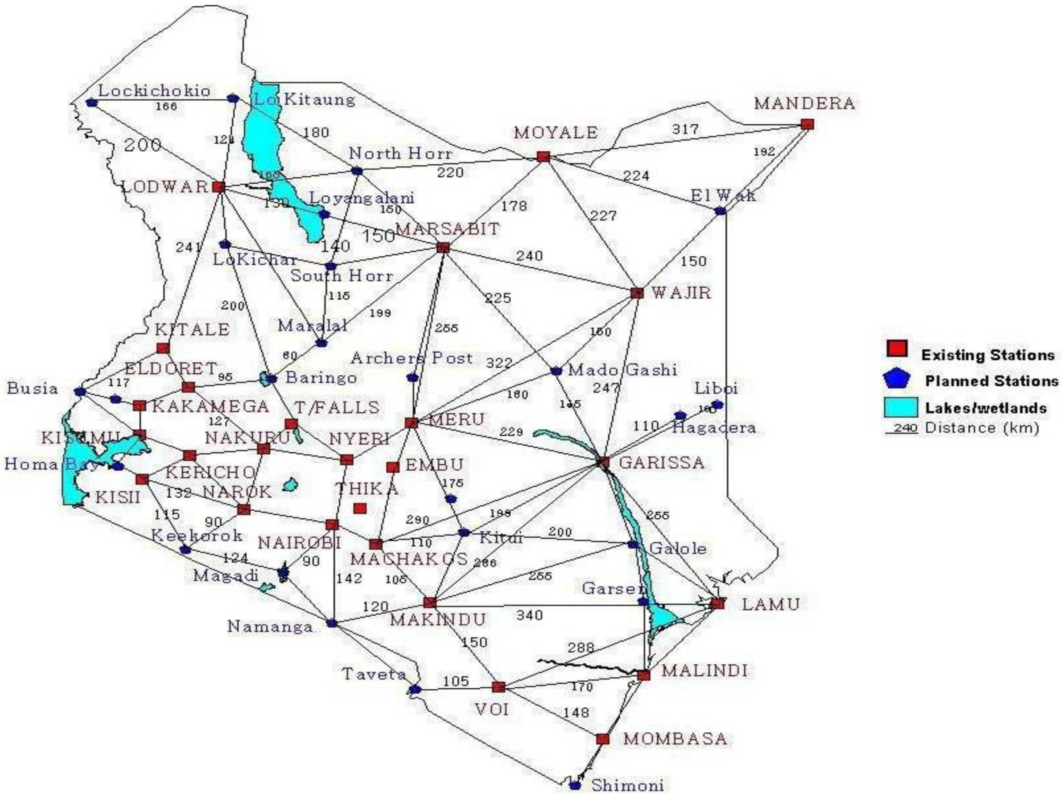
2.5 Current Weather Forecasting Practice in Kenya

The monitoring of climatic/weather variations in Kenya is the mandate of the Kenya Meteorological Department. KMD runs 3 main types of stations that are currently managed by the Climatological Section of the Department (http://www.meteo.go.ke/): 700 rainfall stations; there were 2,000 of such in 1977; this figure drastically dropped to 1,653 by 1988 and down to 1,497 by 1990; 62 temperature stations; 27 automated weather stations; these are used to observe and record all the surface meteorological data; rainfall, temperature, wind speed and direction, relative humidity, solar radiation, clouds, atmospheric pressure, sun shine hours, evaporation and visibility.

The Agro Meteorological Section on the other hand manages 13 stations related to agriculture; data is remitted from these stations every 10 days. Apart from the normal meteorological observations, other observations by the Agro meteorological Section include: soil temperature, sunshine duration, radiation, pan evaporation and potential evapotranspiration. All this data is stored in semi-automated formats at the Department's Head Quarters in Nairobi. The data is available to interested stakeholders at a fee and on request. The Meteorological Department uses the data collected to provide five main types of forecasts: (http://www.meteo.go.ke.)

2.6 Challenges That Affect Weather Forecasting In Kenya

Poor Coverage by Weather Stations; Kenya has few weather stations. It is realized that even the few there, are concentrated in Nairobi and other bigger towns leaving majority of remote areas with nothing. This makes it difficult to get the micro-level weather indicators that are necessary for effective forecasts (http://www.meteo.go.ke.)



Source, (http:www.meteo.go.ke)

Figure 2.6: The Map of Kenya under Technological Advancements

Cost; the cost of procuring, installation and maintenance of AWS has curtailed the fast process of upgrading the surface observing stations for example. The KMD awarded Sutron cooperation a contract to design, build, and install a Synoptic Met Station at each facility and integrate them into a system at a cost of: $230,000 (http://www.sutron.com/pdfs/Kenya_SynopticAWS_2006.pdf)

Source, (http://www.sutron.com/pdfs/Kenya_SynopticAWS_2006.pdf)

Figure 2.7: Automatic Weather Observing Systems

Technical; Technical knowledge required for installation, operation and maintenance of otherwise complex AWS has slowed the impact of AWS.

Security; the installation of AWS at remote areas has proved difficult due to insecurity of the instruments.

Ineffective Information Dissemination; the channels that the KMD uses to disseminate the forecast information are ineffective; the farmers that need it most do not get it and those that do, cannot comprehend the information.

Non-User Centered Weather Forecast Information; The usefulness of forecast information provided by the Kenya's Meteorological Department to key stakeholders especially the farmers and policy formulators is not very reliable to make decisions. It would for example be desirable if the Department could inform the relevant government ministries the actual implications (in operational quantifiable terms) of weather observations e.g. it is not enough to report that; 59.8. mm of rainfall was recorded in Busia”; instead, a report saying, “59.8mm of rainfall that was recorded in Busia raised the available water resource to above the normal for this area hence it is predicted that the rains will continue for a week and this will lead to severe floods in the low-lying areas of the Busia”. This report can be more useful to policy makers to mount rescue operations.

2.7 Factors that Affect Implementation of Technologies in Organizations

Culture; A culture is a system of shared meaning within an organization that determines in large degree how employees act. Shared values, norms and organizational practices do shape the culture that assist organizations to adopt the changes. Slowinkowski and Jarratt(1997) noted that the effect of cultural factors, specifically ‘traditions’, ‘religion’ and ‘fatality’ have greater impact on adoption of technology and must be considered with great care in adoption process. Khalil and Elkordy (1997) pointed out that the cultural sensitivities of host environments are often ignored in technology adoption decision. This is especially true in the work place since the adoption decision is often negotiated by upper-level managers who either work for international companies or who have spent time in the industrialized countries. Yet it is the lower level managers and workers who, without the diverse cultural experiences, have the responsibility of the daily use of the new technology, and ultimately accept or don’t accept it.

Human Factor; Szewczak and Snodgrass (2002) said that individuals play an effective and important role in technology adoption process. A technology is not successful if its user does not accept it. Avergou (1996) said that user participation could be considered as “Taking part” in some activity. Such participation may be direct or indirect, formal or informal, performed alone or in a group, but covering varying scopes of activities during systems development and implementation. Lin and Shao (2000) in this regard argued that the participation of users in the design and implementation of projects promote greater user acceptance.

Social Factor; The social change works into ways: it become the reason for technological change and also plays a role of a great barrier in any technology adoption decision. Godwin and Guimaraes, (1994) said that there are three factors to be considered to see social involvement in technology advances; Social need-to feel strong desire of something, Social resources-the capital, material, and skilled personnel vital for innovation and adoption of new thing, Sympathetic social ethos-an environment in which the dominant groups are prepared to consider innovation seriously and are receptive to new idea.

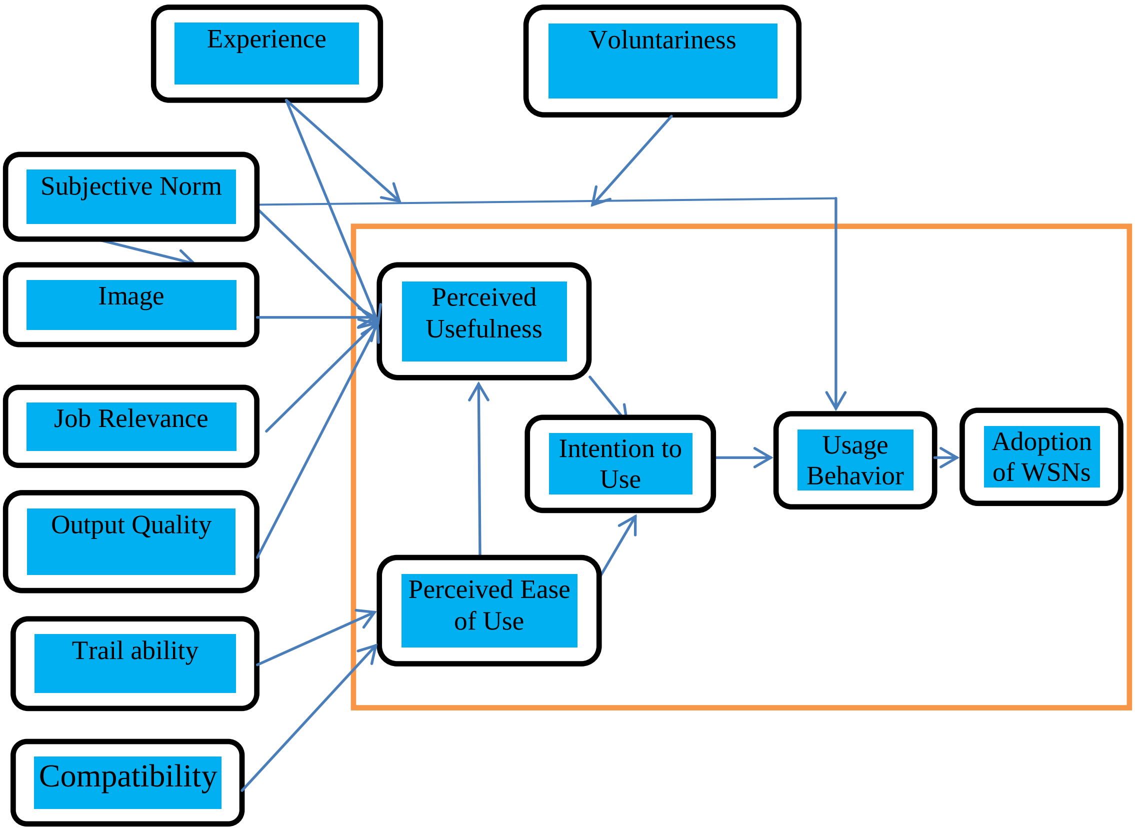
Organizational Structure Factor; Robbins and Coulter (2002) described the organizational structure as a framework, which is expressed by its degree of complexity, formalization, and centralization. An organization is divided into different divisions, departments, sections, teams and work groups for the purpose of smooth working and each member in the organization is given certain responsibility and authority to his position. Joan Woodward (1960) demonstrated that organizations' structure is a significant contributor to the technology adoption, there was a distinct relationship existed between the technology and structure and the effectiveness of the organization is related to the "fit" between technology and structure.

Governmental and Political Factor; Ayeni (2004) said that technology acquisition raises a number of political questions. Such as the dependence of the receiving nations on the supplying nation and this technological dependence could become a political in the sense that it is the responsibility of a government to select carefully the country from where technology acquisition is made so that no political problems could arise in future Also, the possibility of transfer of political power from political elites to the technical specialists. This problem is more prominent in computer-based technologies because these technologies are directly related with retrieval and processing of data and information. The people at the management level are mainly from non-technical backgrounds, as a result of which there is always tension between these two groups.

Economic Factor; Lind (1999) identified that lack of awareness of available technologies and its uses, capabilities, and return on investment are greater barrier to technology adoption. Also lack of knowledge about technology selection, adoption, and implementation as well as lack of knowledge in organizational development and strategic planning restrict to the uses of new technology in organization.

2.8 Conceptual Framework for Adoption of Wireless Sensor Networks

The suggested framework suitable for adoption of WSNs in weather forecasting practices in Kenya was derived from the literature, survey of the KMD division , interaction with theory of theory of reasoned action, theory of planned behavior , the technology acceptance model, the extended technology acceptance model and innovation diffusion theory and the Study carried out on KMD in Kenya. From the reviewed literature, the framework in figure 2.8 was adopted for studying the adoption of WSNs at KMD.



Source, Research

Figure 2.8: Conceptual Framework of adoption of Wireless Sensor Network

Below are the components of the Conceptual Framework:

Compatibility is the degree to which an innovation is perceived to be consistent with existing social cultural values, needs, and past experiences of potential adopters. Compatibility is positively correlated with the rate of adoption. In developing countries, cellular telephony is directly compatible with the need for mobility for the urban poor, who often do not have the luxury of long-term fixed addresses and whose lifestyles dictate that they are often in transit and do not have access to fixed lines. Compatibility will be the degree to which a WSN will be perceived to be consistent with existing social cultural values, needs, and past experiences of potential adopters in the KMD.

Trialability is the degree to which an innovation may be experimented on a limited basis before adoption without undue cost. Trialability is sometimes linked to divisibility of an innovation (Niederman, 1998). Trialability/divisibility is “the degree to which an innovation can be adopted in phases, with each phase potentially leading to a greater adoption” (Niederman, 1998, p153). Trialability might also be influenced by cultural values, the task and its associated stresses, and even social influence (particularly where others might be observing the trials). Innovations that can be tried in pieces are inherently more trial able than those for which the entire technology has to be mastered before any use can be made. In these latter cases, the “trials” are often simply unproductive and unconvincing play-acting or marketing. Trialability will be the degree to which WSNs will be experimented on a limited basis before adoption without undue cost.

Behavioral intention; Masrom and Hussein (2008) define behavioral intention as a measure of the strength of one intention to perform a specific behavior especially the use of an information system. Harthsorne and Ajjan (2008), explain that behavioral intention is the most important predictor of actual behaviour when the user has form a stable intention to take a specific intention. Behavioral intention will be the measure of the strength of one intention to perform a specific behavior especially the use of WSNs.

Subjective norm; Subjective norms explain how the behavior of an individual is influence or change based on how other important people to him/her think he/she should behave. Fishbein and Ajzen (1975) define subjective norm as the person's perception that most people who are important to him think he should or should not perform the behavior in question. Subjective norms will explain how the behavior of an individual will influence or change based on how other important people to him/her think he/she should behave

Perceived usefulness; Davis (1989) explain that perceived usefulness (PU) is “the degree to which a person or a user believes in using a particular technology, as well believes that the technology would enhance his/her job performance.” Thus, belief, attitude, and intention have been identified to have link with PU. However, many attempts have been made to look at PU from user belief and attitude by stream of researchers. A belief that a user develop about information systems explains how he/she perceived it usefulness. According to Hsu and Lin (2008), people's beliefs about blogging to an extent influence their participation in blogging. Moreover, belief in certain thing influences the behaviour intention toward such thing. Hsu and Lin (2008) posited that since social networking site such as blog is a voluntary act used for social interaction, therefore, a user is expected to be intrinsically motivated, which may lead to forming a perception that using social networking site is useful. Perceived usefulness will be the degree to which a person or a user believes in using WSNs and that the WSNs will enhance his/her job performance.

Perceived ease of use; Aside PU, Davis (1989) also posits that perceived ease of use (PEOU) was another determinant for users' acceptance of information system. Perceived ease of use is defined as "the perception about the degree of effort needed to use a particular system," by implication "ease" is conceptualized as "freedom from difficulty or great effort" (Lee *et al.*, 2003). According to Gangartharbatha (2009), PEOU is assumed to mean internet self-efficacy when it comes to social networking site usage. Bandura (1982) posits that self-efficacy is "the belief in one capability to organize and execute a course of action required to manage a situation." That is to say, self-efficacy is a person's belief in his/her ability to perform a specific task. Perceived ease of use is the mean to use WSNs.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research methodology used by indicating the research design, target population, data collection method, and data analysis that was utilized to investigating the framework for adoption of WSNs in the KMD.

3.2 Research Design

In order to investigate the framework for adoption of WSNs in the KMD, the researcher adopted a descriptive research design. A descriptive research design is an in-depth investigation of an individual or a group or an institution with a primary motive to determine factors and relationships that have resulted in the behaviour of the study (Robson, 2002). The researcher undertook her research on KMD as it is the only organization in Kenya charged with dissemination of information of weather in Kenya. The research design enabled the researcher to undertake an in-depth investigation on the framework for adoption of WSNs in the KMD.

3.3 Target Population

The target population for this study comprised of all employees in KMD Divisions. The target population consisted of 108 employees from the various divisions of KMD.

Table 3.1: Target Population at KMD

Division	**Target Population**	**Proportion**
Forecasting	51	47.2
ICT	12	11.1
Public weather dissemination	6	5.6
Instruments	9	8.3
Telecommunication	11	10.2
Disaster prevention and mitigation	4	3.7
International relations	6	5.6
Data processing	9	8.3
Total	108	100.0

Source: KMD (2012)

3.4 Sampling Procedure

To overcome the limitations of this study the researcher employed stratified sampling and simple random sampling to select eighty eight (88) respondents from the target population. The researcher categorized the respondents into eight (8) strata namely: forecasting, ICT, public weather dissemination, instruments, telecommunication, disaster prevention and mitigation, international relation and data processing staff. Simple random sampling was then used to proportionately select respondents from each stratum at 81.5% representative of the study's population. According to Mugenda and Mugenda (2003) a good sample population should be 10% to 30% of the entire population, this study selected 81.5% of the entire population, which is far above the recommended threshold of 30%.

Table 3.2: Sample Population at KMD

Division	Target population	Percentage (%)	Sample size
Forecasting	51	80.4	41
ICT	12	83.3	10
Public weather dissemination	6	83.3	5
Instruments	9	88.9	8
Telecommunication	11	81.8	9
Disaster prevention and mitigation	4	75	3
International relations	6	83.3	5
Data processing	9	77.8	7
Total	108	81.5	88

3.5 Data Collection

This study collected both primary and secondary data relating to framework for adoption of WSNS in the KMD. Primary data was collected by use of questionnaires. The questionnaires contained open and closed ended questions and was divided into two sections, A, B and C. Section A focused on the profile of the respondents while section B and C contained questions on the research objectives. The questionnaires were dropped and picked from the respondents after a reasonable period of time. Secondary data was gathered from organization reports, publications and other literature relating framework for adoption of WSNs in the KMD.

3.6 Reliability and Validity of the Instrument

3.6.1 Pilot Test Report

A pilot study was first carried out with 10 employees, who were not included in the actual survey. The pilot study enabled the researcher to be familiar with research and its administration procedure as well as identifying items that require modification. The result helped the researcher to correct inconsistencies arising from the instruments, which ensured that they measured what was intended. Reliability refers to the consistency of measurement and is frequently assessed using the test–retest reliability method. Reliability is increased by including many similar items on a measure, by testing a diverse sample of individuals and by using uniform testing procedures. Reliability of the research instrument was enhanced through a pilot study that was done with 10 employees. The pilot data was not to be included in the actual study. The pilot study allowed for pre-testing of the research instrument. The clarity of the instrument items to the respondents was established so as to enhance the instrument's reliability.

3.6.2 Reliability Analysis

Reliability of the questionnaires was evaluated through Cronbach's Alpha which measures their internal consistency. The Alpha measures internal consistency by establishing if a certain item measures the same construct. Nunnally (1978) established the Alpha value threshold at 0.6 which the study benchmarked against. Cronbach Alpha was established for every objective in order to determine if each scale (objective) would produce consistent results should the research be done later on. The study found that the instrument had reliability ($\alpha=0.885$). This illustrates that all the four scales were reliable as their reliability values exceeded the prescribed threshold of 0.6, thus the instrument was reliable to use in collecting data as it helped to achieve the desired research objective.

3.7 Data Analysis and Report Writing

Before processing the responses, the completed questionnaires were edited for completeness and consistency. A content analysis and descriptive analysis was employed. The content analysis was used to analyze the respondents' views about a framework for adoption of WSNs in the KMD. The data was coded to enable the responses to be grouped into various categories. Descriptive statistics such as means, median, mode and standard deviation were used to help in data analysis. Tables and other graphical presentations as appropriate were used to present the data collected for ease of understanding and analysis. Factor analysis was applied to determine the relative importance of each of the variables with respect to adoption of WSNs in the KMD.

3.8 Operationalization of Variable

Table 3.3: Operationalization of Variables

Variable/Aspect Of Conceptual framework	Indicator	Measurement Scale	Study Design	Tools Of Analysis
Experience	Experience with Adoption of WSNs	Ordinal	Descriptive	Likert scale
Voluntariness	Voluntariness in the adoption of WSNs	Ordinal	Descriptive	Likert scale
Subjective norms	Influence of behaviour in the adoption of WSNs	Ordinal	Descriptive	Likert scale
Image	prestige in the use of WSNs Use of WSNs has high profile Use of WSNs has status symbol	Ordinal	Descriptive	Likert scale
Job relevance	WSNs is important in the current job	Ordinal	Descriptive	Likert scale
Output quality	High output due to WSNs adoption	Ordinal	Descriptive	Likert scale
Trail ability	Ease of trail ability Trial with minimal errors	Ordinal	Descriptive	Likert scale
Compatibility	WSNs is compatible with the structure of	Ordinal	Descriptive	Likert

	the organization			scale
Perceive ease of use	WSNs has perceived ease of use	Ordinal	Descriptive	Likert scale
Perceive d usefulness	WSNs is perceived to be useful in KMD	Ordinal	Descriptive	Likert scale
Intention to use	Employee have intention to use WSNs	Ordinal	Descriptive	Likert scale
User behaviour	Use behaviour for WSNs	Ordinal	Descriptive	Likert scale

After the definitions of the variables, this Operationalization table gave the insight on how the various variables were to be measured so that they could be analyzed and conclusions drawn thereafter.

CHAPTER FOUR:

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter presents analysis and findings of the research. From the study population target of 88 respondents, 81 respondents filled and returned their questionnaires, constituting 92% response rate. Data analysis was done through Statistical Package for Social Scientists (SPSS). Descriptive statistics was used to analyze the data. In the descriptive statistics, relative frequencies were used in some questions and other were analyzed using mean scores with the help of Likert scale ratings in the analysis.

4.2 General Information

From the findings, the study revealed that the respondents were working in various divisions which included; ICT, forecasting, public weather dissemination, instruments, telecommunications , disaster prevention and mitigation , international relation and data processing. This was an indication that the divisions in the KMD were well represented.

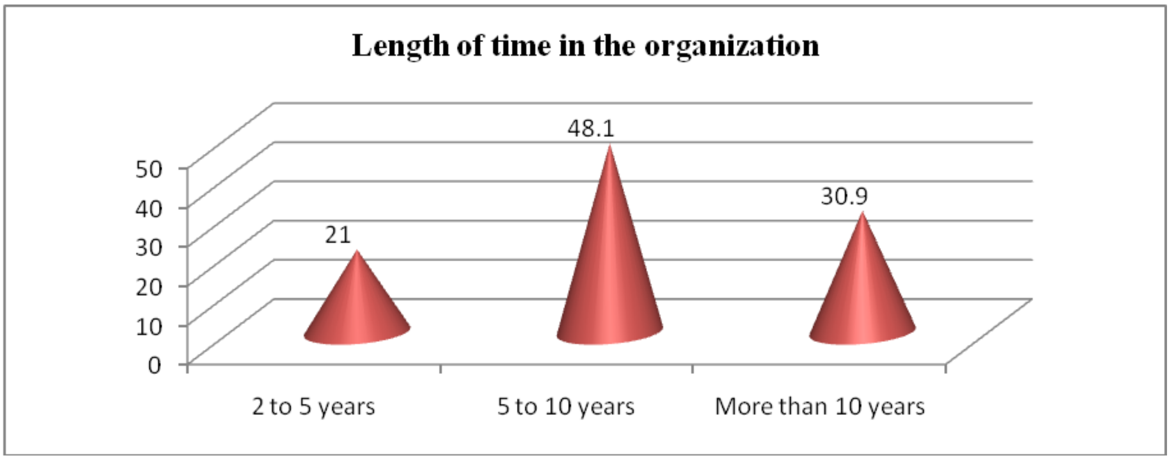


Figure 4.9: Length of time in the organization

From the findings on how long the respondents had served in the KMD, the study found that most of the respondents as shown by 48.1% indicated that they had served the KMD for 5 to

10 year , 30.9% of the respondents indicated that they had served in their KMD for more than 10 year whereas 21% of the respondents indicated that they had served in the KMD for 2 to 5 years. This was an indication that majority of the respondents had served in the KMD long enough to give credible information to the study on the adoption of WSNs technology.

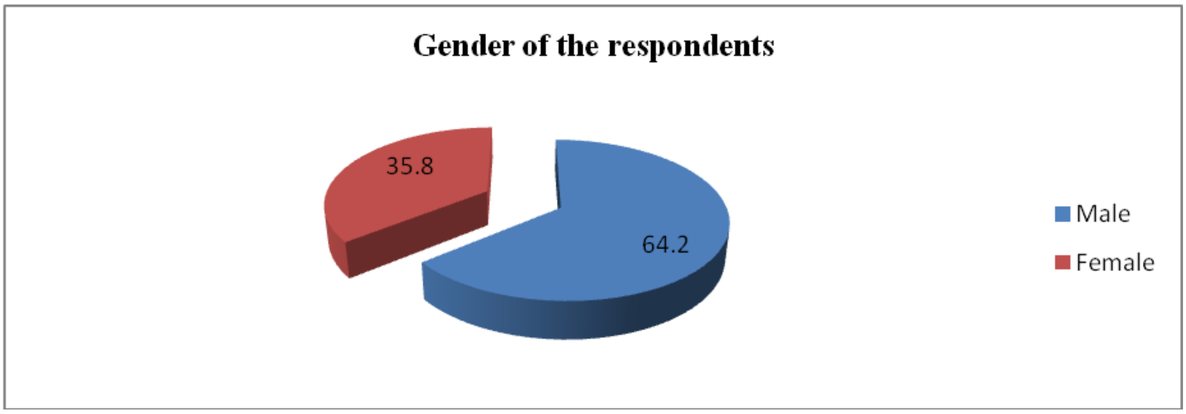


Figure 4.10: Distribution of Respondent by Gender

From the findings of the study on the gender of the respondents, the study found that majority of the respondents as shown by 64.2% were males whereas 35.8% of the respondents were females. This was an indication that both male and females were working at the KMD, though there were more males than females.

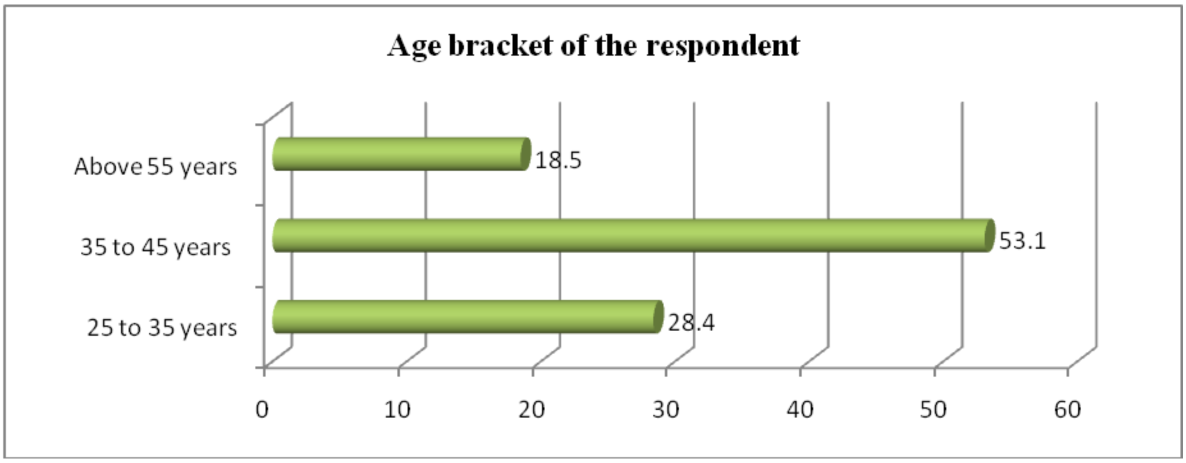


Figure 4.11: Age Bracket of the Respondents

On the age bracket of the respondents the study found that majority of the respondents as shown by 53.1% were aged between 35 to 45 years, 28.4% of the respondents were aged between 25 to 35 years whereas 18.5% were aged above 55 years .This was an indication that the respondents were well distributed in terms of their age.

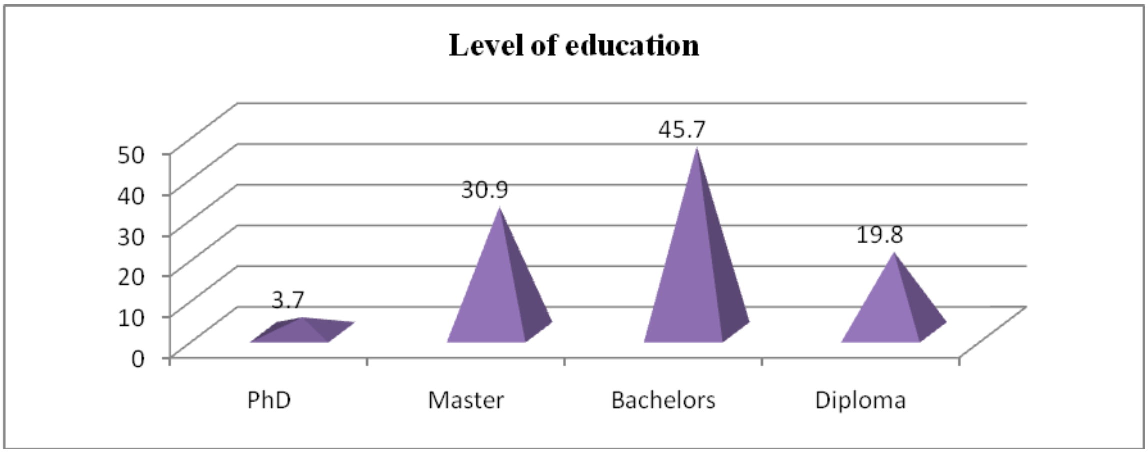


Figure 4.12: Respondent's Highest Level of Education

From the findings on the respondents highest level of education, the study found that 45.7% of the respondents indicated that they were in possession of bachelor's degree , 30.9% of the respondents had attained master level of education , 19.8% of the respondents indicated that they had attained diploma level of education whereas 3.7% of the respondents were in possession of PhD. This was an indication that majority of the respondents were well educated and were in a position to understand and give credible information to the study.

4.3 Views on Weather Forecasting in Kenya

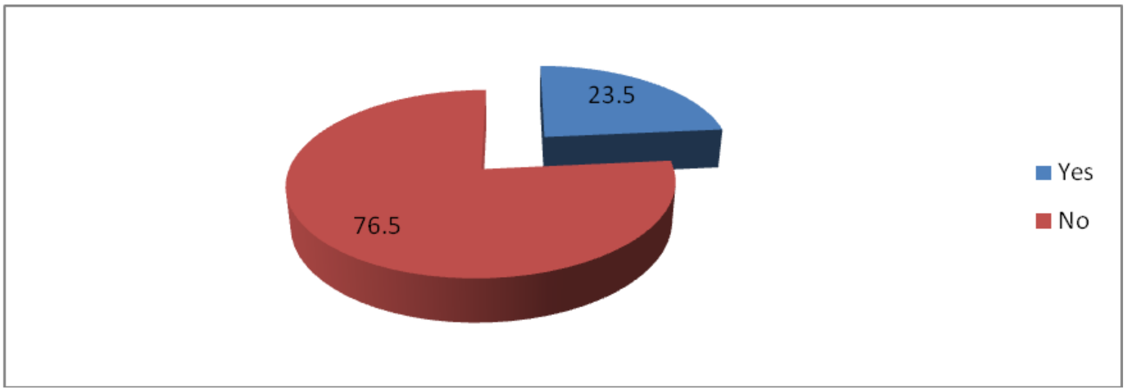


Figure 4.13: Satisfaction on Current Weather Forecasting Practices

From the findings on the respondents' opinion on whether the current weather forecasting practices in Kenya were satisfactory, the study found that majority of the respondents as shown by 76.5% indicated that the methods were not satisfactory, whereas 23.5% of the respondents indicated that the current weather forecasting practices were satisfactory. This indicated that there was need for adoption of WSNs in weather forecasting in Kenya.

The study found that KMD faced various external challenges which affected weather forecasting in KMD as shown by 100% of the respondents who indicated yes to the question. The study further revealed that there was need to adopt WSNs in the weather forecasting practices in Kenya as shown by 100% of the respondents who indicated yes to the study.

On the benefits of WSNs, the study revealed that the various benefits of WSNs were ; Sensing accuracy, large area coverage, minimal human interaction, sensor nodes can be deployed in harsh environments that make the sensor networks more effective, fault tolerance, connectivity and dynamic sensor scheduling.

The study revealed that the various challenges faced by the KMD in weather forecasting were; poor coverage by weather stations, high cost of procuring, installation and maintenance of AWS, lack of technical knowledge required for installation, operation and maintenance of otherwise complex AWS has slowed the impact of AWS, insecurity of the instruments, ineffective information dissemination and non-user centered weather forecast information.

The study established that the possible solutions to improve current challenges of weather forecasting by KMD were adoption of WSNs in the weather forecasting practices in Kenya and dissemination of the information, purchase of new equipment for weather forecasting and training of the staff of WSNs in weather forecasting.

4.4 Framework for Adoption of Wireless Sensor Networks

Table 4.4: Perceived ease of use Wireless Sensor Networks

	Mean	Std deviation
Adoption of WSNs is easy for me	1.863	.6834
I find it easy to adopt Wireless Sensor Networks	1.996	.7387

From the findings on the respondents' level of agreement on various aspects of perceived ease of use of WSNs, the study found that majority of the respondents agreed that adoption of WSNs is easy for them as shown by mean of 1.863 and they found it easy to adopt WSNs as shown by mean of 1.996. All this information was supported by low standard deviation, an indication that respondents had similar opinion.

Table 4.5: Perceived usefulness of Wireless Sensor Networks

	Mean	Std deviation
Adoption of WSNs will allows the KMD to save money	2.051	.7063
Adoption of WSNs is more convenient than AWS	1.637	.5844
Privacy violation is a major problem for Adoption of WSNs	1.726	.5452

On perceived usefulness of WSNs, the study found that majority of the respondents agreed that adoption of WSNs is more convenient than AWS as shown by mean of 1.637, privacy violation was a major problem for adoption of WSNs as shown by mean of 1.726 and adoption of WSNs would allow KMD to save money as shown by mean of 2.051. This information was supported by low standard deviation which was an indication that respondent had similar opinion.

Table 4.6: Opinion on intention to use of Wireless Sensor Networks

	Mean	Std deviation
Assuming I have access to a WSN, I intend to use it	1.515	.5765
Given that I have access to a WSN, I predict that I would use it.	1.510	.6139

From the findings on the respondents' opinion on the intention to use of WSNs, the study revealed that majority of the respondents agreed that given that they had access to WSNs, they predicted that they would use it as shown by mean of 1.510 and assuming they had access to WSNs, they intended to use it as shown by mean of 1.515. The study further found that the above information was supported by low standard deviation, an indication that the respondents had similar opinion.

Table 4.7: Perceived Ease of Use of Wireless Sensor Networks

	Mean	Std deviation
My interaction with WSNs would be clear and understandable	1.729	.8950
Interacting with WSNs would not require a lot of my mental effort.	1.860	.9099
I find Adoption of WSNs easy to do	2.123	.6319
I find it would be easy to adopt WSNs	1.732	.8647

On the respondents' opinion on perceived ease of use of WSNs, the study revealed that the respondents agreed that they found it easy to adopt WSNs as shown by mean of 1.732, their interaction with WSNs would be clear and understandable as shown by mean of 1.729, interacting with WSNs would not require a lot of their mental effort as shown by mean 1.860 and they found adoption of WSNs easy to do as shown by mean of 2.123. This was supported by low standard deviation.

Table 4.8: Perceived Usefulness of Wireless Sensor Networks

	Mean	Std deviation
Using WSNs would improve my performance in my job	1.088	.4521
Using WSNs in my job would increase my productivity	1.566	.9890
Using WSNs would enhance my effectiveness in my job	1.324	.6421
I find WSNs would be useful in my job	1.722	.6337

On the respondents' opinion on perceived usefulness of WSNs, the study established that majority of the respondents strongly agreed that using WSNs would improve their performance in their jobs as shown by mean 1.088 and using WSNs would enhance their effectiveness in their jobs as shown by mean of 1.324, the respondents further agreed that using WSNs in their jobs would increase their productivity as shown by mean of 1.566 and found WSNs would be useful in their jobs.

Table 4.9: Opinion on Subjective Norms of Wireless Sensor Networks

	Mean	Std deviation
People who influence my behaviour (work) think that I should use WSNs	1.685	.6532
People who are important to me think that I should use WSNs	1.644	.8503

On the respondents' opinion on subjective norms of WSNs, the study found that majority of the respondents agreed that people who were important to them thought that they should use WSNs as shown by mean of 1.644 and people who influenced their behaviour (work) thought that they should use WSNs as shown by mean of 1.685, the above information was supported by low standard deviation an indication that respondents had similar opinion on subjective norms of WSNs.

Table 4.10: Opinion on Image of Wireless Sensor Networks

	Mean	Std deviation
Other metrological organizations that have adopted WSNs have more prestige than those who do not	1.165	.1393
Employee in other organization who use WSNs would have a high profile	1.768	.6139
Having the adopted WSNs would be a status symbol in my organization	1.517	.6132

From the findings on the respondents' opinion on the image of WSNs, the study found that respondents strongly agreed that other metrological organizations that had adopted WSNs had more prestige than those who did not as shown by mean of 1.165, respondents further agreed that having the adopted WSNs would be a status symbol in their organization as shown by mean of 1.517 and employees in other organization who used WSNs would have a high profile as shown by mean of 1.768.

Table 4.11: Opinion on Job Relevance of Wireless Sensor Networks

	Mean	Std deviation
In my job, usage of WSNs would be important	1.578	.7155
In my job, usage of WSNs would be relevant	2.055	.7696

From the findings on the respondents' opinion on job relevance of WSNs, the study established that in their jobs, usage of WSNs would be important as shown by mean of 1.578 and In their jobs, usage of WSNs would be relevant as shown by mean of 2.055.This information was supported by low standard deviation, an indication that respondents had similar opinion on job relevance.

Table 4.12: Opinion on Output Quality of Wireless Sensor Networks

	Mean	Std deviation
The quality of the output I get from WSNs will be high	2.027	.8201
I would have no problem with the quality of WSNs systems' output	2.259	.8152

From the findings on the respondents' opinion on output quality of WSNs, the study found that the respondents agreed that the quality of the output they got from WSNs would be high as shown by mean of 2.027 and they would have no problem with the quality of WSNs systems' output as shown by mean of 2.259.

Table 4.13: Relative Advantage of Wireless Sensor Networks

	Mean	Std deviation
Using WSNs would enhance my efficiency in protecting information in the organization	1.463	.6858
Using WSNs would enhance my efficiency in interacting with other organization	1.741	.6558
Using WSNs would make it easier to interact with other organization	1.691	.6393
Using WSNs would give me greater control over my interaction with other organization	1.426	.5087

From the findings on the respondents' opinion on the Relative advantage of WSNs, the study revealed that majority of the respondents strongly agreed that using WSNs would give them greater control over their interaction with other organization as shown by mean of 1.426 and that using enterprise WSNs would enhance their efficiency in protecting information in the organization as shown by mean of 1.463, respondents further agreed that using WSNs would make it easier to interact with other organizations as shown by mean of 1.691 and using WSNs would enhance their efficiency in interacting with other organization as shown by mean 1.741.

Table 4.14: Trust of Wireless Sensor Networks

	Mean	Std deviation
WSNs could be trusted to provide data accurately	1.907	.8679
In my opinion, WSNs are trustworthy	1.985	.5397

From the finding on the respondents' opinion of trust of WSNs, the study found that respondents agreed that WSNs could be trusted to provide data accurately as shown by mean of 1.907 and WSNs was trustworthy as shown by mean of 1.985.

Table 4.15: Compatibility of Wireless Sensor Networks

	Mean	Std deviation
I think using WSNs would fit well with the way that I like to gather information from other organization	1.628	.5501
I think using WSNs would fit well with the way that I like to interact with other organization	1.741	.6558
Using WSNs to interact with other organization would fit into my lifestyle.	1.460	.5971
Using WSNs to interact with other organization would be compatible with how I like to do things.	1.485	.5397

On the compatibility of WSNs, the study found that using WSNs to interact with other organization would fit into their lifestyle, as shown by mean of 1.460 and using WSNs to interact with other organization would be compatible with how they liked to do things as shown by mean of 1.485, respondents further agreed that they thought using WSNs would fit well with the way that they liked to gather information from other organization as shown by mean of 1.628 and that they thought using WSNs would fit well with the way that they liked to interact with other organization as shown by mean of 1.741.

4.5 Factor Analysis

Factor analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. The study selected those factors that related to the various independent variables that were being investigated. The indentified factors were subjected to factors analysis using SPSS version 20.

Table 4.16: Communalities

	Initial	Extraction
Adoption of WSNs is easy for me	1.000	.857
I find it easy to adopt WSNs	1.000	.750
Adoption of WSNs allows me the organization to save money	1.000	.830
Adoption of WSNs is more convenient than other models	1.000	.773
Privacy violation is a major problem for Adoption of Wireless Sensor Networks	1.000	.826
Assuming I have access to WSNs, i intend to use it.	1.000	.845
Given that I have access to WSNs, I predict that I would use it.	1.000	.794
My interaction with WSNs would be clear and understandable	1.000	.794
Interacting with WSNs would not require a lot of my mental effort.	1.000	.758
I find Adoption of WSNs easy to do	1.000	.847
I find it would be easy to adopt WSNs	1.000	.793
Using WSNs would improve my performance in my job	1.000	.668
Using WSNs in my job would increase my productivity	1.000	.775
Using WSNs would enhance my effectiveness in my job	1.000	.700
I find WSNs would be useful in my job	1.000	.780
People who influence my behaviour (work) think that I should use WSNs	1.000	.801
People who are important to me think that I should use WSNs	1.000	.812
Organization that have adopted WSNs have more prestige than those who do not	1.000	.809

Employee in other organization who use WSNs would have a high profile	1.000	.869
Having the adopted WSNs would be a status symbol in my organization	1.000	.837
In my job, usage of WSNs would be important	1.000	.815
In my job, usage of WSNs would be relevant	1.000	.750
The quality of the output I get from WSNs would be high	1.000	.826
I would have no problem with the quality of WSNs systems' output	1.000	.844
Using WSNs would enhance my efficiency in protecting information in the organization	1.000	.716
Using WSNs would enhance my efficiency in interacting with other organization	1.000	.730
Using WSNs would make it easier to interact with other organization	1.000	.774
Using WSNs would give me greater control over my interaction with other organization	1.000	.806
I think using WSNs would fit well with the way that I like to gather information from other organization	1.000	.908
I think using WSNs would fit well with the way that I like to interact with other organization	1.000	.770
Using WSNs to interact with other organization would fit into my lifestyle.	1.000	.852
Using WSNs to interact with other organization would be compatible with how I like to do things.	1.000	.813
In my opinion, WSNs are trustworthy	1.000	.846

The eigenvalue for a given factor measures the variance in all the variables which is accounted for by that factor. The ratio of eigenvalues is the ratio of explanatory importance of the factors with respect to the variables. If a factor has a low eigenvalue, then it is contributing little to the explanation of variances in the variables and may be ignored as redundant with more important factors. Eigenvalues measure the amount of variation in the total sample accounted for by each factor. The above table helps the researcher to estimate the communalities for each variance. This is the proportion of variance that each item has in common with other factors. For example ‘I think using WSNs would fit well with the way that I like to gather information from other organization' has 90.8% communality or shared relationship with other factors. This value has the greatest communality with others, while 'Using WSNs would improve my performance in my job' has the least communality with others of 66.8%.

Table 4.17: Component Matrix

	Component										
	1	2	3	4	5	6	7	8	9	10	11
1	.508	-.106	-.307	.208	.319	.249	-.193	.029	.261	.217	.388
2	.659	-.078	-.046	.159	-.335	-.036	-.327	.206	.128	.071	-.052
3	.380	.692	-.025	.089	-.428	-.350	.443	-.150	-.245	.290	.012
4	-.019	.715	.361	.626	.025	.325	.272	.190	.036	-.173	.059
5	.128	.946	.253	.156	-.259	-.274	.163	-.268	-.493	.032	.420
6	.061	-.131	.562	.435	-.171	.484	-.019	-.001	-.127	-.096	.174
7	.287	-.456	.450	-.074	-.033	-.027	.405	.066	.319	-.097	.120
8	.338	-.244	.626	.491	-.037	.164	-.038	-.038	.400	-.014	-.023
9	.419	-.160	.210	.502	-.152	.305	.153	.243	.030	-.031	.247
10	.461	-.051	.224	.673	.193	.379	-.101	-.340	.208	.395	.042
11	.049	.278	-.040	.571	.211	-.329	.329	-.107	.359	-.364	.416
12	.198	.544	.378	.014	.532	-.221	-.154	-.210	.110	-.075	-.034
13	-.119	.564	.278	.053	.883	-.171	-.311	-.337	-.018	.048	.201
14	-.379	-.208	.517	.149	.706	-.012	.088	.344	-.175	.191	-.140
15	.050	.348	.642	-.142	.711	-.187	-.022	-.208	-.028	.305	-.083
16	.415	-.017	.601	.284	-.099	.717	-.144	.087	-.218	.027	.002
17	.436	-.419	.017	-.104	.473	.825	.072	-.110	.120	-.191	-.195
18	.681	-.302	-.033	.002	.101	-.041	.689	-.315	.114	-.148	-.315
19	.581	-.129	-.570	-.080	.141	.078	.663	-.158	-.188	.197	.181
20	.486	-.398	.256	.338	.293	.067	.899	-.101	-.154	-.356	-.044
21	.403	.058	-.040	-.396	.118	.230	-.372	.752	-.265	-.297	-.057
22	.448	.507	-.008	.266	-.357	.114	-.188	.730	.194	-.082	.006
23	.603	.122	-.193	.429	.201	-.194	-.026	.146	.800	.242	-.168
24	.384	.140	-.566	.397	-.040	.198	.370	-.124	.656	-.022	-.050
25	.356	.065	.017	-.238	.408	.222	-.176	.337	-.285	.918	.199
26	.382	.652	.173	-.193	-.250	.072	-.146	.029	.015	.843	-.013
27	.094	.522	.027	.205	.594	-.019	.000	-.054	-.118	.861	.230
28	.115	.293	.208	.099	.309	.400	.527	-.002	.012	.771	-.217
29	.792	-.037	-.201	.105	.063	-.189	-.103	.204	-.369	.007	.821
30	.097	.623	-.117	.149	-.085	.346	.174	-.181	-.207	-.206	.747
31	.064	.603	.107	-.233	.027	-.055	.503	.355	-.122	-.136	.848
32	.525	.094	-.217	-.244	-.502	.098	-.083	.158	.282	.027	.922
33	.153	.220	.023	.153	.176	-.504	.051	.589	.310	.141	.708

The initial component matrix was rotated using Varimax (Variance Maximization) with Kaiser Normalization. The above results allowed the researcher to identify what variables fall under each of the 11 major extracted factors. Each of the 33 variables was looked at and placed to one of the eleven factors depending on the percentage of variability; it explained the total variability of each factor. A variable is said to belong to a factor to which it explains more variation than any other factor. From the above table, the individual variables constituting the eleven factors extracted are summarized and identified below. The cumulative value of 79.902, mean that the various factors considered by the study as influencing adoption of WSNs up to 79.902% which was an indication that they were the major factors that explained the adoption of WSNs. Extraction sums of squared loadings, initial eigenvalues and eigenvalues after extraction were the same for Principal Component Analysis (PCA) extraction, but for other extraction methods, eigenvalues after extraction would be lower than their initial counterparts.

Perceived Ease of Use

Adoption of WSNs is easy for me

I find it easy to adopt WSNs

Perceived Usefulness

Adoption of WSNs allows me the organization to save money

Adoption of WSNs is more convenient than other models

Privacy violation is a major problem for Adoption of WSNs

Intention to Use

Assuming I have access to WSNs, I intend to use it

Given that I have access to WSNs, I predict that I would use it.

Perceived Ease of Use

My interaction with WSNs would be clear and understandable

Interacting with WSNs would not require a lot of my mental effort

I find Adoption of WSNs easy to do

I find it would be easy to adopt WSNs

Perceived Usefulness

Using WSNs would improve my performance in my job

Using WSNs in my job would increase my productivity

Using WSNs would enhance my effectiveness in my job

I find WSNs would be useful in my job

Subjective Norm

People who influence my behaviour (work) think that I should use WSNs

People who are important to me think that I should use WSNs

Image

Other meteorological organizations that have adopted WSNs have more prestige than those who do not

Employee in other organization who use WSNs would have a high profile

Having the adopted WSNs would be a status symbol in my organization

Job Relevance

In my job, usage of WSNs would be important

In my job, usage of WSNs would be relevant

Output Quality

The quality of the output I get from WSNs would be high

I would have no problem with the quality of WSNs systems' output

Relative advantage

Using WSNs would enhance my efficiency in protecting information in the organizations

Using WSNs would enhance my efficiency in interacting with other organizations

Using WSNs would make it easier to interact with other organizations

Using WSNs would give me greater control over my interaction with other organizations

Trust

WSNs could be trusted to carry out online transactions faithfully and provide online data accurately

In my opinion, WSNs are trustworthy

Compatibility

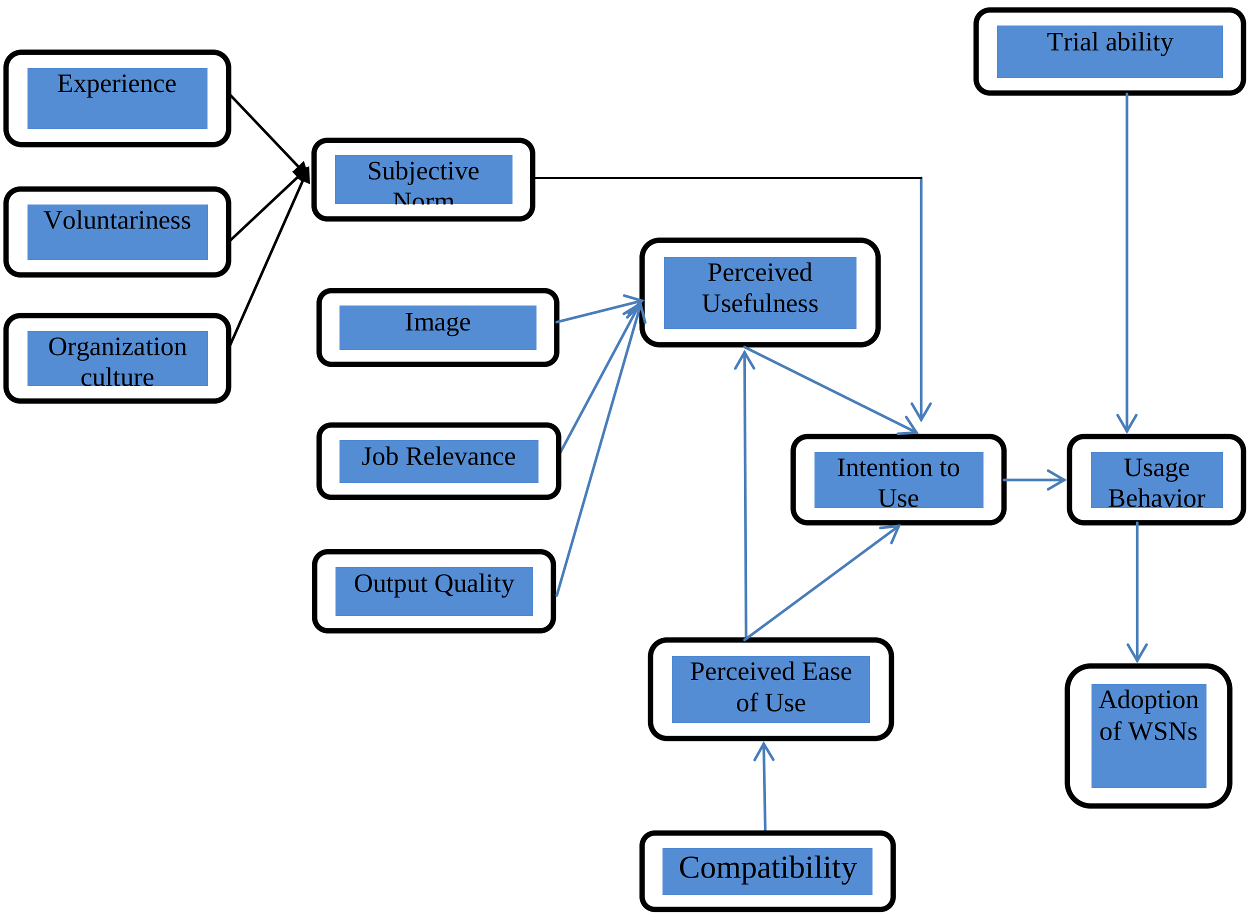
I think using WSNs would fit well with the way that I like to gather information from other organizations

I think using WSNs would fit well with the way that I like to interact with other organizations

Using WSNs to interact with other organization would fit into my lifestyle

Using WSNs to interact with other organization would be compatible with how I like to do things

4.6 Validated Framework for Adoption of Wireless Sensor Networks



Source, Research

Figure 4.14: Validated framework for Adoption of Wireless Sensor Networks

Components of Framework

Compatibility is positively correlated with the rate of adoption. WSNs is directly compatible with the need for weather forecasting practices

Trial ability is linked to divisibility of an innovation. WSNs can be adopted in phases, with each phase potentially leading to a greater adoption. Trial ability of WSNs is influenced by cultural values, the task and its associated stresses, and even social influence.

Perceive ease of use; Adoption of WSNs is easy for them and they find it easy to adopt WSNs.

Adoption of WSNs is more convenient than AWS. Privacy violation is a major problem for adoption of WSNs and adoption of WSNs will allows KMD to save money.

Perceived usefulness; employee will have access to WSNs; they predict that they would use it and assuming they have access to WSNs, intend to use it.

Job relevance; it is easy to adopt WSNs, interaction with WSNs would be clear and understandable, interacting with WSNs would not require a lot of my mental effort and they find adoption of WSNs easy to do.

Output quality; using WSNs would improve my performance in my job and using WSNs would enhance my effectiveness in my job, using WSNs in my job would increase my productivity and they find WSNs would be useful in my job.

Subjective norms; people who are important to employee of KMD think that they should use WSNs and people who influence employees behaviour (work) think that they should use WSNs.

Image ; organization that adopt WSNs have more prestige than those who do not, having the adopted WSNs would be a status symbol in my organization and employee in other organization who use WSNs would have a high profile.

Job relevance of WSNs, the study established that in my job, usage of WSNs would be important and in my job, usage of WSNs would be relevant.

Output quality; the quality of the output from WSNs would be high and they would have no problem with the quality of WSNs systems' output.

Organization cultures; using WSNs would give me greater control over interaction with other organization, using enterprise WSNs enhance efficiency in protecting information in the organization, using WSNs would make it easier to interact with other organization and using WSNs would enhance efficiency in interacting with other organization.

Experience; WSNs could be trusted to provide data accurately and that WSNs are trustworthy. Using WSNs to interact with other organization would fit into lifestyle and using WSNs to interact with other organization would be compatible with how I like to do things, respondents further agreed that they using WSNs would fit well with the way that I like to gather information from other organization and that they think using WSNs would fit well with the way that I like to interact with other organizations.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Achievements

The research was intended to examine the challenges faced by KMD in their current weather practices, to determine factors influencing the adoption of WSNs by KMD, to determine the benefits of adopting WSNs in weather forecasting practices by KMD and to develop a framework for adoption of WSNs in the weather forecasting practices by KMD. The challenges faced by KMD in their current weather practices have been identified as poor coverage by weather stations, high cost of procuring, installation and maintenance of AWS, lack of technical knowledge required for installation, insecurity of the instruments, ineffective information dissemination and non-user centered weather forecast information

The factors influencing the adoption of WSNs by KMD are Perceived Ease of Use, Perceived Usefulness, Intention to Use, Image, Subjective Norm, Perceived Ease of Use, Job Relevance, Output Quality, Compatibility, Trust, Relative advantage. Among the benefits of adopting WSNs in weather forecasting practices are Sensing accuracy, large area coverage, minimal human interaction, sensor nodes can be deployed in harsh environments that make the sensor networks more effective, fault tolerance, connectivity and dynamic sensor scheduling.

The research study has successfully developed a framework for addressing weather forecasting challenges in Kenya using WSNs technology

5.2 Summary of Findings

From the findings on the opinion on whether the current weather forecasting practices in Kenya were satisfactory, the study found that majority of the respondents as shown by 76.5% indicated that the methods were not satisfactory. This indicated that there was need for adoption of WSNs in weather forecasting in Kenya. The study found that KMD faced various external challenges which affect weather forecasting in KMD as shown by 100% of the respondents who indicated yes to the question. The study further revealed there was need to adopt WSNs in the weather forecasting practices in Kenya as shown by 100% of the respondents who indicated yes to the study. On the benefits of WSNs, the study revealed that the various benefits of WSNs were ; Sensing accuracy, large area coverage, minimal human interaction, sensor nodes can be deployed in harsh environments that make the sensor networks more effective, fault tolerance, connectivity and dynamic sensor scheduling.

The study revealed that the various challenges faced by the KMD in weather forecasting were; poor coverage by weather stations, high cost of procuring, installation and maintenance of AWS, lack of technical knowledge required for installation, operation and maintenance of otherwise complex AWS has slowed the impact of AWS, insecurity of the instruments, ineffective information dissemination and non-user centered weather forecast information. The study established that the possible solutions to improve current challenges of weather forecast by KMD were adoption of WSNs the weather forecasting practices in Kenya and dissemination of the information, purchase of new equipment for weather forecasting and training of the staff of WSNs in weather forecasting.

5.3 Conclusions

The study found that the current weather forecasting practices in Kenya were not satisfactory, thus the need for adoption of WSNs in weather forecasting practices in Kenya. The study found that KMD faced various external challenges which affects weather forecasting in KMD, which necessitate the need to adopt WSNs in the weather forecasting practices in Kenya. On the benefits of WSNs, the study revealed they were; Sensing accuracy, large area coverage, minimal human interaction, sensor nodes can be deployed in harsh environments that make the sensor networks more effective, fault tolerance, connectivity and dynamic sensor scheduling.

The study concluded that the various challenges facing the KMD in weather forecasting were; poor coverage by weather stations, high cost of procuring, installation and maintenance of AWS, lack of technical knowledge required for installation, operation and maintenance of otherwise complex AWS has slowed the impact of AWS, insecurity of the instruments, ineffective information dissemination and non-user centered weather forecast information. The study established that the possible solutions to improve current challenges of weather forecast by KMD were adoption of WSNs in the weather forecasting practices in Kenya and dissemination of the information, purchase of new equipment’s for weather forecasting and training of the staff of WSNs in weather forecasting.

The study found that factors affecting the adoption of WSNs in weather forecasting practices were, culture where culture is a system of shared meaning within an organization that determines in large degree how employees act, shared values, norms and organizational practices do shape the culture that assist organizations to adopt the changes and human factor in which individuals play an effective and important role in technology adoption process. Technology is not successful if its user does not accept it, it is argued that the participation of users in the design and implementation of projects promote greater user acceptance. Social need-to feel strong desire of something, Social resources-the capital, material, and skilled personnel vital for innovation and adoption of new thing, Sympathetic social ethos-an environment in which the dominant groups are prepared to consider innovation seriously and are receptive to new idea, organizational structure, Governmental and Political Factor and the cost of adopting WSNs.

5.4 Limitation of the Study and Suggestions for Future Research

In the process of conducting this study, it encountered a number of limitions some of which offer opportunities for future research. The duration of the study was not long enough to enable a proper investigation of the responses and survey, therefore the results may suffer from internal validity threats. Majority of the respondents were managers in the department who may not have the final authority in making decsion to adoption of WSNs . Since the study is solely conducted on KMD in kenya, the results may suffer from regional biases. Therefore the results needs to be interpreted carefully and repricated in other Departments in other countries to improve their relevance. The results of this study suggest new directions for future research. Researchers in the field of information system ought to put more emphasis on adoption and assimilation of WSNs as a technological innovation rather than administrative innovation. Furthermore an in-depth study is required to rationalize the moderating factors.

5.5 Recommendations

The study recommended that the possible solutions for KMD were; creating awareness of the new technologies in the weather forecasting practices, improving staff training on new technologies in weather forecasting , installation of more weather stations, more research to be done to explore new and efficient methods of weather forecasting , use of mobile technology in the dissemination of information on weather , use of automated wireless sensor weather stations, employement of qualified personnels, government financial inputs and proper use of effective drought index .

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Appendix I: Questionnaire

Questionnaire to be used to collect data from the Head of Divisions

Please fill in each question on the spaces provided where applicable.

PART I:

1. Name of the Division you are working for…………………………….....

2. How long have you served in the company?

   Less than 1year [ ]
   2 to 5 years [ ]
   5 to 10 years [ ]
   More than 10 years [ ]

3. What is your gender?

   Male [ ]
   Female [ ]

4. What is your age bracket?

   Below 25 years [ ]
   25 to 35 years [ ]
   35 to 45 years [ ]
   45 to 55 years [ ]
   Above 55 years [ ]

5. What is your level of education? (Tick where appropriate)

   PhD [ ]
   Master [ ]
   Bachelors [ ]
   Diploma or equivalent [ ]

PART II: Views on Weather forecast in Kenya

6. Are the current weather forecasting practices in Kenya satisfactory?

   Yes [ ]

   No [ ]

7. Are there external challenges do you think affect weather forecasting in KMD?

   Yes [ ]

   No [ ]

8. Is there need to adopt WSNs in the weather forecasting practices in Kenya?

   Yes [ ]

   No [ ]

9. What are various benefits of Wireless Sensor Networks?

   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………
   ………………………………………………………………………………………………..

10. What are the challenges faced by the Kenya meteorological department in weather forecasting

    …………………………………………………………………………………………………
    …………………………………………………………………………………………………
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    ……………………………………………………………..……

11. What possible solutions do you think can be recommended to improve current challenges of weather forecast by KMD?

    …………………………………………………………………………………………………
    …………………………………………………………………………………………………
    …………………………………………………………………………………………………
    …………………………………………………………………………………………………
    ……………………………………………………………………………………………......

Part III: Framework for Adoption of Wireless Sensor Networks

(*Please indicate the level which you agree/disagree with the following statements based on the following rankings by ticking 1,2,3,4,5 as per ranking:1(Strongly agree), 2(Agree)3 (Neutral), 4(Disagree), 5(Strongly disagree*).

12. Perceived ease of use *(Your opinion on perceived ease of use Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Adoption of WSNs is easy for me					
I find it easy to adopt Wireless Sensor Networks					

13. Perceived usefulness *(Your opinion on perceived usefulness of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Adoption of WSNs allows me the organization to save money					
Adoption of WSNs is more convenient than other models					
Privacy violation is a major problem for Adoption of Wireless Sensor Networks					

14. Intention to use (IUSE) *(Your opinion on intention to use of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Assuming I have access to Wireless Sensor Networks, i intend to use it.					
Given that I have access to Wireless Sensor Networks, I predict that I would use it.					

15. Perceived ease of use (PEOU) *(Your opinion on perceived ease of use of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
My interaction with WSNs would be clear and understandable					
Interacting with WSNs would not require a lot of my mental effort.					
I find Adoption of WSNs easy to do					
I find it would be easy to adopt Wireless Sensor Networks					

16. Perceived usefulness (PU) *(Your opinion on perceived usefulness of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Using WSNs would improve my performance in my job					
Using WSNs in my job would increase my productivity					
Using WSNs would enhance my effectiveness in my job					
I find WSNs would be useful in my job					

17. Subjective norm (SN) *(Your opinion on subjective norms of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
People who influence my behaviour (work) think that I should use Wireless Sensor Networks					
People who are important to me think that I should use Wireless Sensor Networks					

18. Image (IMG) *(Your opinion on image of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Other metrological organizations that have adopted WSNs have more prestige than those who do not					
Employee in other organization who use WSNs would have a high profile					
Having the adopted WSNs would be a status symbol in my organization					

19. Job relevant (JR) *(Your opinion on job relevance of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
In my job, usage of WSNs would be important					
In my job, usage of WSNs would be relevant					

20. Output quality (OQ) *(Your opinion on output quality of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
The quality of the output I get from WSNs would be high					
I would have no problem with the quality of WSNs systems' output					

21. **Relative advantage (RA)** *(Your opinion on relative advantage of WSNs)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Using WSNs would enhance my efficiency in protecting information in the organization					
Using WSNs would enhance my efficiency in interacting with other organization					
Using WSNs would make it easier to interact with other organization					
Using WSNs would give me greater control over my interaction with other organization					

22. Trust (TRUST) *(Your opinion on trust of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
WSNs could be trusted to carry out online transactions faithfully and provide online data accurately					
In my opinion, WSNs are trustworthy					

23. Compatibility *(Your opinion on compatibility of Wireless Sensor Networks)*

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I think using WSNs would fit well with the way that I like to gather information from other organization					
I think using WSNs would fit well with the way that I like to interact with other organization					
Using WSNs to interact with other organization would fit into my lifestyle.					
Using WSNs to interact with other organization would be compatible with how I like to do things.					

Thank you