FACULTY OF SCIENCES AND ENGINEERING DEPARTMENT OF PHYSICS DEPARTMENT AND ENGINEERING

A PROJECT IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE BACHELOR OF SCIENCE HONOURS DEGREE IN AGRICULTURAL ENGINEERING

TOPIC: DEVELOPMENT OF INTERNET OF THINGS FRAMEWORK OF MONITORING POULTRY HOUSING IN THE POULTRY FARMING SECTOR IN ZIMBABWE

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DECLARATION

I CHUMA MUFARO, B193279B, declare that, with the exception of what is noted in the acknowledgement and references, all of the research and work for this study was done by me, with my knowledge NO other university has received this project, in whole or parts.

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Date: 06 June 2024

Dedication

I dedicate this final project to the people who have made a significant impact in my life and have been my source of inspiration and motivation throughout my academic journey. Firstly I dedicate this work to my parents the late Mr. Chuma and Mrs. Chuma for their unwavering support, love and encouragement. They have been my pillars of strength and have always believed in me, even during my toughest times. Their sacrifices and selfless love have been driving force behind my success. I also want to dedicate this work my friends and classmates who have been my support system throughout my academic journey. Their encouragement and motivation have made my college experience memorable; will always be grateful for their unwavering friendship. For all your contributions building the person I am today, will forever be grateful.

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Abstract

The use of latest technologies such as internet of things has enabled farmers to better care for their animals and produces more food and minimized cost of labor through the use of technology. Most farmers used traditional methods such as in person inspection to monitor bird welfare and its environmental conditions which was expensive. This research relates to the development of internet of things framework of monitoring poultry housing in the poultry farming sector in Zimbabwe.

The study objectives were to design a model aimed at monitoring temperature, humidity and water levels in the poultry house, to develop an application or software which was linked on a mobile device to monitor temperature, humidity and water levels in the poultry house, to evaluate the performance of the developed model focusing on its accuracy, predictive power and its reliability.

Its aim was to improve farm productivity, bird welfare and resource efficiency. The developed model comprised of three main components: the perception layer consists of various sensors such as the water level sensor, ultrasonic sensor and devices that measured parameters such as temperature, humidity and water levels. The network layer enabled communication between devices and transmitted information. The application layer processed and analyzed information and provided useful information to end users through a user friendly interface. This data was analysed to provide actionable insights and driven farmers to make decision. A system analysis was conducted to identify stakeholder needs, functional and nonfunctional requirements, and technical specifications for the IoT system. A pilot implementation was carried out to evaluate the systems performance, usability and impact on farm operations. The study explored the potential integration of machine learning algorithms and artificial intelligence to enhance data analysis and predictive modeling capabilities. After the model was developed, the model was tested for its performance focusing on its accuracy, predictive and reliability which was a success. The experiment that was carried out for five days and its success, failures, Mean Time between Failures, Mean Time to Repair, and Uptime and downtime percentages was calculated and results showed that:

1. Reliability

A system's reliability is a measure of its ability to perform its intended function without failure. With a mean time between failures of 60h and an uptime percentage of 98 % , the system

appeared to be quite reliable. Because the observed and recorded temperature, humidity and water levels in the coop”s water system which was recorded was taken from both the dashboard and the blynk application showing real time data. For example on Tuesday between 12pm to 16:00 pm the temperatures ranged from 20 to 26 ºC and humidity ranged from 39 to 42 % and water levels in the coop”s water system ranged from 40 % decreasing to 10 %. This was because during the day temperature raised to 26 ºC and humidity to 42 % (optimum conditions), the chickens will be active as well and the food consumption will be high so they will be drinking water that’s why it dropped from 40 to 10 %. When the water level dropped below 15 % the model did sent a notification to the application flashing the blue light meaning that the water level has dropped and a refill is needed also a buzzer started producing a sound, notifying people who were around that water levels had dropped. Also on Wednesday the temperaturewas high at 30 degrees around 3pm the system responded very well to the condition which was considered to be high end of the comfortable temperature range for chickens and the system gave a notification on the application that ventilation was needed in the coop.

2. Maintainability

This refers to how a system can be easily repaired and maintained. With a Mean Time to Repair of 1 hour, the system appears to be fairly maintainable;

3. Availability

This refers to the proportional of time a system is operational and available for use. With this system, a downtime percentage of 3.3 %, the system is highly available, with limited downtime.

The findings in this study contributed to the advancement of precision agriculture and informed the development of tailored IoT solutions for poultry farming industry. The proposed system framework was expected to help farmers to optimize resource usage, detect and mitigate potential risks and also to enhance farm productivity. However addition of other parameters on the model is recommended such as measure of illumination and number of chickens in the coop to be shown on the dashboard.

Tables of symbols

Symbol	**Definition**
IoT	Internet of things
LCD	Liquid crystal display
AI	Artificial intelligence
WAP	Wireless application protocol
LAN	Local area network

Table of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

1.0 Introduction

Most farmers across the globe have been making use of cloud-based tools, intelligent equipment and computer intelligence in order to assist with large farms. These can assist in identifying sick birds, monitor their diet, assessing the conditions of their homes, and keeping a record of the items that they produce. This chapter intends to present background of the study, statement of the problem, research objectives, and research questions, significance of the study, limitations and delimitations of the study. Other aspects such as definition of key terms shall be outlined.

1.1 Background of the study

The poultry farming industry is a demanding and complicated industry that necessitates careful keep track of and management in order to guarantee the well-being of the animals and the profitability of the operation (Ajayi et al, 2020). Amraei, Abdanan and Salari (2017) the application of technology that is connected to the IoT has emerged as a potentially useful option in recent years for the purpose of enhancing the efficiency and efficacy of poultry farming. Technology is now assisting farmers in taking care of their chickens more effectively.

Globally in United States of America a company called E-AWARE Technologies have been developing innovative and high-quality solutions for the poultry industry and the organization has helped farmers around the world to improve their operations and achieve better results with coming up with latest technologies (Cheng, Rong & Cao, 2019). E-AWARE Technologies has had a substantial impact in a number of vital sectors, one of the most important of which is the track of and management of environmental conditions in poultry houses (Choukidar & Dawande, 2017). Cheng, Rong & Cao (2019) E-AWARE Technologies gives farmers the ability to remotely monitor temperature, humidity, ventilation, and other elements that can all have an impact on the health and well-being of their birds. This is accomplished by the deployment of a variety of sensors and other devices. The use of this real-time data gives farmers the ability to swiftly identify and address any problems that may occur, which ultimately results in birds that are healthier and higher production yields (Cuan et al., 2022).

In Nigeria, researchers such as Ojo, Anuoluwapo, Owolabi, Oyedele & Akanbi (2022) conducted a study on Internet of things and machine learning techniques in chickens health and welfare management: A systematic literature review, Ojo et al (2022) noted that the introduction of digital technologies has resulted in significant advancements in a variety of fields. Also a study was thorough assessment of research that focused on applications of IoT connected to artificial intelligence in the management of chickens health and welfare. The welfare of poultry was the primary subject of Ojo et al (2022 research since contemporary chickens management is currently facing challenges with the establishment of standardized parameters for welfare evaluation and the implementation of robust monitoring systems, in particular with regard to the health of broilers and the prevention of disease outbreaks. It has been demonstrated that contemporary digital technologies offer a great deal of potential for the intelligent automation of chickens management activities, both in the present and in the future, with the goal of facilitating the production of chickens that is both of high quality and cheap cost. Meanwhile the study did not manage to design the model aimed at monitoring temperature and humidity in poultry farming, come up with an application or software which can be linked on a mobile device to monitor chicken activity and evaluate the performance of the developed Internet of things model focusing on its accuracy, predictive power and reliability using data therefore this study intends to close this gap.

In Zimbabwe, Mazikana (2022) Zimbabwe's poultry output has surpassed 5 million chicks and between 60,000 and 70,000 dozen eggs per month. This represents a gain of between 16 and 19 % in comparison to the previous years that is year 2020, 2021 and 2022. Zawe (2023) the chairperson of the Zimbabwe Poultry Association, stated that the industry, which is comprised of informal traders 65 % of the time and official dealers 35 % of the time, is contributing 6,500 metric tonnes of meat on a monthly basis. Zawe (2023) the most significant obstacles that the expanding industry must overcome are extremely high utility costs, power outages, monitoring temperature and humidity and the prohibition of the use of genetically modified organisms as a source of food for the chickens. Despite the fact that chicken has become increasingly popular over the years as a low-cost source of protein, the poultry industry in Zimbabwe continues to face a number of challenges (Mazikana, 2022).

1.2 Problem statement

Poultry farmers are using traditional remote methods and procedures to remotely monitor temperature, humidity and water levels which tend to affect the health and well being of the birds. These traditional methods include employing people who walk around the coop, monitoring the environment and its time consuming. Farmers are failing to carefully monitor and manage the welfare of chickens to attain profitability. Zimbabwe veterinary (2023) reports revealed that poultry farmers have been facing an increased death in chickens due to parasites, poor nutrition and organ failure. This situation compromises farmers operations and achievements of set objectives. These farmers have attempted to adopt latest technology but their efforts were unsuccessful. If farmers adopt a range of sensors and other devices they can remotely monitor temperature, humidity and other factors which can affect the health and well-being of chickens. This study therefore formulates a model aimed to monitor the environment of the poultry house in Zimbabwe.

1.3 Specific Objectives

i. To design the model aimed at monitoring temperature, humidity and water levels in the poultry house in poultry farming
ii. To develop an application or software which can be linked on a mobile device to monitor temperature, humidity and water levels in the coop in poultry farming
iii. To evaluate the performance of the developed IOT model focusing on its accuracy, predictive power and reliability uses data from farmers.

1.4 Research Questions

i. Which model can be designed to monitor temperature, humidity and water levels in the poultry house in poultry farming?
ii. Which application or software can be developed which can be linked on a mobile device to monitor temperature, humidity and water levels in the poultry house?
iii. Can the developed model be evaluated based on its accuracy, predictive power and reliability using data from farmers?

1.5 Significance of the study

IOT, allows monitoring and automation because the systems allow real time track of of various parameters such as temperature, humidity, and water levels. This enables prompt responses to any changes in productivity of birds in terms of their health. There is also reduction of labour costs because certain tasks will be automated and efficiency is improved. Sustainability, IOT systems help minimizes environmental impacts and promotes sustainable practices by optimizing resource usage and reducing waste.

1.5.1 Farmers in Zimbabwe

This study will benefit farmers in Zimbabwe in finding the best model which they can use to monitor temperature, humidity and water levels in chicken farming. Farmers will be able to spot potential health issues and make informed decisions about how to optimise their operations with the help of IOT technologies. This is accomplished through the utilisation of sensors and other devices that collect data on feeding patterns, activity levels, and other metrics. The implementation of IoT solutions in the poultry sector has the potential to bring about a revolutionary change in the way that farmers approach the management of their operations. It is abundantly evident that the future of poultry farming will be digital, connected, and data-driven. Using one-of-a-kind devices, farmers are able to exert control over their barns from a considerable distance. Considering that the weather is constantly shifting, it is essential.

1.5.2 Researcher

This study will assist the researcher in partial fulfillment and completing her degree. The researcher knowledge and ability to make good decisions will be improved because of conducting research. Researchers investigate the particulars of a subject and contribute to the process of drawing knowledgeable judgements. As a result, this study will enable the researcher to tackle difficult problems and make more informed decisions.

1.6 Delimitations of the study

Cost, it require investment in hardware for example sensors they are quite pricey, software and technical support can be expensive for small farmers. Technical expertise, IoT systems requires technical knowledge and skills in both installing the system and understanding the data collected to make informed decisions. Power and connectivity, also require and rely on reliable power sources and internet connectivity so in remote or underserved areas, reliable internet connectivity may not be available, which disrupts the function of the system.

1.6.1 Time period

This study is delimited to a period of between 2015 up to 2023. This is the period when most farmers have been adopting latest technologies in their operation.

1.6.2 Targeted population

Farmers in Zimbabwe which owns large chicken farms shall be the targeted population of this study.

1.6.3 Nature of data (Quali or Quants or mixed)

This study adopted the use of both quantitative and qualitative study. This data for this study was mixed that is both qualitative and quantitative. This enabled the researcher to explore diverse perspectives on formulating a model aimed to monitor poultry in Zimbabwe.

1.6.4 Geographical area

The study focus was not on the entire Zimbabwe, but selected farms in Zimbabwe. The choice of selecting only few farms in Zimbabwe was centered on the fact that they are the ones which make informed decisions in regards to the use of the developed model.

1.7 Limitations of the study

Due to time and resource constraints, focuses on a very small case study investigated over a short period of time. This means that generalizability to a larger population could be problematic. However, since it is a qualitative study which seeks to understand realities of formulating a model aimed to monitor chickens enviroment in Zimbabwe hence generalizability would not be the goal of the study.

1.8 Definition of key terms

IOT, is a network of interconnected physical devices, sensors, and software that enables communication and data exchange, allowing for real time monitoring and automation of various processes.

Machine learning: a branch of artificial intelligence that enables systems to automatically learn and improve from experience, without being explicitly programmed.

1.8.1 Machine learning

Krizhevsky et al (2017) machine learning is the process of identifying relevant data patterns through the use of algorithms in an automated manner. Nwokolo et al (2022) noted that the field of machine learning focuses on development of methods that can process and convert data into intelligence that can be put to use.

1.8.2 Internet of things

The IoT can be thought of as a network of interconnected devices that communicate with one another through the use of the internet (Belkhiria, 2020). In addition to making farming more efficient, it enables farmers to take better care of their livestock. Through the use of IoT it is possible to identify sick birds, monitor their food, assess the conditions of their home, and keep a record.

1.8.3 Algorithms

An algorithm relates to mathematical which are used in learning or uncovering underlying patterns embedded in the data (Watson, 2019).

1.8.4 Data set

In the field of machine learning, a dataset is, in its most basic form, a collection of individual data points that may be processed by a computer as a single entity for the purposes of analysis and prediction (Azzeh et al., 2018). This indicates that the data that is collected ought to be standardized and made comprehensible for a machine, as machines do not see data in the same way that humans do.

1.9 Organization of the study

Chapter 1 of this study provided an introductory chapter which outlines the background of the study, statement of the problem, research objectives and questionnaires, significance of the study to various stakeholders and definition of key terms used.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

In this study the purpose of literature review is to demonstrate the researcher's expertise and comprehension of the academic literature on a particular subject by placing it in context. A critical analysis of the material is also included in a literature review. This chapter shall be guided by research objectives such as designing the model aimed at monitoring temperature, humidity and water levels in poultry farming, developing an application or software which can be linked on a mobile device to monitor chicken activity and evaluating the performance of the developed model focusing on its accuracy, predictive power and reliability using data from farmers. Theoretical and empirical literature shall also be outlined in this study.

2.1 Internet of things

Alizadehsani et al (2022) IoT is a relatively new technology that is gaining widespread awareness and acceptance in a variety of industries because of its practical usefulness in the enhancement of day-to-day living. The IoT is a network of physical things, gadgets, vehicles, buildings, and other items that are integrated with electronics, software, sensors, and network connectivity (Boonsong et al., 2017). This connectivity enables these objects to collect and share data (Barot, Kapadia & Pandya, 2020). It is a network of physical objects. It makes it possible for items to be sensed and controlled remotely across existing network infrastructure (Choukidar & Dawande, 2017). This opens the door to prospects for more direct integration between the physical world and computer-based systems, which ultimately leads to improvements in efficiency, accuracy, and economic value. As an illustration the developed model, anything that is able to recognize, connect, and communicate with other objects is considered to be an example of the IoT (Chung, 2021). This kind of farming, which is also known as precision farming, makes use of data analysis to customize activities in order to maximize agricultural output based on changeable inputs. When considering the fact that as much as 6 % of water that is pumped or diverted for irrigation is wasted, these methods may make it possible to realize large prospects for cost savings.

Wortmann and Flüchter (2015), the IoT) can alternatively be defined as a network of networked devices and systems that are made for the goal of collecting and sharing data. In order to connect products and systems to each other and the internet, it utilizes wireless networks that are embedded with a variety of data collection sensors. This allows for minimal human contact, as stated by García et al (2020). Previously, the transfer of data was restricted to portable electronic gadgets and computing devices. What is known as the IoT is a relatively new notion that has emerged within the realm of computer telecommunications. Therefore, it is an extension of computer network engineering. It results in a significant increase in the number of smart devices, systems, and appliances that are connected to the internet (Palattella, 2015).

A poll conducted by the Global System for Mobile Communications (GSMA) in 2014, the total number of linked devices around the globe is expected to reach 25.5 billion by the year 2020. It is anticipated that the total number of linked devices around the globe will reach 28.5 billion by the year 2020, something that is supported by Cisco's Internet of things Connectivity report, which also supports the widespread adoption of IoT technology. By the year 2020, the average broadband internet speed is projected to reach somewhere between 11.7 and 28 megabits per second, (Emear et al., 2018).

2.1.1 Hardware Infrastructure

The Internet of things hardware consists of a collection of physical components that are responsive in nature and have the capability to collect data from the environment from which they are located. The products that are now available on the market include sensors, switches, routers, and single-board processors like Arduino and Raspberry Pi. These products are available in a broad variety. A sensor is the most important piece of hardware that lies at the heart of the systems.

Serpanos and Wolf 2017, sensors are devices that generate electrical pulses based on a physical condition. These devices are made up of modules that contain power, radio frequency, and energy. The basic objective of the sensor is to collect electronic signals from the devices that are being monitored and then transform those signals into pulses that can be utilised by a computer system. The moisture content, pressure, humidity, speed, vibration, and temperature are typically included in the data that is collected by sensor hardware. Generally speaking, irrigation sensors are quite pricey, which makes them prohibitive for communal irrigation on a smaller scale. On the other hand, manufacturers are working on developing new sensors that are inexpensive.

These devices are the ones that are accountable for transforming the data that is provided by sensors into a form that is more meaningful.

Traditional networking infrastructure will include connectivity equipment including hubs, routers, modems, and wired and wireless technologies. These devices will be used to link device Serpanos and Wolf 2017. These devices are responsible for performing fundamental dedicated functions in order to offer access to network services. Determine whether the existing state of network infrastructure is adequate to handle the load that is generated by billions of devices that need to exchange data. This is an extremely important question to answer. In general, wireless networking technologies are capable of delivering between 300 megabits per second and about 1 gigabit per second, whereas fibre optic connectivity is capable of delivering up to 100 gigabits per second (GSMA, 2014).

García (2020), the cost of sensors has been steadily falling throughout the course of the coming years.

On the other hand, a reduction in the cost of sensors might result in a reduction in the quality, performance, and dependability of the sensor. Abba et al (2019), previous experimental research have demonstrated that when determining the performance of a sensor in relation to its cost, it is necessary to take into consideration a number of different aspects. Variables like as setup settings, calibration settings, application usage, and deployment characteristics are other important factors that play a vital part in influencing the performance of a sensor. The data processing devices or modules constitute the next group of devices that need to be taken into consideration.

When it comes to Internet of things systems, the most popular processing devices are ESP 8266, Arduino and Raspberry Pi. The processing devices in question are stripped-down versions of computer processing systems that are capable of carrying out fundamental processing activities that are capable of being carried out by a computer. Nandhini et al (2017), the widespread acceptance of these two processing modules in IoT systems may be partly ascribed to the fact that they are inexpensive, open source, comprise a straightforward programming platform, and have the capability to be extended. Marso and Macko (2019) carried out a comprehensive literature review study on the topic of prototype solutions that made use of Raspberry Pi. The survey was conducted with the primary objective of determining whether or not ESP 8266 can be useful. Based on the results of the survey, it was found that the majority of scientists and engineers prefer to use ESP 8266 for the creation of prototypes. The primary reason given for this preference was the price in comparison to the performance of the device. In conclusion, the infrastructure of communication networks is an essential necessity for the successful implementation of Internet of systems.

2.1.2 IoT systems architecture

The architecture can be thought of as a system that can be either physical or virtual, or a combination of the two. This system is comprised of a collection of active physical devices, sensor actuators, and cloud services that are tailored to accommodate Internet of things protocols. However, despite the fact that there are many different implementations of the system, the fundamental architecture and principles of information processing have not changed. Even though the IOT is still a relatively new concept in the world of technology, it is still working to develop its own reference architecture model.

It is not reaching its full potential since there is not yet universal defector architecture for the Internet of things. Porter and Heppelmann (2014), the architecture will help in providing a set of design guidelines for device makers, which will promote interoperability, particularly for legacy devices and systems. When attempting to conceptualize how the various components of an Internet of things-based poultry farming system communicate with one another, having architecture in mind is significantly helpful. When it comes to the construction and functionality of a system, a model serves as a blueprint. Nevertheless, it is often suggested that architectural frameworks could impede practical use on a variety of circumstances due to the fact that they are frequently broad, complex, and include an excessive amount of theoretical considerations (Kumar and Mallick, 2018).

2.1.2.1 Three Layer IoT Architecture

In spite of the fact that there is no agreement on a single design that is universally approved. During the early stages of development, the three-layer design was first implemented. In terms of simplicity, convenience, and ease of comprehension, it is regarded as the most fundamental. The well-known Transmission Control Protocol / Internet Protocol (TCP/IP) architecture model, which also makes use of the layered method, served as a source of inspiration for the development of the layered approach (Kumar and Mallick 2018). The Transmission Control Protocol/Internet Protocol (TCP/IP) is composed of four levels, each of which specifies a family of protocols that collaborate with one another. In the architecture, the three levels that are proposed are the perception layer, the network layer, and the application layer. It has been stated by Kumar Mallick 2018 that the following characteristics are possessed by these layers:

1) In the TCP/IP architecture model, the network access layer is precisely the same thing as the perception layer. The document outlines the devices and sensors that are used to collect information about the environment in which smart objects are situated. Following the transmission of the data acquired at this layer, it will be sent to the subsequent middleware layer, where it will be stored and processed using data analytics techniques (Muccini and Moghaddam, 2018).

2) The Network layer is the one that is accountable for providing connectivity to the internet works with other intelligent devices. Al-Qaseemi et al (2016), this layer is referred to as the transmission layer rather than the Network layer by other researchers. Due to the fact that it serves as a bridge between the perception layer and the application layer, this layer receives a significant amount of research focus. As a result, it is sensitive to interoperability difficulties as well as basic security vulnerabilities.

3) Application Layer is responsible for determining how application-specific services are supposed to be provided to the end user (Muccini and Moghaddam, 2018). Explains the applications that has the potential to be available. In this particular scenario, the end users consist of many systems, including but not limited to automated health care services, smart cities, and smart irrigation systems. When it comes to sustaining the IoT, basic elements that enable interoperability and integration of smart devices and systems begin with the three-layer architecture that underpins the IoT. That being said, Kumar Mallick 2018 claimed that it is not sufficient to explain the nitty-gritty details of the deployment of the systems. As a result, more research suggested increasing the number of levels in the design to incorporate the processing, business, and support layers in order to develop the four and five layer architecture.

The processing layer is the backbone of the traditional architecture of the Internet of things. This layer is primarily accountable for the collection of data that is produced by the layers below it, and it is also responsible for transforming the data into information that is usable for data analytics. Database management systems, network communications systems, and information process management are some of the supporting technologies that are utilised by this layer.

End users are able to manage and control the functionality of the systems thanks to the services that are provided by the Business Layer. It goes on to define business and profit models that are utilised in the construction of the systems.

Layers of Support to address the security risks that are widespread on the internet, the support layer was added to the three-layer architecture for the sole purpose of providing protection against these threats. Authentication and the secure movement of data between the three layers of the Internet of things architecture are two of the important security functions that are recommended to be addressed by the support layer. Al-Qaseemi et al (2016), authentication is an essential component of IoT systems by virtue of the fact that it permits safe access to resources such as data, hardware, and applications. In order to protect against typical network risks, the support layer's second job is to guarantee the secure delivery of data. In particular, it is responsible for preventing denial of service assaults. The term denial of service (DoS) assault is an attack that is aimed at preventing systems from functioning properly.

2.2 Theoretical framework

Theories and concepts that were adopted in the development of an Internet of things framework for monitoring poultry housing are, System theories, that views the type of farming as a complex system consisting of interconnected elements, it monitors these elements to optimize the overall functioning of the system. Data driven decision making was also a theory adopted which underpins the value of IoT by collecting and analyzing data from various sensors, farmers will make informed decisions to improve farm productivity and bird welfare. Machine learning and artificial intelligence, these are technologies that can be integrated into the developed model to improve data analysis, also to identify patterns and trends, and support predictive modeling.

2.2.1 Machine learning theory/ computational learning theory

Samuel 1952 established the theory of machine learning with the purpose of comprehending mathematical models on a precise level. In addition, he developed the model with the purpose of gaining an understanding of the fundamental algorithmic principles involved in getting computers to learn from data and improve their performance with feedback. This was done with the intention of comprehending what capabilities and information would be fundamentally required in order for computers to successfully learn various types of tasks. In addition to shedding light on fundamental issues that are present within the learning process itself, the purpose of this theory is to provide assistance in the development of superior automated learning systems. The study of the creation and analysis of machine learning algorithms is the primary emphasis of this subfield of artificial intelligence (AI), which is essentially a subfield of AI. The principle of machine learning is illustrated in the figure1.

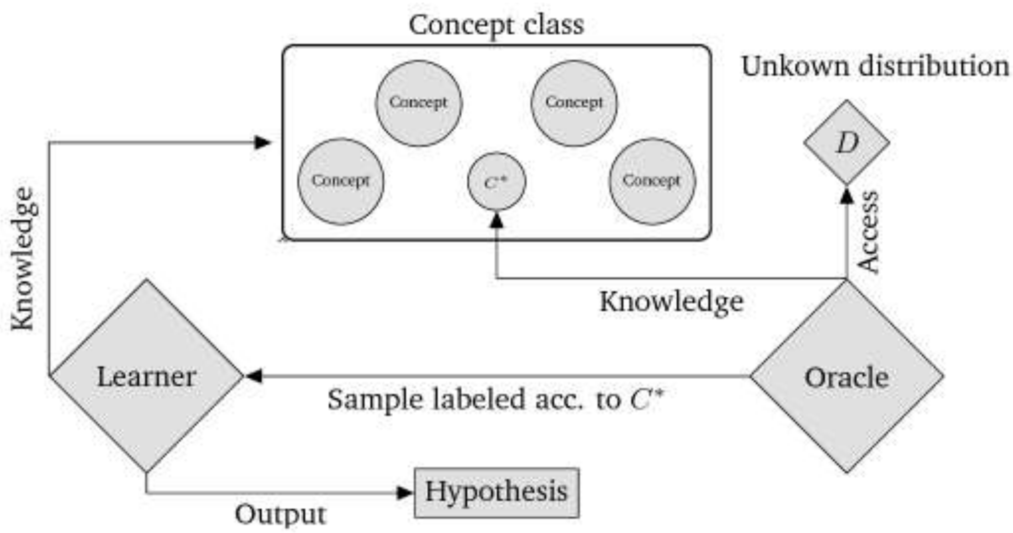

Figure 1: Machine learning theory

Source: Samuel (1952)

This theory is more relevant to this study because this is due to the fact that he observed that the creation of mathematical models that capture essential characteristics of machine learning and the provision of an environment can assess the underlying ease or complexity of a variety of learning challenges and issues that affect organisations. In addition to demonstrating that algorithms have specific guarantees (under what circumstances will they be successful, how much data and processing time is necessary), the development of machine learning algorithms that can demonstrably meet given criteria while also demonstrating that they have certain guarantees.

2.2.2 Technology acceptance model

The technology acceptance model was proposed by Davis around the year 1989. The Technology Acceptance Model, often known as TAM, is comprised of two criteria that influence whether or not a computer system will be accepted by its potential users. These criteria are as follows: (1) the perceived usefulness of the system, and (2) the perceived simplicity of using the system. The significance of both of these aspects cannot be overstated. One of the most distinguishing features of this strategy is that it focuses a significant amount of importance on the viewpoints of individuals who may perhaps make use of it in the future. That is to say, even if the person who is responsible for the development of a certain piece of technology is under the impression that the product is advantageous to customers and simple to use, the product will not be accepted by other people who would use it if they are not under the same impression. An illustration of the technology acceptance model may be found in Figure 2

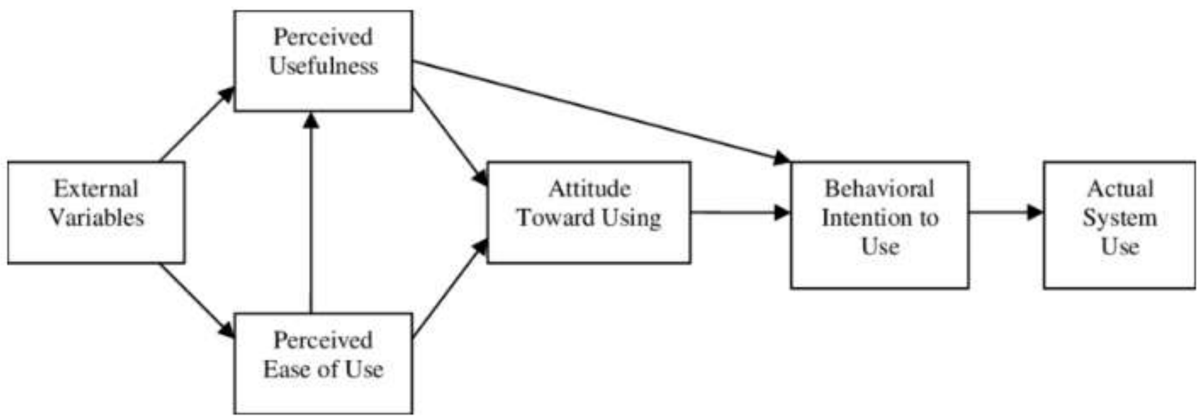

Figure 2: Technology acceptance model

Source: Davis (1989)

One may deduce from the preceding figure 2 that the intention to adopt a model or system is influenced by the perceived usefulness of the model or system as well as the perceived convenience of using the model or system. It is possible that this will bring to a particular attitude towards that particular sort of technology, which may then lead to a behavioural intention to use as well as adoption rates. In this particular instance, farmers who are interested in adopting or developing an Internet of things framework are required to take into consideration the perceived value of the framework as well as its perceived ease of use, both of which can ultimately lead to its actual application.

2.2.3 Diffusion of innovation theory

Rogers (1962) is the one who first conceived and developed the Diffusion of Innovation (DOI) hypothesis, which is considered to be one of the oldest theories in the field of information technology. Initially, it was utilised in the field of communication to provide an explanation for how, over the course of time, a concept or product accumulates momentum and diffuses (or spreads) throughout a specific population or social system. The dissemination of knowledge ultimately results in individuals, as members of a social system, embracing a new concept, behaviour, or product (Davis, 1989). This is the ultimate outcome of the transmission of information. Azzeh et al (2018), a person or organisation is considered to have adopted something when they move away from the practices that they had been using in the past and begin to implement new practices. It is necessary for the individual to initially see the concept, behaviour, or product in question as being unique or pioneering in order for them to accept what is being discussed. Due to this, the prospect of diffusion being able to take place is made possible. The diffusion of innovation theory is illustrated in the following figure 3.

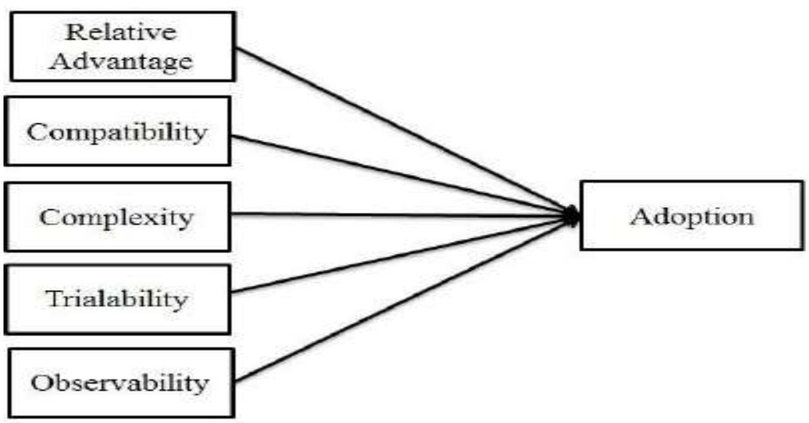

Figure 3: Diffusion of innovation theory

Source: (Miller, 2018)

An organisation or individuals decide to adopt the most recent technology or design a new model, they have the capacity to take into consideration a variety of aspects, including relative advantage, compatibility, complexity, trialability, and observability. The process by which some individuals or businesses are more likely to accept a new idea, mode of behaviour, or product is also referred to as innovation. This process does not take place instantly within a social system; rather, it is a process by which some individuals are more likely to adopt the innovation than others. Researchers have found that people who adopt a new technology at an earlier stage have a distinct collection of characteristics in comparison to those who acquire a technology at a later level (Hussain et al., 2020). This is especially true for those who embrace a technology at an earlier stage. Schultz et al (2021), it is essential to have a strong understanding of the characteristics of the target audience in order to successfully convince a certain set of people to embrace a new invention. It is also essential to have an awareness of how those characteristics would either help or hinder the adoption of the innovation

2.3 Designing of a model aimed at monitoring temperature, humidity and water levels in poultry farming

The farms of many poultry farmers are staffed with people who do a wide range of physical labour jobs. The fact that they are unable to fully automate the track of and management of environmental variables such as temperature, humidity, light, and air quality, as well as to guarantee a sufficient supply of feed and water, is the primary reason for the enormous loss that they experience (Du et al., 2017). There is a detrimental influence on the chicks as a result of these variables, and if they are not regulated, the chicks may face health problems. As a consequence of this, the infants take less food, which leads to a rise in their mortality rate and makes them more susceptible to experiencing illness (Janczak & Riber, 2015).

Within the scope of this research, an embedded poultry farm will be developed in order to support the automation of those factors. The system will have the ability to detect changes in environmental parameters and respond properly in order to keep the environment in which the chicks are kept in a state that is optimal for their health. Both the production of the poultry farm and the climate conditions are increased as a result of the automated system, which is beneficial for the broiler chicks (Lavric & Popa, 2017). In addition to being difficult to employ in huge parallel computing, it is also complex to install and manage. It is essential to consider environmental parameters such as temperature, humidity, air quality, and illumination while attempting to maintain and expand chicken production. For a large chicken farm, especially one that is operated in the traditional style, it is absolutely necessary to keep a close eye on all of the environmental conditions (Mazunga et al., 2023). Recently, the IoT and block chain technology have been utilised to autonomously monitor and direct the farm. Both the management of chicken farms and the costs associated with them have been found to be improved by this. The researcher will begin, temperature data are saved in the JSON format and monitored with sensors that are based on the IoT for both temperature and humidity. It will be determined that the data was successfully transmitted to the IoT block chain during the process.

2.4 Empirical studies

Mochid et al (2024) conducted a study on applications of IoT and sensors technology to increase food security and agricultural sustainability: Benefits and challenges. Agriculture is facing an increasing number of challenges that must be overcome in order to feed a growing population while also protecting the environment and the natural resources that are available. In recent times, it has been abundantly evident that sensors and the IoT are powerful instruments that may be utilised to enhance agricultural sustainability and food security simultaneously. The findings of Mochid et al (2024) study offer some insights into the size of the worldwide market for smart agriculture in the years 2021 to 2030 across the globe. In addition, this study presented four levels of the architecture for smart agriculture. These layers include the perception or sensing and actuator layer, the network layer, the cloud layer, and the application layer. A study examined the current state of the art in IoT and sensor technologies for agriculture, as well as some of the potential applications of these technologies. These applications include the following: 1) irrigation monitoring systems; 2) fertilizer administration; 3) crop disease detection; 4) monitoring yield, quality monitoring, processing monitoring, logistic monitoring), forecasting, and harvesting; 5) monitoring climate conditions; and 6) fire detection. In addition, this evaluation provides a selection of agricultural sensors that are capable of detecting a variety of factors, including soil NPK, moisture, nitrate, pH, electrical conductivity, CO2, temperature, humidity, light, weather station, water level, livestock, plant disease, smoke, flame, and flexible wearables. As a result, a study demonstrated the benefits of IoT in smart agriculture, which include increased efficiency, expansion, decreased resources, a cleaner method, increased agility, and improved product quality. In spite of this, there are still problems that need to be solved before technology utilize it in agriculture.

Implementation of IoT technologies in Agriculture, due to the fact that a large number of commercial enterprises have made the decision to implement IoT technologies, it is frequently startling to observe that even company sectors that are regarded to be well-established, such as the agricultural industry, are also adopting these technologies. One of the primary objectives of this study project is to ascertain whether or not Internet of things technologies are, in fact, a resource that adds value to the agricultural industry. In order to better assimilate with the technology that is involved with two primary agribusiness sectors, namely crop cultivation and livestock rearing, the literature that is being analyzed in this study focuses on the differences between these two sectors as well as the various technologies that have been developed for these sectors.

Some examples of these technologies include cloud computing, sensors and actuators, drones, and automated machinery. It was necessary to conduct research in order to be able to collect pertinent data that may provide a response to the primary research question. This was necessary since the objectives revolve around establishing whether or not this aim is fulfilled in the agriculture sector of the local Maltese economy. A research was conducted by conducting a series of interviews with various members of the Maltese agricultural workforce, with participants coming from a wide range of backgrounds. These individuals included fieldworkers, IT experts, and even farming supporters. Throughout the course of the interviews, the questions that were asked gave each participant the opportunity to share their ideas and opinions regarding the agricultural industry in Malta, as well as their thoughts regarding whether or not Internet of Things technology can be considered a viable modern farming tool in Malta.

Despite the fact that the technology in agriculture is still mostly considered to be either a conceptual tool or a basis for a pilot project in Malta at the time of this writing, there is interest from every participant that was interviewed, despite the fact that some reservations were also stated across the board. The advantages that the technology possesses, such as its automation features, variable rate technology that enables farmers and ranchers to apply different materials on the field at different rates, and remote track of capabilities, were the reason why those who felt more strongly about the implementation of the technology in Malta's agricultural sector felt more strongly about it. Other participants, on the other hand, voiced their concern regarding the financial commitment and technical knowledge that is necessary in order to be able to successfully utilise such instruments to their fullest potential. After analyzing the findings, it was ultimately determined that Malta needs to enhance their IoT implementations in order to catch up with new technologies.

CHAPTER 3: RESEARCH METHODOLODY

3.1 Introduction

Corbin and Strauss (2018) defined research methodology as the different ways in which a researcher might think about and investigate a subject that they find fascinating. Research methodology, as defined by Crotty (2017), can be thought of as an action plan, a strategy, or a design that serves as the foundation for selecting and employing a particular approach in order to reach the desired conclusion. One can understand a research methodology by considering the research philosophy, research strategy, research design, targeted population, sample size, and sampling methods. These ideas are connected to one another and are dependent on being related to one another. Within the scope of this chapter, the key focuses are on the research philosophy, research strategy, research design, data analysis, and ethical considerations that are relevant to the study.

3.2 Research philosophy

Kothari (2015), a research philosophy is a collection of beliefs concerning the right techniques for data collection, analysis, and application in the context of the study of a specific issue. It has been suggested by Galliers (2020) that there are two prevalent ideas that are representative of the several ideologies that are associated with research methods. Epistemology, which is the study of what is true, and doxology, which is the study of what individuals believe to be true, are the terms that are being discussed here. It is possible to locate both of these concepts inside the descriptions of the numerous ideologies that are utilised in research methodologies. In accordance Levin (2018), positivists are individuals who subscribe to the belief that reality is observable and can be explained in an objective manner without the necessity of having direct experience with the phenomena that is the subject of the study. People who subscribe to the positivist philosophy are those who hold the belief that the realities that have been seen in the past may be employed to provide forecasts for the future.

Positivists are of the opinion that reality is unchanging and that it is possible to observe and describe it from an objective standpoint Levin (2018). This means that one must refrain from influencing the phenomena that are being researched in order to maintain the positivist perspective. Those who subscribe to the positivist philosophy believe that phenomena should be distinguished from one another and that observations should be able to be replicated. They also believe that it is feasible to make predictions by basing those forecasts on facts that have been seen and described in the past, as well as the interrelationships that exist between those realities. When it comes to making predictions regarding the results of experiments, the positivist methodology is one that is scientific, quantitative, and objective. It also makes use of statistics. This study corresponds to the positivist ideology that supports that approach since it relies on scientific methods to make predictions regarding the formulation of a model that is intended to monitor chickens housing in Zimbabwe.

3.3 Research strategy

The experiment technique, which involved gathering data on temperature, humidity and water levels using sensors installed in the poultry housing. This data was transmitted wirelessly to a central server for analysis and storage. A mobile application Blynk that was developed to receive data from the server and present it in a user friendly format, allowing farmers to monitor their coops in real time and receive alerts if any parameters fall outside of acceptable ranges.

3.4 Research design

A research design refers to a blueprint for gathering, measuring, and analyzing data (Borg, 2015). In this study a research design refers to the overarching method the researcher shall use to integrate the study components in a consistent and logical manner. A research design is a framework for gathering and analyzing data; it provides responses to issues regarding who, what, and where of a study (Du Plooy, 2017). Cuthill (2020), a research design is an overarching approach that ties together the many different aspects of the research in a fashion that is consistent and makes sense. A research design is like a plan that lays out how the data will be collected, measured, and analyzed. It guarantees that the research problem will be tackled in an efficient manner. A research design makes certain that the evidence gathered from the research will answer the research topic in a manner that is open to interpretation. The CRISP-DM approach, which stands for Cross Industry Standard Process for Data Mining, was utilised for this study. Shearer (2020) the technique offers a well-organized and well-structured framework for carrying out data mining activities. Wirth and Hipp (2020), the CRISP-DM methodology delivers a comprehensive summary of the project life cycle for data mining initiatives. Martinez-Plumed, Contreras-Ochando, Ferri, and Orallo (2019), CRISP-DM is currently considered to be the de facto standard for data mining and knowledge discovery. Chapman, Clinton, Kerber, Khabaza, Reinartz, and Shearer (2020) were the ones that came up with the idea for the CRISP-DM model. The CRISP-DM project was a collaborative effort between three different companies with an interest in the data mining business. SPSS, NCR, and DaimlerChrysler were the original companies that participated in the collaboration. Knowledge discovery in databases, or KDD, is an approach to data mining that is more general in nature (Fayyad, 2016). The CRISP-DM model is an offshoot of this more general method.

3.5 Data understanding

The phases of initial data capture, data description, data exploration, and data quality verification make up the components of data comprehension. During this phase, data is gathered and investigated so that the links between attributes may be studied, and so that any problems with the data's quality, such as missing numbers or outliers, can be found and addressed. To address the quality concerns that have been uncovered, a strategy is devised. In addition, the strategies for data selection and data pre-processing are investigated and then ultimately put into practice during the phase of data preparation. CRISP DM life cycle model, it is possible to turn back the clock to the business understanding phase and perform reviews on the goals as well as some of the business needs (Chapman et al., 1999). Despite the fact that the data exploration step is designed for this phase, it is now possible to perform data exploration during the business understanding phase because to advancements in technology. Utilising exploration techniques at an early stage allows for the early discovery of potential data concerns as well as the provision of insights regarding the data Shearer (2020). The datasets that were utilised in this research study are going to be discussed in the next part.

3.6 Data acquisition

One of the challenging tasks in EDM is acquisition and integration of data which is scattered across multiple distributed systems in various data formats (Romero & Ventura, 2016). This study is based on one main datasets.

3.6.1 Software development

Figure 4 shows the implementation model

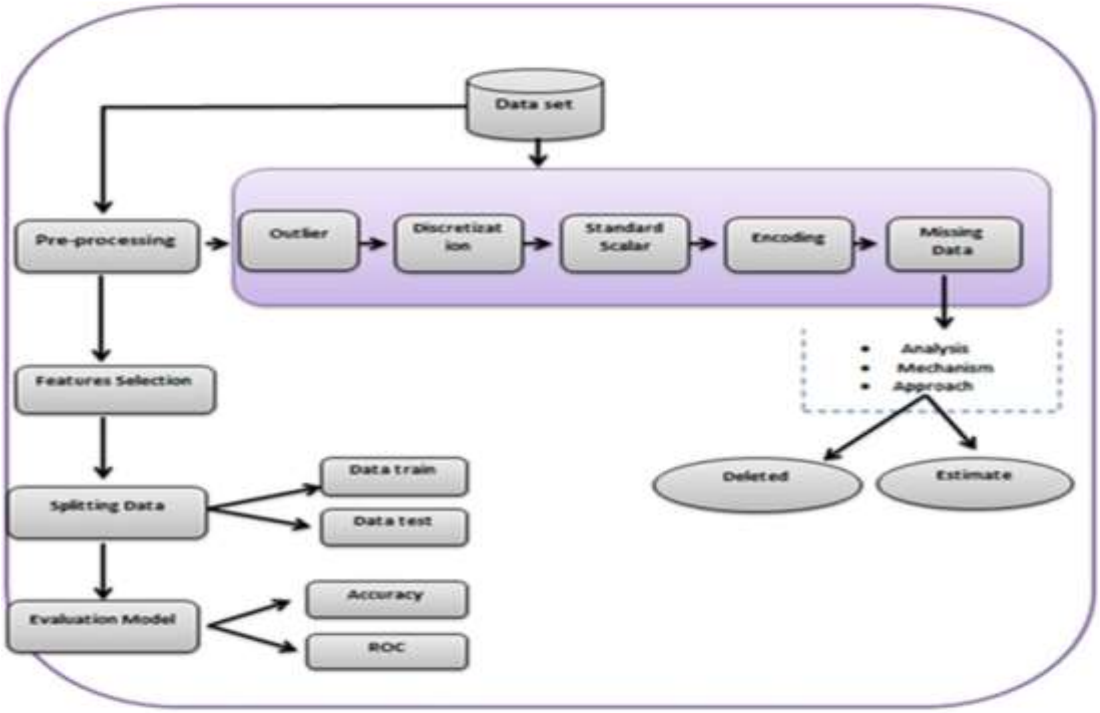

Figure 4: Overall structure of the proposed model

In this research, the researcher will design a model to predict liquidity coverage ration by applying Techniques (MLT) based on the Loans, deposits, and securities shown in figure 3.1 above. phase to prepare the proposed model consists of (1) Data collection phase, (2) Data preprocessing of the data before applying the MLT, (3) data splitting into data training and data testing, (4) Selection of classification models, (5) evaluation phase to evaluate the accuracy of the built model using a technique.

3.7 Internet of Things system analysis

Needs Assessment: there are specific needs and challenges in poultry farming that the developed model should address such as the track of environmental conditions that birds experience in the coop that affects productivity such as temperature and humidity. These parameters should be kept at their moderate levels which are favorable to chickens.

Stakeholder analysis: farmers, farm managers, technology providers and other regulatory bodies should understand their roles, interests and expectations related to IoT systems in order for the systems to deliver its designed solutions.

Prototyping and Testing

Deployment and maintenance

3.7.1 Existing system

Traditional methods of chicken production are utilised by the majority of business people and farmers. Manual, more complicated, and more expensive are the characteristics of the existing systems. Temperature and humidity readings are not very accurate in their measurements. The current systems are relatively inefficient and prone to errors in their operation. More than that, the cost of maintenance is quite reasonable. Inaccurate readings of temperature and humidity have the potential to influence the atmosphere of the coop. The way in which the door is opened and closed in accordance with the current arrangement between the hours of dawn and nightfall presents a significant threat to the hens.

The automated closure and opening of the chicken coop at dawn and dusk can put the hens' lives in jeopardy. This is due to the fact that the primary objective of the automated chicken coop should be to monitor and manage the chickens in order to make sure that they are protected from predators such as snakes and foxes. The data that has been analyzed cannot be stored in a secure manner for the time being. Due to the fact that the user interface is quite complicated, access to the system is restricted to only those who are authorized to do so. In addition to not being particularly user-friendly, the systems that are now in place are also not particularly ecologically friendly. Within the framework of the system, it does make use of manual labor. This system is associated with complexity, expensive and power outages.

3.7.2 Proposed system

Using the IoT concept, Poultry Pal creates a coop that is proof against predators. Because it does not have a latch, it is extremely difficult for predators to pry open. Considering that standard chicken coop doors are equipped with a latch, it is not difficult for certain predators to figure out how to unlock the latch and gain access to the coop. Consequently, our chicken companion is more effective in terms of ensuring the safety of the hens during their upbringing. In addition, the temperature, humidity, and water sensor are utilised in order to ensure the birds' continued good health. On the other hand, the monitoring of the data can be viewed and kept in the Bylnk application, and the user will be notified about the values in the application.

3.8 Requirements for the proposed IoT

Functional and non-functional requirements are the two categories that are used to classify the needs. Non-functional requirements are a description of the characteristics of the system that are necessary for its successful functioning, whereas functional requirements are a description of what the system should be able to perform in order to provide the service that the user has intended. As an illustration, non-functional requirements include things like availability, dependability, scalability, and security related concerns. While conducting this study, both primary and secondary sources were utilised in order to ascertain the needs for the proposed Internet of things-based system for monitoring environmental conditions in chicken houses, which was given the name ZIMBAKUKU. One of the primary sources consisted of conducting interviews with chicken farmers, during which they were given a description of the system's most important aspects and asked to score those features. Reading extracted information from documents, manuals, and other publications that could be retrieved was the secondary source. The functional and non-functional needs for ZIMBAKUKU are summarised below, once these procedures have been applied.

Proposed functional requirements for ZIMBAKUKU

- A farmer should be able to remotely monitor temperature, humidity, water levels using the system, and the system should provide both graphical and textual viewing options
- It is expected that the system would be able to function in an offline mode given that the client is located inside the Local Area Network (LAN) environment. It is very important to have a local server that can synchronise with an online server once the internet connection is restored. This is especially important in situations where there is no internet connection
- The mechanism ought to make it possible for a farmer to know whether there is need of ventilation in the coop through temperature detection.
- It should be possible for the user to enable automatic monitoring and control of the temperature and humidity within the system
- A farmer should be able to use the same dashboard to monitor and adjust the temperature and humidity parameters of multiple scattered coops
- Before allowing the farmer to use the system, the system ought to verify the farmer's identity
- The farmer should be able to observe the monthly trend of temperature, humidity and water levels in a graphical style (line graph) through the use of the system
- It is the responsibility of the system administrator to have the ability to create, suspend, or delete user accounts and accounts
- Any new nodes, also known as sensor units, should be able to be added to the system by the administrator

- Administrators should be able to examine the current state of all nodes in relation to their respective customers or farmers through the system
- Admin should have the ability to enable or disable any client's node for maintenance purposes within the system
- It is necessary for the system to provide the administrator with the ability to register new users or clients with the corresponding coops that they control
- It is recommended that the system be able to be powered by micro solar panels in order to provide cost-effective functionality

Proposed non-functional requirements for ZIMBAKUKU

- The mobile application should be able to run on the Android operating system, and the web system should be compatible with all existing browsers
- Availability of the application ought to be guaranteed at all times
- The system need to be simple to keep up with updates
- During the time that one service is being maintained, it should not interfere with the operation of existing services

3.9 The IoT system is made up hardware and software, which are separately defined below

Hardware

- ESP 8266
- Servo Motor
- Water level Sensor
- Piezo Electronic Buzzer
- Ultra sonic sensor
- Connecting Wires.
- LED
- LCD
- DHT11

3.10 Software

- Arduino IDE Version1.8.13
- Operating System Windows 11 and above (64bits)
- Bylnk application

3.10.1 List of modules

- Ultrasonic sensor for motion detection in the coop
- Opening and closing the coop using a servo motor
- DHT11 detects temperature and humidity in the coop
- Water level depth sensor identify the level of water in coop
- ESP 8266, a Wi-Fi micro controller.

3.10.2 Coop Open and close using a servo motor

There is a servo motor installed in the coop that is used on an angle of 90 ºC to open and close the coop. Any movement/ motion is detected by the ultrasonic sensor and impulses are send to the servo motor then the door will open and close automatically, and the user will be notified through their mobile device using the Blynk application. A servo motor is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for position feedback. It also requires a servo drive to complete the system, which uses the feedback sensor to precisely control the rotary position of the motor, Figure 5.

Figure 5: Servo motor

3.10.2 DHT11 detects the range of temperature and humidity

Both a sensor and a module version of the DHT11 humidity and temperature sensor are available for purchase. This particular sensor and module are distinguished from one another by the presence of a pull-up resistor and a power-on LED. DHT11 is a sensor that measures relative humidity and temperature. This particular sensor makes use of a thermistor and a capacitive humidity sensor in order to measure the air that is all around it. A capacitive humidity detecting element and a thermistor for temperature sensing are the two components that make up the DHT11 sensor respectively. A moisture-holding substrate serves as a dielectric between the two electrodes that make up the humidity sensor capacitor at the center of the device. There is a correlation between the fluctuation in humidity levels and the change in capacitance value. The IC is responsible for measuring, processing, and converting the resistance values that have changed into digital form. This sensor makes use of a Negative Temperature coefficient thermistor, which results in a decrease in its resistance value as the temperature rises. This thermistor is used for the purpose of sensing temperature. Semi-conductor ceramics or polymers are typically used in the construction of this sensor. This is done so that it can achieve a higher resistance value even for the slightest change in temperature. With a precision of 2 ºC , the DHT11 thermometer has a temperature range that extends from 0 to 50 ºC . This sensor has an accuracy of 5 % and can measure humidity anywhere from 20 to 80 percent. This particular sensor has a sampling rate of one hertz, which means that it provides a single reading for every second. Having an operational voltage that ranges from 3 to 5 volts, the DHT11 is a compact device. 2.5 mill amperes is the maximum current that can be utilised for measuring. Four pins make up the DHT11 sensor: a VCC pin, a GND pin, a data pin, and a pin that is not attached. In order to facilitate communication between the sensor and the micro-controller, a pull-up resistor with a range of 5k to 10k ohms is provided. One wire is all that is required for communication with DHT11. The logic one or logic zero on this pin is determined by the voltage levels that occur concurrently with a particular time value. There are three stages to the communication process: the first stage involves sending a request to the DHT11 sensor, and the second stage involves the sensor sending a response pulse, Figure 6.

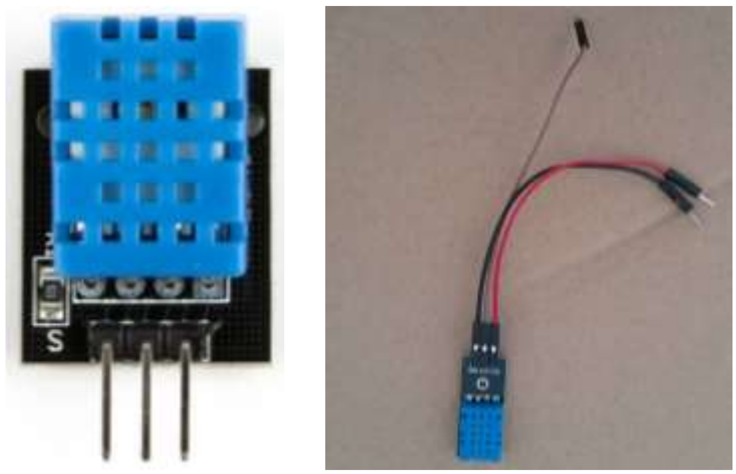

Figure 6: DHT11

3.10.3 Water level depth sensor identify the level of water in the coop

A supply of water is kept at the entrance of the chicken coop so that the chickens can drink it whenever they feel the need to. The user's mobile device will receive a notification from this water level sensor in the event that there is no water in the coop. This sensor will assist in sending the notification. Sensors that measure water levels are mostly employed for the purpose of monitoring and controlling the levels of a specific free-flowing liquid within a compartment. In most cases, these chemicals are liquid; however, level sensors can also be employed to monitor certain solids, hence powdered compounds are included in this category. There is a widespread application of level sensors in the industrial sector since level sensor is an essential monitoring indicator. It is simple to use and comes at a modest cost. In order to determine the water level, this water level sensor module is equipped with a number of parallel exposed traces that are specifically designed to monitor the volume of water droplets.

Due to the fact that the output of an analogue signal is directly proportional to the water level, monitoring the water level takes very little effort. This is a water level sensor that is of the probe kind. The single point probe sensor principle is the basic operating idea of this type. The majority of point probe sensors are either resistive or capacitive in structure. Constants of di electricity will be present in the sensor. After the sensor has been submerged in the liquid, they take measurements of the changes that occur in the capacitance value. This adjustment is in accordance with the variance in Level. It is possible to choose between two distinct kinds of sensors: one that has high dielectric constants and another that has low dielectric constants. This sensor is capable of functioning with a wide variety of samples, including solids, liquids, and mixed materials. In addition, these sensors are available in both contact and non-contact types of their sensors. One of the most crucial things to know is whether or not the sensor is compatible with all kinds of tanks or materials. Due to the fact that the dielectric constant changes, the sensor needs to be calibrated for the particular type of material, as well as for the design of the tank, Figure 7.

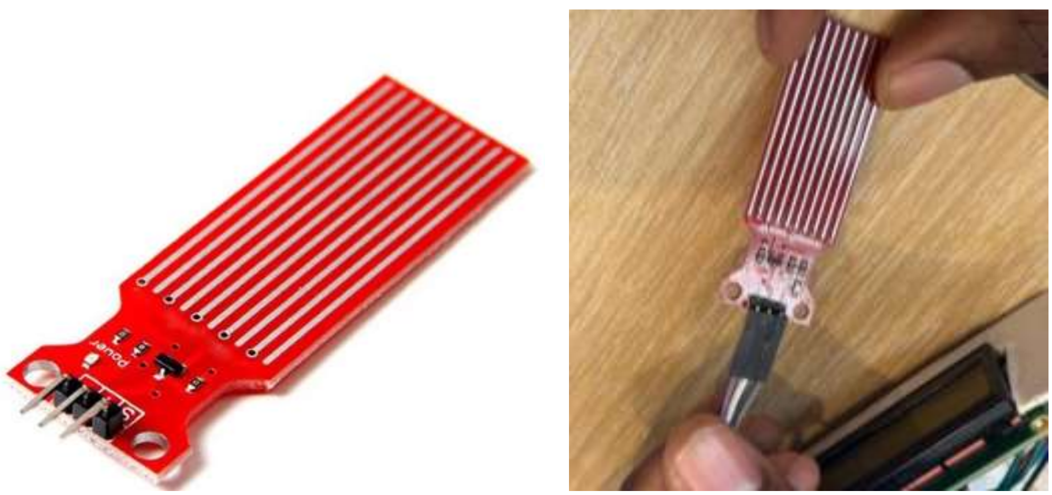

Figure 7: **Water level sensor**

3.10.2 System architecture

Figure 8 The system architecture

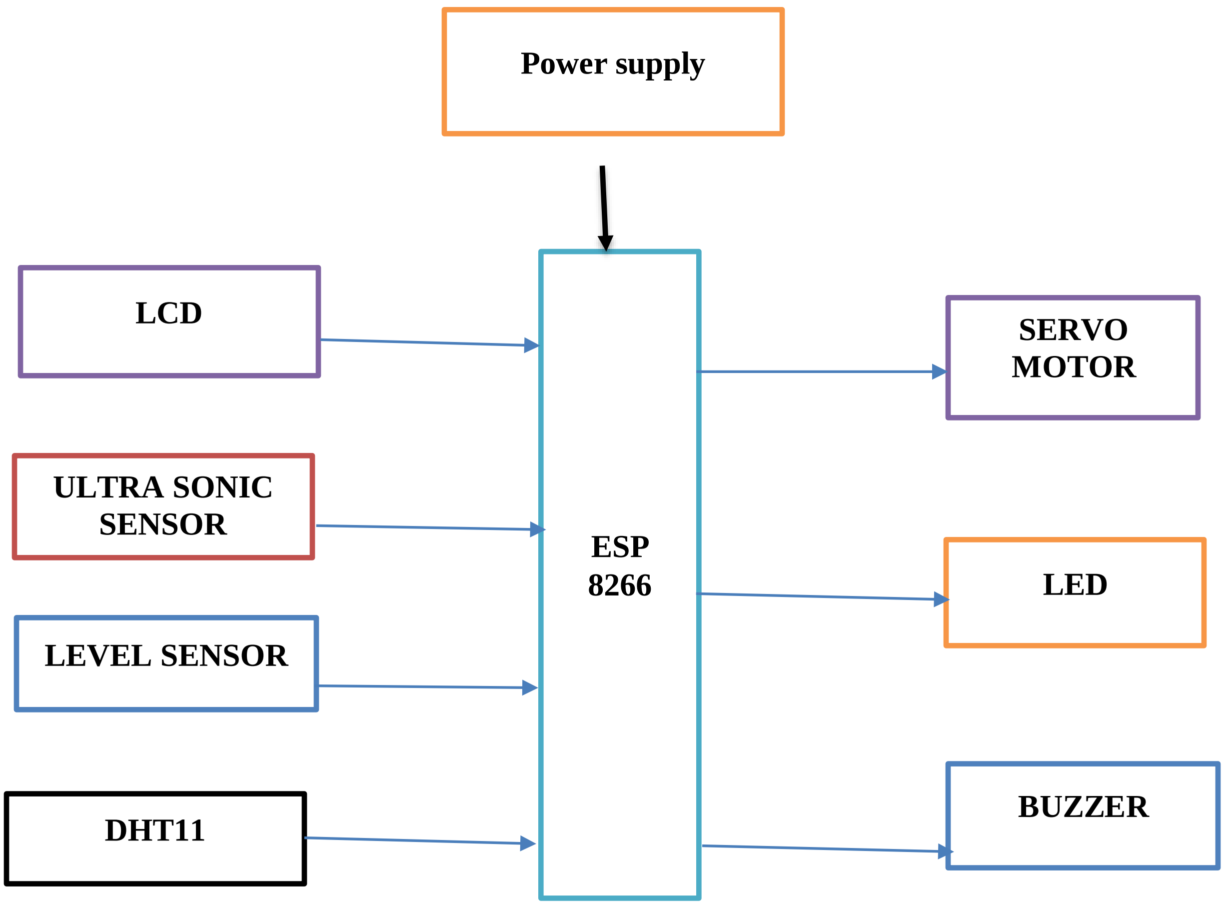

Figure 8: system architecture

3.11 Software Design

There is no strict procedure in mathematical modelling for reaching a solution by using the given information (Erbas et al. 2014:2). Salija, Bilandzic and Stanic (2017), model development considers variable inclusion and selection, logistic model assumptions, multicollinearity and interpretability of the model. In addition, assumptions of the model, multicollinearity and interpretability of the model will be catered for. Figure 9 shows the cyclic nature of research. The essence of mathematical modelling stems from the existence of two 4worlds in life, namely, the reality and mathematics as shown in Figure 9. Phenomena occurs in real life and results are observed. On the contrary, in the mathematics world, mathematical models are built and used, and their results observed/recorded. Man uses the modelling to understand real world phenomena. This is achieved through comparing results from mathematical models and real life model results.

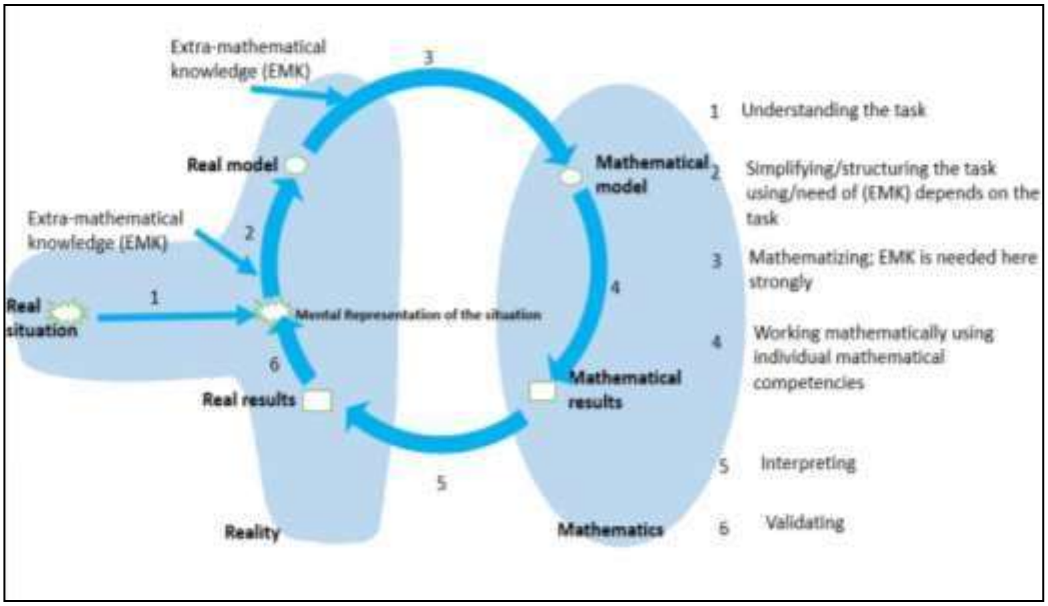

Figure 9: Bloom and LeiB Modelling Cycle

Source: (Ren et al., 2020)

Modelling is a non-linear process that includes five interrelated steps:

- Identifying and simplifying the real world.
- Building a mathematical model.
- Transform and solve the model.
- Interpret the model.
- Validate and use the model.

Steps shown in figure 10 shall be followed

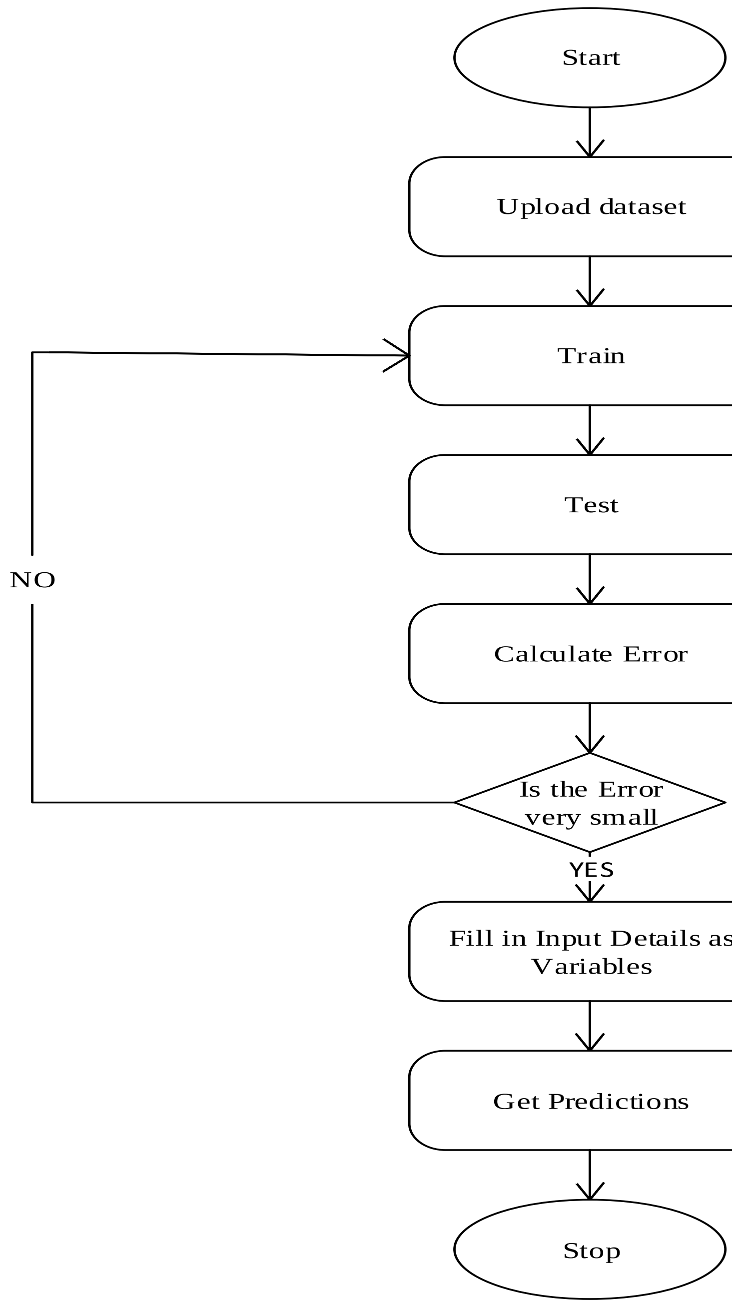

Figure 10: Activity diagram

3.11.1 Development of an application or software which can be linked on a mobile device to monitor poultry activity.

In poultry-related business (Layers), the poultry Care software will be developed to make day-to-day activities a great deal simpler and help the business become significantly more successful. A poultry farmer who raises chickens and eggs for the purpose of selling them, a trader who delivers poultry products to retailers, or a store who sells eggs or chickens can be assisted by this application. A well-managed application has is the primary focus of to provide it to renowned poultry customers. With the poultry Care App, a farmer will be able to better manage poultry farm's daily operations, including feeding, egg collecting, vaccine and medication administration, sales, and expenses. Through the use of this application, the farmer will also be able to manage flock of poultry. This application can assist the farmer in keeping track of the number of eggs that your chickens actually produce. Through the use of Poultry Care a farmer may also be able to simply calculate the amount of feed that is consumed by each bird, as well as the percentage of mortality, production, hen day production, and hen house production.

3.12 Evaluating performance of the developed model focusing on its accuracy, predictive power and reliability using data from farmers.

The majority of farmers and businesspeople still rely on the conventional ways of chicken rearing. Manual, more complicated, and more expensive are the characteristics of the existing systems. In terms of precision, the measurements of temperature and humidity are not entirely accurate. When compared to other systems, the existing ones are relatively inefficient and imprecise. More than that, the cost of maintenance is quite reasonable. Temperature and humidity data that are not correct have the potential to influence the atmosphere of the coop. Under the current technique, the chickens are put in a precarious situation because of the manner in which the door is opened and closed at dawn and nightfall.

The automated closure and opening of the chicken coop at dawn and dusk can put the hens' lives in jeopardy. This is due to the fact that the primary objective of the automated chicken coop should be to monitor and manage the chickens in order to protect them from potential predators such as rabbits and foxes. Currently available technology is not capable of storing the analysed data in a secure manner. Due to the fact that the user interface is somewhat difficult, any anyone who is authorised to use the system is required to do so. The existing systems are not particularly user-friendly, nor are they particularly ecologically friendly. Neither of these points is particularly true. Within the framework of the system, we make use of manual labour.

3.13 Ethics

Before data collection the researcher will seek permission from the university to carry out the research. During data collection, the main objective of the study along with ethical considerations, such as informed consent, anonymity and confidentiality, were explained in the introduction letter of the questionnaire. It was indicated in the introductory letter that participation is voluntary and that participants may withdraw from the study at any time. After data collection presented the data as it was and the collected data was solely used for academic research purposes.

3.14 Validity

When developing and testing any instrument, such as a content assessment test or questionnaire, for use in a research study, validity and reliability are two crucial variables to keep in mind as you go through the process. Paying attention to these factors helps to ensure the quality of the measurement that you take as well as the data that is collected for the study. The degree to which an instrument measures precisely what it is designed to measure is referred to as its validity (Gill & Johnson, 2017). Validity can be broken down into several categories, the most popular of which are content, construct, and criteria validities, which are all considered by researchers and evaluators. On the other hand, reliability describes the degree to which an instrument produces the same results time and time again (Gill & Johnson, 2017).

CHAPTER 4: RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter intends to present findings in relation to designing the model aimed at monitoring temperature, humidity and water levels in poultry farming, developing an application or software which can be linked on a mobile device to monitor conditions in poultry houses and evaluating the performance of the developed model focusing on its accuracy, predictive power and reliability using data from farmers.

4.0 To design the model aimed at monitoring temperature, humidity and water levels in the poultry house in poultry farming.

The model designed, aimed at monitoring temperature, humidity and water levels in the poultry house in poultry farming is shown on Figure 11. The hardware configuration shown in Figure below shows several components that work together to collect process and transmit data.

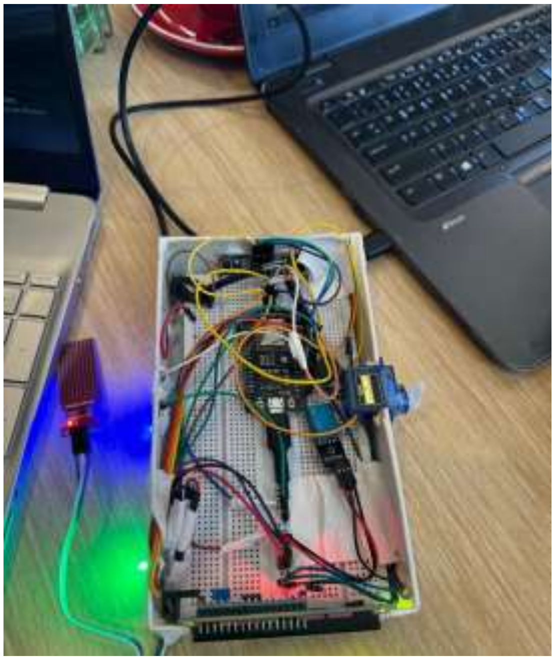

Figure 11: model designed to monitor temperature, humidity and water levels in the coop These components include LCD display.

It provides local visualisation of sensor data within the coop. Displaying the temperature, humidity, water levels and the coop"s status.it is a dashboard like as shown in figure 12.

Figure 12: Hardware setup showing the LCD

- **ESP 8266** it is a Wi-Fi connectivity built –in microcontroller that is used to connect devices to the internet and communicate with other devices. In this experiment it is a central controller/ backborne for the sensors, collecting and transmitting data to the blynk application for analysis and storage.
- **Servo motor** it enables precise control of angular position, on my prototype its used on automation of the opening and closing of the coop at 90 ºC which is a closed loop system in control systems.
- **Water level sensor** it is a sensor used to monitor the amount of water in the coop" s drinking system. If the water level drops below 15 %, the microcontroller will trigger the buzzer to notify the people around the coop by producing a sound and a blue light will be flashing showing the need for a refill.
- **DHT11** it is a sensor used to measure temperature and humidity.
- **Buzzer** it is linked with a water level sensor, to give a signal by producing a sound when the water levels drops at 15 % in the water supply system

4.2 Developing an application or software which can be linked on a mobile device to monitor poultry activity

The Arduino IDE software application was used to write, upload and monitor code for the IoT system.

The following steps were followed when the application or software was being developed:

Step 1: Arduino IDE

On the software codes were written including all the components on the IoT, which were coded with the functions they were going to perfom on the IoT.

Step 2: Blynk Website

On the website you open the bylnk, create an account and create a new template. Also create datastreams, these datastreams will link what is being recorded on the model showing it on the website(transferring of data). Create a dashboard adding whatever you want on it for example gauge and lights. Link the gauges and lights with the data streams.

Step 3: Arduino IDE

Back to the software, link the template from blynk website to the code. Also code the wifi details including the names and passwords. Upload the code to the microcontroller (ESP 8266) board using a USB code.

Step 4: Accessing the results to the phone

Download blynk application on your device, log in (template and data streams). Create a dashboard and link it to the data streams.

In figure 13 an authentication panel is depicted. This panel requires the user to provide their username and password in order to log in to the system. To complete the verification process, they then provide the code (a One-Time Password) that was provided to their cell phone. Once the user has successfully logged in they will be shown the primary dashboard, which is depicted in Figure 14. The primary dashboard includes functionalities that enable the user to examine the state of parameters in the house in both a graphical and textual format, as well as to add additional coops, new nodes, and other similar features within the house.

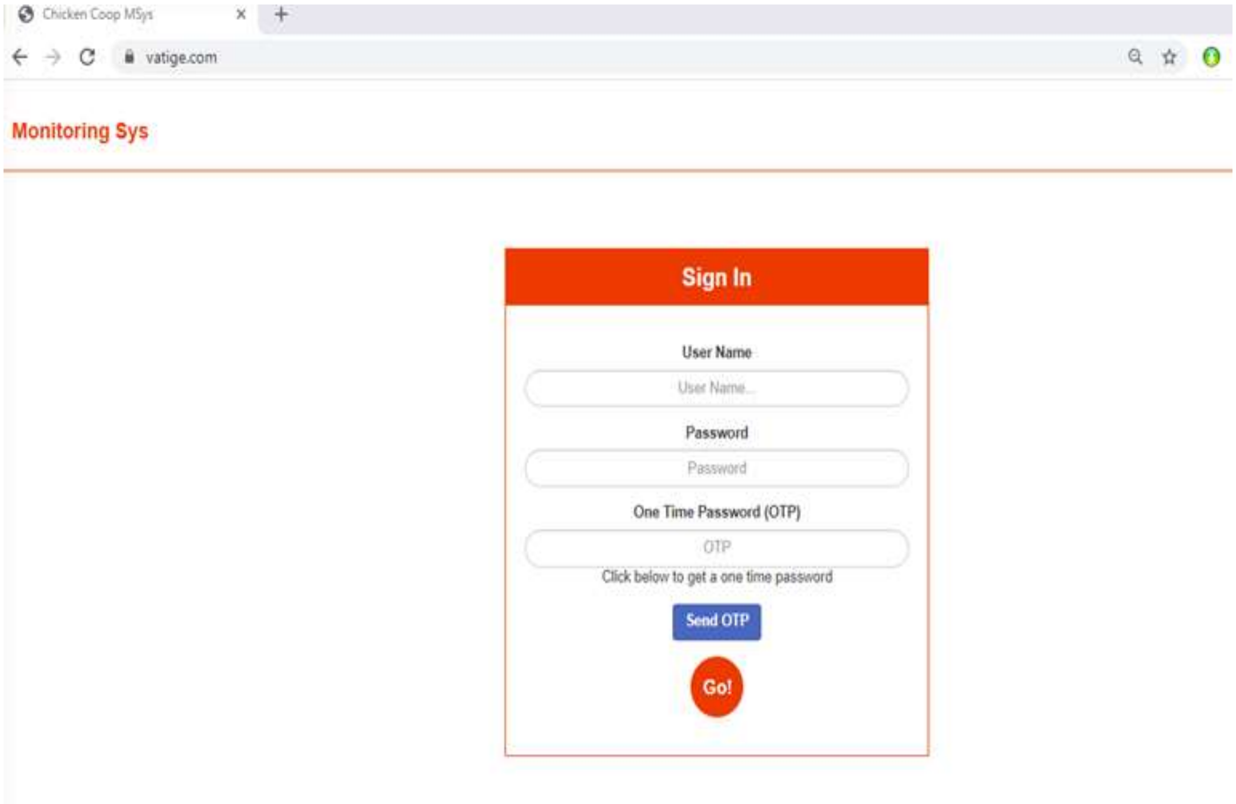

Figure 13: authentication panel

For example a farmer Mr Banda Anthony account can be as follows

Figure 14: Main Dashboard

4.3 Algorithm for a system to work online

When the farmer does not configure the node to do otherwise, the node will automatically send data to the local server after every 15 seconds. Despite the fact that the ESP 8266 is connected to local area network (LAN). If the client and the server are both located in the same local area network (LAN), the client will still be able to view the information and manage the settings. A flow chart for a system that can operate in both offline and online nodes is depicted in Figure 15 and Table 3 contains the algorithm that corresponds to this flow chart. In this algorithm, the local server will send data to the cloud server if the online mode is enabled and there is internet connectivity. If the online mode is not enabled, the system will store the data locally until it is processed by a synchronization subroutine, the flow chart and algorithm for which are shown in Figure 16 and Table 4 respectively. In the event that there is data that has to be synchronized, the online mode is enabled, and the internet is accessible, the synchronization subroutine will send the data to the cloud portal. After then, the material is erased if it has been stored for more than two days without being removed. This is done to protect the local server from running out of memory. In any other case, the system will continue to monitor the data that is saved locally.

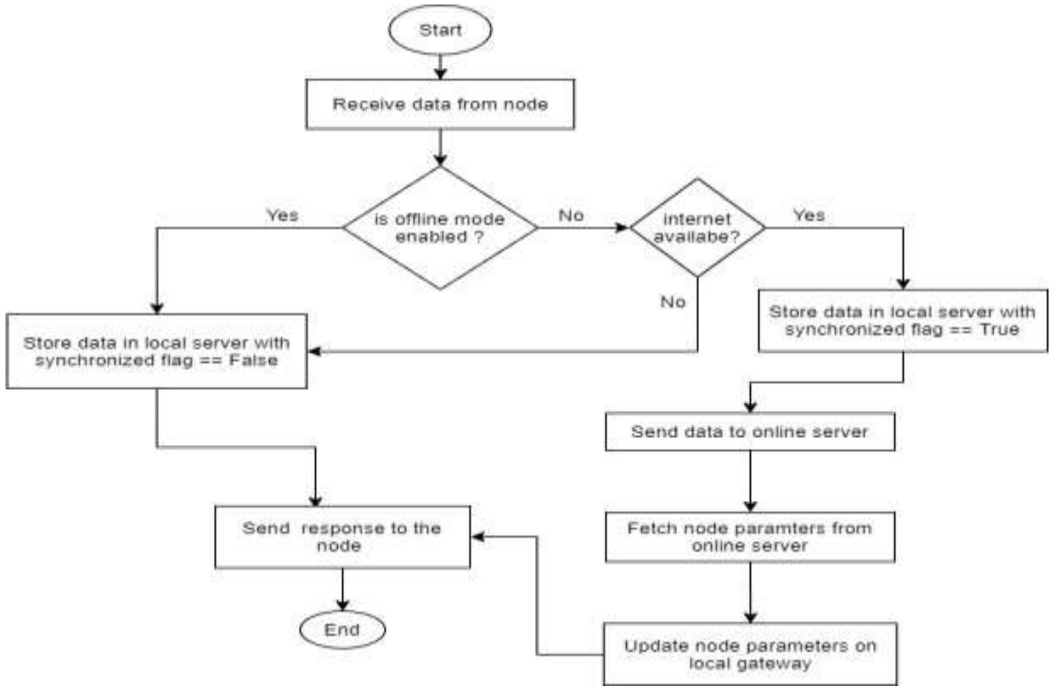

Figure 15: A flow chart for a system to work online

Table 1: An algorithm for a system to work online

1.	*Receive data from a node - after every predefined time interval*
2.	*If is_offline_mode == True || is_internet_available ==False Then*
3.	*Data_synchronized_flag □ False*
4.	*Store data in local DB server*
5.	*Send response to the Node*
6.	*Else*
7.	*Data_synchronized_flag □ True*
8.	*Store data in local DB server*
9.	*Send data to online DB server*
10.	*Fetch node parameters from online server*
11.	*Update node parameters on local server*
12.	*Send response to the Node*

13.	*End If*

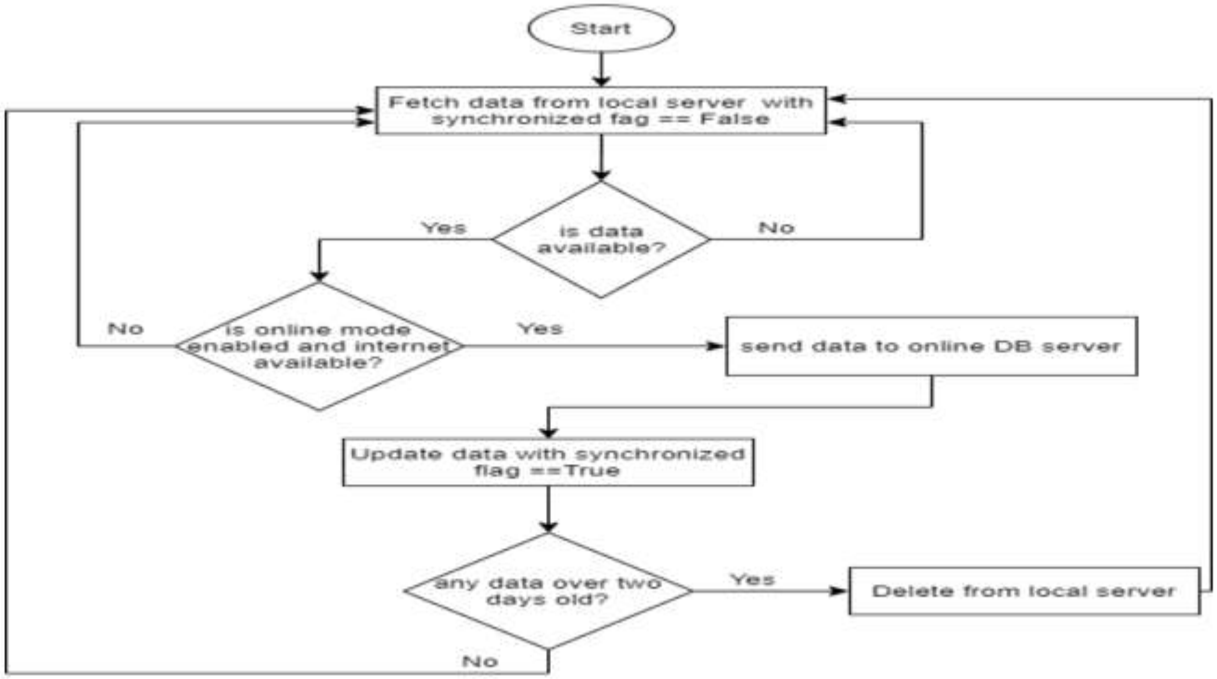

Figure 16: A synchronization flowchart to data between the local and online server

Table 2: A synchronization algorithm for data between the local and online server

1.	*Do While (is_data_available == False)*
2.	*μ □ Fetch data with data_synchronized_flag == False*
3.	*If μ ! = Null Then*
4.	*is_data_available □True*
5.	*Else*
6.	*is_data_available □ False*
7.	*End If*
8.	*End While*
9.	*If is_offline_mode==False && is_internet_available ==True Then*
10.	*Send data to online DB server*
11.	*Data_synchronized_flag □ True*
12.	*End If*
13.	*If is_data_over_two_days == True Then*

14.	*Delete the data in the local DB server*
15.	*Call step 1*
16.	*Else*
17.	*Call step 1*
18.	*End if*

4.4 Evaluating the performance of the developed model focusing on its accuracy, predictive power and reliability

The statistical measure that indicates the degree to which a system operates correctly over a specified period of time is referred to as reliability (Menčík, 2016). For the purpose of determining and enhancing the dependability of our proposed solution, we conducted an experiment throughout the course of five working days assessing 50 chickens in a coop, during which temperature, humidity and water levels in the water system were recorded. With that being said, the experiment was conducted with the following presumptions:

(i) The reliability of the system was monitored 24 h a day, five days a week.

(ii) The system was given a score of "1" in each and every observation if it successfully carries out all of the main capabilities that are listed: (a) monitor parameters (temperature, humidity and water levels in the coop and (b) works in online mode. In every other case, it is scored a "0." Reliability is equal to one, and failure is equal to zero.

The failure, in addition to the amount of time required for fixing it, considered to have occurred within one hour if the system was tagged with a "0."

4.4.1 Results

On table 5 above, observed results during the experiment of five days were recorded to test the performance of the developed IoT model focusing in its accuracy**,** predictive power and reliability. The DHT11, component on the model gathered the temperatue and the humidity data and the water level sensor gathered the water in the coop"s water system data. The data was shown on the LCD on real time reducing the inperson inspection of the coop"s environment giving farmers room to make informed decisions

Table 5:Observed results of temperature and humidity for five days, 24 h /day

TIME	T [MON]	H [MON]	T [TUES]	H [TUES]	T [WED]	H [WED]	T [THURS]	H [THURS]	T [FRI]	H [FRI]
0:00	**16**	**42**	**15**	**54**	**16**	**44**	**16**	**34**	**12**	**80**
1:00	**16**	**44**	**15**	**56**	**15**	**47**	**16**	**34**	**12**	**81**
2:00	**15**	**45**	**14**	**59**	**14**	**51**	**15**	**34**	**11**	**81**
3:00	**15**	**46**	**14**	**61**	**14**	**53**	**14**	**36**	**11**	**82**
4:00	**14**	**47**	**14**	**62**	**14**	**52**	**14**	**40**	**11**	**82**
5:00	**14**	**48**	**14**	**64**	**14**	**52**	**14**	**42**	**11**	**83**
6:00	**14**	**49**	**14**	**66**	**14**	**54**	**13**	**51**	**10**	**84**
7:00	**15**	**45**	**14**	**63**	**14**	**52**	**12**	**62**	**9**	**89**
8:00	**17**	**38**	**17**	**53**	**17**	**43**	**14**	**65**	**12**	**74**
9:00	**21**	**30**	**20**	**42**	**21**	**34**	**17**	**57**	**14**	**63**
10:00	**24**	**25**	**23**	**34**	**24**	**27**	**19**	**51**	**16**	**54**
11:00	**26**	**23**	**25**	**28**	**26**	**23**	**21**	**46**	**18**	**49**
12:00	**27**	**21**	**26**	**24**	**27**	**20**	**22**	**41**	**19**	**43**
13:00	**27**	**22**	**27**	**22**	**28**	**18**	**23**	**39**	**20**	**40**
14:00	**27**	**21**	**27**	**21**	**28**	**17**	**23**	**38**	**21**	**38**
15:00	**28**	**20**	**27**	**20**	**29**	**16**	**23**	**39**	**21**	**38**
16:00	**27**	**21**	**27**	**20**	**28**	**16**	**21**	**43**	**20**	**40**
17:00	**26**	**23**	**26**	**21**	**26**	**18**	**19**	**49**	**18**	**45**
18:00	**23**	**27**	**23**	**26**	**24**	**21**	**17**	**57**	**16**	**52**
19:00	**21**	**31**	**21**	**30**	**22**	**25**	**16**	**65**	**15**	**57**
20:00	**19**	**36**	**20**	**35**	**20**	**29**	**15**	**71**	**14**	**61**
21:00	**17**	**42**	**19**	**37**	**19**	**31**	**14**	**75**	**13**	**64**
22:00	**16**	**48**	**18**	**39**	**18**	**32**	**13**	**78**	**12**	**66**
23:00	**16**	**51**	**17**	**41**	**17**	**33**	**12**	**80**	**11**	**69**

Table 3: Observed results of temperature and humidity

The data on the table 5 above was tabulated on line graphs below to clearly show the pattern of the recorded parameters on different days and at different time. The parameters inversley relied on each other for example on Monday around 12 pm to 16:00 pm temperature, humidity and water level, raised and was low respectively because during the day the temperatures rises leading to more water uptake by the chickens cause high temperatures causes heat exhaustion, dehydration and sometimes death in poulty. That is why these parameters need to be monitored.

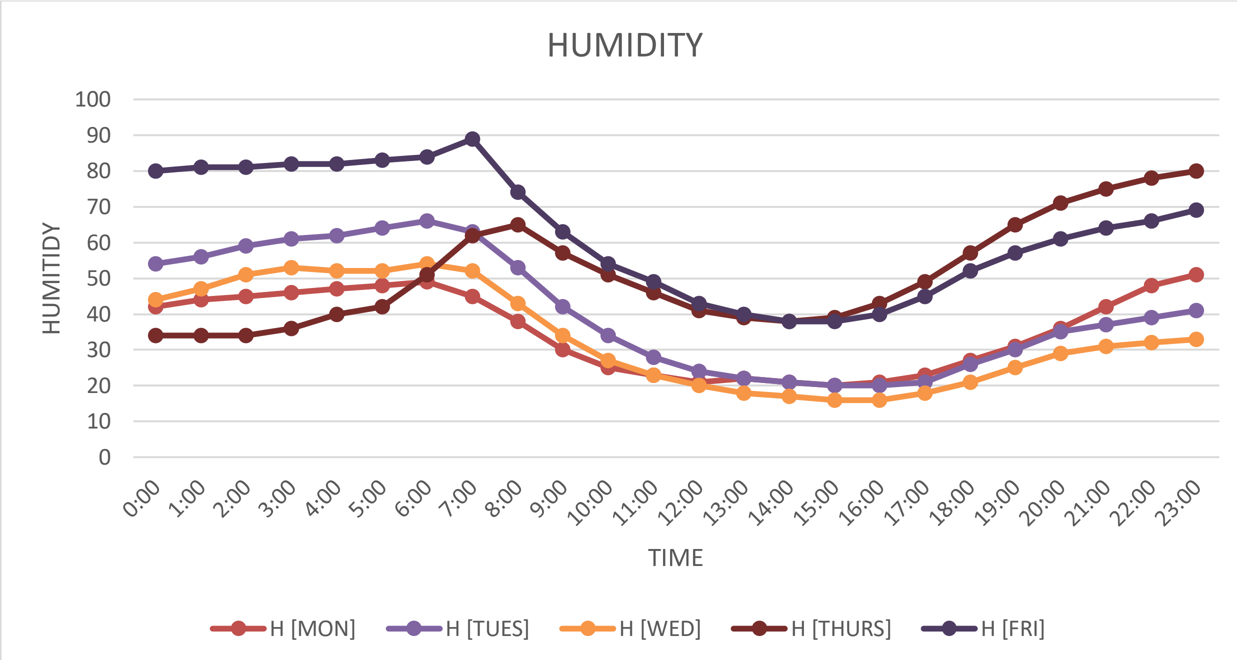

Figure 17: Observed results of humidity for 5 days

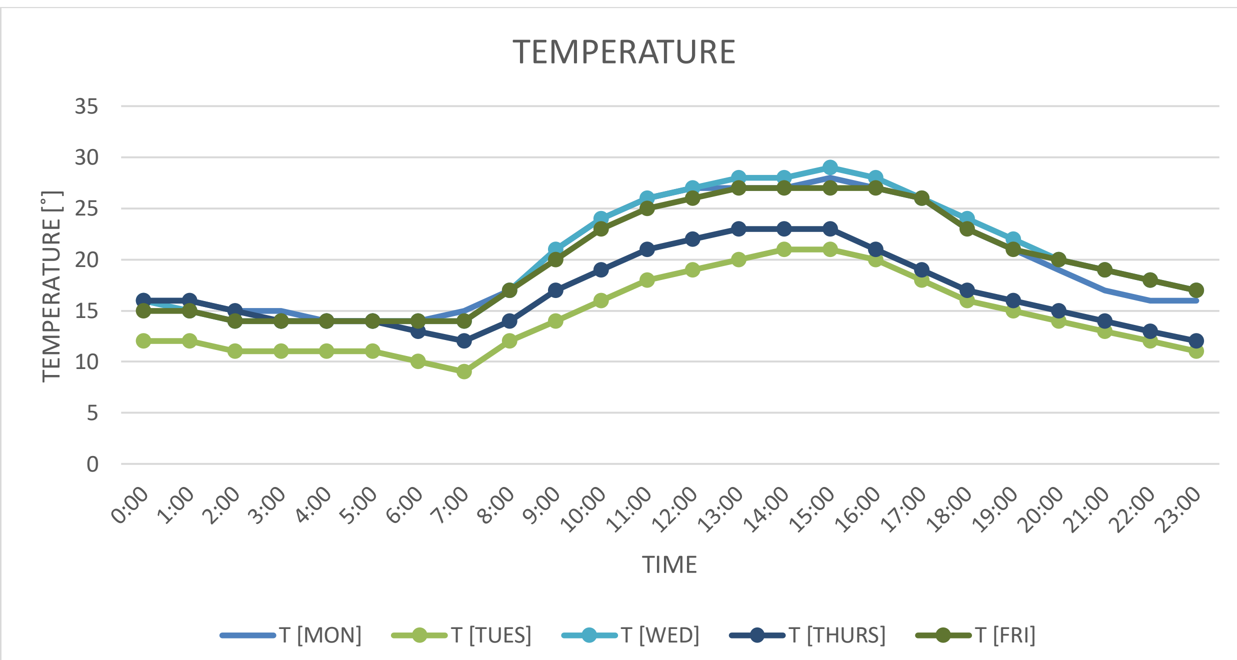

Figure 18: Observed results of temperature for 5 days

time duration

24 h /day and 5days/week (Monday to Friday)

Monitoring hours

24 h/day

System scoring

1 for success (if the system successfully performs its capabilities: monitoring and working in online mode) and 0 for failure.

1. Total hours of observations (N) during the 5 days experiment

That's 24 h/day · 5 days/week

N = 120 h

2. Number of failures = 2

It failed to distinguish the movement of chicken in the coop and and a predator.

Calculating failure frequency = number of failures/ total observations

= 2/120

= 0.0166 failures/observation

Mean time between failure = total operating time / number of failures

=24 h /day · 5 days/wk. /2

=60 h

Mean time to repair = total repair time /number of failures

Therefore from the assumptions it took an hour to repair the model

2 h /2 failures

= 1 hour

Uptime percentage = total operational hours – total downtime / total operational hours

= 24rs/day · 5 days/wk – 4 h /total failures/ 245 ·

= 76/120

= 0.98

Downtime percentage = total down time /total operational hours · 100 %

= 4 h /120

= 3.3 %

4.5 Discussion of Results

Objective 1: To design the model aimed at monitoring temperature, humidity and water levels in the poultry house in poultry farming

The objective of designing the model aimed at monitoring temperature, humidity and water levels in the poultry house in poultry farming was successful, as the system got to function as what had been planned. Though it was a small prototype than the actual system, this was proved when the sensors accurately collected data on temperature, humidity and water levels and the data was shown on the dashboard and also in the blynk application showing the data of the parameters on real time providing farmers with detailed information of the environment within their poultry housing and they made informed decisions such as refilling water in th coop and ventilation as well as reducing the frequent inperson monitoring of the coop, since it is linked to the blynk application that shows the status of the coop and other components like the buzzer that gave a notification by producing a loud sound when the water levels drop below 15 %.

Objective 2: To develop an application or software which can be linked on a mobile device to monitor temperature, humidity and water levels in the coop in poultry farming?

The blynk application that was developed was linked on a mobile device to monitor temperature, humidity and water levels in the coop in poultry farming, was successful because real time data on temperature, humidity and water levels in the coop was accessed through the app, enabling timely decisions and adjustments to be made. The app also allows farmers to monitor and manage their coops from anywhere, reducing the need for frequent in person inspections, which can be time consuming and costly. The app also allows an individual to add other people on it as well as deleting them whenever they want to for security reasons, for instance the team to monitor chickens is increased one just need to enter their credentials and a one time password will be provided and they will access the application. On the application the coop" s status will be shown on the screen if its closed or opened this is done to know wether the is a predator that has entered or not especially during the night.

Objective 3: To evaluate the performance of the developed Internet of things model focusing on its accuracy, predictive power and reliability using data from farmers.

The performance of the system focusing on its accuracy, predictive and reliability was a success as shown on the experiment that was carried out for five days, 24h/day. Its success, failures, Mean Time Between Failures, Mean Time to Repair, Uptime and downtime percentages have been calculated above showing that:

1. Reliability

A system's reliability is a measure of its ability to perform its intended function without failure. With a mean time between failures of 60h and an uptime percentage of 98 %, the system appears to be quite reliable. Because the observed and recorded temperature, humidity and water levels in the coop"s water system which was recorded was taken from both the dashboard and the blynk application showing real time data. For example on Tuesday between 12pm to 16:00 pm the temperatures ranged from 20 to 26 ºC and humidity ranged from 39 to 42 % and water levels in the coop"s water system ranged from 40 % decreasing to 10 %. This was because during the day temperature rises to 26 ºC and humidity to 42 % (optimum conditions), the chickens will be active as well and the food consumption will be high so they will be drinking water that's why it dropped from 40 to 10 %. When the water level dropped below 15 % the model did sent a notification to the application flashing the blue light meaning that the water level has dropped and a refill is needed also a buzzer started producing a sound, notifying people who were around that water levels had dropped. Also on Wednesady the temperature was high at 30 degrees around 3pm the system responded very well to the condition which was considered to be high end of the comfortable temperature range for the chickens and the system gave a notification on the application that ventilation was needed in the coop.

2. Maintainability

This refers to how a system can be easily repaired and maintained. With a Mean Time to Repair of 1 hour, the system appears to be fairly maintainable;

3. Availability

This refers to the proportional of time a system is operational and available for use. With this system, a downtime percentage of 3.3 %, the system is highly available, with limited downtime.

It was also a scalable system that gives farmers the ability to monitor as many coops as they own in real time, to switch a system to either automatic or manual management, to establish threshold levels based on the age of chicken, and to configure time intervals for the sensor to relay data. In the event that the water level has decreased below 15 % of the permitted range, the system was able to detect it and the buzzer will start to give out a loud sound notifying the person in charge and a blue light will flash. When the manual mode is activated, the tool will just monitor the parameters, and it will wait for the user to issue the command in order to modify those parameters. Generally speaking, the farmer can use the same software system to keep chickens of varying ages and to add more coops as they see fit without the software system being affected in any way.

4.6 Project evaluation

Project evaluation is a critical process that helps to determine whether a project has achieved its objectives and goals at the end of its life cycle. The evaluation process involves a systematic and objective assessment of the project, focusing on the various parameters such as cost, schedule, quality and performance. The evaluation of this project is going to include cost benefit analysis, cost of labour, materials.

4.6.1 Cost benefit analysis

A cost benefit analysis is a valuable tool used to evaluate the economic feasibility of a proposed project or investment. In this case of developing an Internet of Things framework of monitoring poultry housing in the Poultry Farming sector in Zimbabwe, a cost benefit analysis would weigh the costs and potential benefits of installing and operating such a system.

Table 4: Cost benefit analysis

Item description	Quantity	Amount (USD)
DHT11	1	6
ESP 8266	1	6
SERVO MOTOR	1	3
WATER LEVEL SENSOR	1	2
ULTRASONIC SENSOR	1	3
BUZZER	1	3

LDR	1	1
LCD	1	8
CONNECTING WIRES	20	2
Total		34

Benefits

Improved efficiency: with real time data collection and automated systems, farmers can optimize processed, reduce mortality of chickens and increase productivity, leading to higher profitability'

Better decision making: accurate and timely data allow farmers to make informed decisions regarding feed management, water supply as well as ventilation to improve poultry health.

Enhanced animal welfare: Internet of things technology enables the monitoring of environmental factors such as temperature, humidity ensuring that birds are comfortable and free from stress, improving animal welfare.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Recommendations

- To improve reliability, one can consider implementing preventative measures or investing in more robust components
- To consider establishing a maintenance schedule, identifying potential failure points and stockpiling spare parts to further improve maintainability.
- The designed model needs someone with knowledge on how to operate and manage the parameters.
- There is need to improve on the application to add other parameters such as to show the number of chickens in the coop as well as the ones who are unhealthy on the dashboard.
- The research can also be expanded to include a camera that provides a live view, which will offer some value and confidence to the investigation.
- This research would be enhanced with the addition of sensors that measure luminance as well as sensors that monitor the replenishment of water and food supplies. The development of a mobile application that includes extra functions, like as a reminder scheduler for vaccinations, is another project that has the potential to make a substantial contribution to the ongoing effort.

5.2 Conclusions

- The designed model aimed at monitoring temperature, humidity and water levels in poultry housing in the poultry farming sector in Zimbabwe was designed and demonstrated excellent performance in achieving its intended objectives. The system has shown high reliability and availability, with minimal downtime and quick identification of failures.
- This model had the potential to revolutionize the poultry farming sector by providing accurate and timely data, enabling farmers to make informed decisions and improve the overall health and productivity of chickens. The success of this model highlights the immense possibilities of IoT in the agricultural industry and encourages further exploration of its applications.
- The Blynk application"s excellent performance in providing real time data to farmers enables them to make informed decisions and optimize environmental conditions for their birds, resulting in improved productivity and overall health.
- Hence the developed IoT has proven to be highly successful, demonstrating accurate, powerful predictive capabilities and reliability.

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