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Literature Review

# Towards an Integrated Mobile Technology on Animal Disease Surveillance Framework in Tanzania: A Systematic Review

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**ABSTRACT**

Tanzanian Government, through its national audit office in March 2020, reported the prevalence decline of two animal diseases, namely; Foot and Mouth Disease (FMD) and Contagious Bovine Pleuropneumonia (CBPP). Similarly, an increase in three animal diseases, which are African Swine Fever (ASV), Contagious Caprine Pleuropneumonia (CCPP), and Lumpy Skin Disease (LSD). The national audit office mentioned inadequate animal disease surveillance system in the country was among the challenges that hinder diseases control. Therefore, this study reviews the existing animal diseases surveillance systems global and suggests measures to enhance animal diseases surveillance systems in Tanzania. This review focuses on the possibility of sharing surveillance data among livestock stakeholders (including livestock keepers) in Tanzania, considering available resources such as animal diseases existing prediction models and mobile-based surveillance systems. Also, the availability of mobile technologies such as Short Message Service (SMS), Unstructured Supplementary Service Data (USSD) and automatic voice calls (Robocalls). Reviews synthesize the previous studies to explore strengths, opportunities, weaknesses and challenges for better future interventions through proper and timely information sharing. This study selected 46 records from the 147 identified for review. The selected records include 24 from bibliographic databases, 14 from full-text journals and other non-bibliographic databases, and 8 from the open search on websites.

**Keywords:** Animal Disease Surveillance Framework; Tanzanian livestock keepers' demographics data; feature mobile phone; Animal diseases surveillance system; animal diseases prediction models; Robocalls; System interoperability.

## INTRODUCTION

Although Tanzania contributes 1.4% of the world's cattle population and 11% in Africa, the diseases surveillance system is challenged with several factors that may need to be addressed (The United Republic of Tanzania National Audit Office, 2020). Despite control and prevention measures instituted previously to some major diseases such as Contagious bovine pleuropneumonia (CBPP), Contagious Caprine Pleuropneumonia (CCPP) and Foot and Mouth Disease (FMD), they observed an upsurge in the magnitude (The United Republic of Tanzania National Audit Office, 2020). The performance audit report on the prevention and control of livestock disease of the Tanzanian national audit office of 2020 reported several drivers which accelerating this situation including, the outdated surveillance and reporting mechanism used by the government (95% paper-based) and the delays in identifying and reporting cases due to poor communication between the livestock keepers and the livestock field officers (The United Republic of Tanzania National Audit Office, 2020). Also, the audit mentioned the lack of timely feedback on the reported cases from the Zonal Veterinary Center (ZVC) to the District Veterinary Officer (DVO) to the livestock keepers was another challenge that hindered the livestock sector. Similarly, the audit observed inadequate information sharing between the Ministry of Livestock and Fisheries (MoLF), President's Office - Regional

Administration and Local Government (PO-RALG), and other stakeholders due to an unclear chain of command between the parent Ministries and respective Local Government Authorities (LGAs). General sharing of animal diseases surveillance data in time among livestock stakeholders in the country especially during animal diseases outbreaks is the major challenge that hinders livestock diseases control.

This study aims to review the existing animal diseases surveillance systems and prediction models worldwide and suggest measures to enhance animal diseases surveillance systems in Tanzania (Colangeli et al., 2011; E. Karimuribo et al., 2016; Mwabukusi et al., 2014). Hence, the literature of the current animal disease surveillance systems in the country and other related materials worldwide were reviewed, including surveillance systems situation in the country, other existing surveillance systems globally, and livestock diseases prediction models. Livestock keepers are at the grass-root of animals' disease reporting chain, and diseases start from their animals (Namayanja et al., 2019a). Therefore, this study also reviewed Tanzanian livestock keepers demographic data in line with their capability to report and receive animal disease-related information, realizing their importance in the animals' diseases reporting chain (Namayanja et al., 2019a). Livestock demographic data enables the review to suggest suitable technology for sharing animal diseases related information/data in time between livestock keepers and top-level stakeholders such as Field, District, Regional, Zonal and National Veterinarian officers, researchers and laboratories.

# METHODOLOGY

## Study Area Selection

Researchers selected Tanzania as the study area where the animal disease surveillance system is ill-informed (The United Republic of Tanzania National Audit Office, 2020). The government does not own a surveillance system. However, few stakeholders developed their electronic-based surveillance systems and deployed them in the few districts in the country to enhance surveillance process. Due to the inadequate deployment of electronic-based surveillance systems, the government still relies on paper-based surveillance mechanisms in most districts with high fragmentation. As a result, the government and other stakeholders are still struggling to improve the animal diseases surveillance process in the country. Therefore, the researcher believes that the output of the review would provide valuable information to livestock stakeholders inside and outside the country for improving existing surveillance systems or developing new surveillance systems.

## Exclusion and Inclusion Criteria for Considering Studies for this Review

Information and literature gathered took place between 2010-2021. The research was limited to animal disease surveillance systems, prediction models and livestock keeper's demographic data. The study considered animal disease surveillance systems and prediction models studies globally and livestock keepers' demographic data studies only in Tanzania. The study collected information about Tanzania livestock keepers' demographic data in line with their capability to report and receive animal disease-related information such as outbreaks in their localities and other places, prediction in their localities, precaution measures, negative impacts, transmission pathways and clinical signs via the surveillance systems. The detailed inclusion and exclusion criteria applied to this review are illustrated (see **Table 1**).

## Search Strategies for Identification of Studies

The search strategy involves three steps: searching literature from peer-reviewed Bibliographic databases; Full-Text Journals and other non-Bibliographic databases; and open search on websites of trusted institutions repositories (**Table 2**). Researchers conducted a review materials search using the Google Scholar database as the primary source of information. Since Google Scholar did not provide sufficient information for the study, other sources of information were utilized, including IEEE Xplore, PubMed and the National Center for Biotechnology Information (NCBI), Institutions websites and documents repositories. The following keywords were used for searching materials, Tanzanian livestock keepers' demographics data; Cell phone usage by livestock keepers; Animal disease surveillance system in Tanzania; Animal diseases surveillance system; Animal diseases prediction models; Animal diseases modelling in Tanzania; Robocalls; System interoperability. The Robocalls are automatic computer generated mobile calls from a computer program that can dial many phone numbers at once and play a prerecorded or computer-generated voice message to anyone who answers the voice call (The Conversation, 2019).

# RESULTS

## Summary of Reviewed Literature

After conducting the literature search in bibliographic databases, full-text journals and other non-bibliographic databases, as well as the open search on the website (**Table 2**), 147 records were identified before filtering based on the inclusion and exclusion criteria (**Table 1**). The number of records obtained from each search strategy includes 116 from bibliographic databases, 23 from full-text journals and other non-bibliographic databases, and 8 from the open search on the websites (**Figure 1**). General the output after searching through the bibliographic databases, full-text journals and other non-bibliographic databases were the following document types; journal articles (111), conference papers (2), books (1), magazines (2), reports (22), websites (8), and white paper (1).

After conducting records filtering based on inclusion and exclusion criteria (**Table 1**), 101 records were excluded from the list (**Figure 1**). As a result, the study includes 46 for reviewing of which, 24 from bibliographic databases, 14 from full-text journals and other non-bibliographic databases, and 8 from the open search on the website (**Figure 1**). The records selected for review involve the following document types: journal articles (24), magazines (2), reports (11), websites (8) and white paper (1). The contents of the selected records for review include web-based animal diseases surveillance systems (9), animal diseases prediction models (12), and mobile-based animal diseases surveillance systems (14). The study also included publications on Tanzanian livestock keeper's demographic data (2). Lastly, the study included publications providing general information about the Tanzanian animals' diseases surveillance system situation (1), various contagious animal diseases such as CBPP, ASV, CCPP, LSD and FMD (3), and various communications technologies such as USSD, SMS, Robocalls, and systems interoperability (7).

**Table 1.** Exclusion and Inclusion criteria for identified studies

| S.No | Inclusion Criteria |
|---|---|
| | Papers on the subject of livestock keeper's demographic data, animal disease surveillance systems and prediction models that meet the following criteria: |
| 1 | Written in the English language |
| 2 | Animal disease surveillance should base in Tanzania or elsewhere |
| 3 | Livestock keeper's demographic data from Tanzania |
| 4 | Websites |
| 5 | Project reports, conference reports/proceedings, peer-reviewed studies and audit reports published between 2010-2021(At most 11 years) |
| | **Exclusion Criteria** |
| 1 | Materials that provide limited information |
| 2 | Materials with repeated titles (Duplicates materials). The study includes the first study during the search and ignores the rest. |

**Table 2.** Systematic literature and information search strategy

| Step | Description | |
|---|---|---|
| 1 | Bibliographic databases | (1) Google Scholar<br>(2) National Center for Biotechnology Information (NCBI) |
| 2 | Full-Text Journals and other non-Bibliographic databases | (1) IEEE Xplore<br>(2) PubMed,<br>(3) College of Business Education (CBE) Institutional Documents Repository<br>(4) Sokoine University of Agriculture (SUA) Institutional Documents Repository<br>(5) National Audit office of Tanzania (NAOT) |
| 3 | Open search on the website | (1) South African Centre of Infectious Disease Surveillance (SACIDS)<br>(2) World Organization for Animal Health (OIE), OIE World Animal Health Information System (OIE-WAHIS)<br>(3) Food and Agriculture Organization (FAO) of the United Nations<br>(4) ProMED-mail, Map of the Latest Alerts on Infectious Disease Around the World<br>(5) European Commission, Animal Disease Notification System (ADNS)<br>(6) African Union, Inter African Bureau for Animal Resources, AU-IBAR<br>(7) Africa's Talking.<br>(8) SMS Deliverer.<br>(9) China.cn |

## Animal Disease Surveillance Systems and Prediction Models

The current animal disease surveillance system used by the Tanzania government is 95% paper-based (**Figure 2**). The government officials use physical documents to pass surveillance data and information between and among administrative offices instead of being electronic (Mwabukusi et al., 2014; The United Republic of Tanzania National Audit Office, 2020). Often this surveillance system has many challenges that hinder the control of animal diseases in the country. Among the challenges is the long chain of communicating disease outbreaks/incidents and delayed response among livestock stakeholders. Normally, the ward livestock extension officers receive disease outbreaks/incidents from livestock keepers either by routine visits or phone calls from immediate livestock keepers. Sometimes, veterinarians leave unreported cases due to unfriendly terrains that hinder access to remote livestock keeping communities, especially during rainy seasons (E. Karimuribo et al., 2016). Once the veterinarians receive the information, they report the incident to the district veterinary officer (DVO) by calling or visiting the DVO's office (A. Kijazi et al., 2021). The DVO forwards the information to the Directorate of Veterinary Service (DVS) for decision making and response. Sometimes, communication breakdown may happen if somebody is irresponsible along the reporting chain (**Figure 2**).

Similarly, whenever there is a threat of a disease outbreak, the veterinarians/field officers use to visit individual livestock keepers to alert them about the disease and any precaution measures which could be easily done by an electronic-based animal diseases surveillance system instead of the human being. The process of visiting livestock keepers for collecting or giving information is costly and requires a higher number of livestock field personnel for it to be effective. However, the country reported below 30% of ward livestock field officers available in the entire country (The United Republic of Tanzania National Audit Office, 2020). Also, information from livestock keepers was further complicated by the geographical terrains, especially during the rainy season where most of the roads are impassable in rural areas (E. D. Karimuribo et al., 2016).

Furthermore, the paper-based mechanism does not timely capture data from individual livestock keepers, wildlife and private sectors hence contributing to the delay of reporting and response during disease incidents and outbreaks (The United Republic of Tanzania National Audit Office, 2020). Due to the technology growth, different livestock stakeholders developed electronic-based surveillance systems to replace the existing paper-based surveillance system has been used in the country. An excellent example is an android mobile application named Afyadata developed by Sokoine University of Agriculture (SUA) in collaboration with the Africa Centre of Excellence for Infectious Diseases (SACIDS) for collecting animals diseases field data for them (E. Karimuribo et al., 2016). Similarly, the Food and Agriculture Organization (FAO) developed the mobile application named Event Mobile Application (EMA-i) for animal disease's early detection and timely reporting in developing countries, including but not limited to Tanzania, Mali and Zimbabwe (FAO, 2021, 2015).

The main purpose of EMA-i was to upload surveillance data to the FAO public portal (EMPRES-i), which serves its member countries (FAO, 2021). The Afyadata and EMA-i utilize the trained community-based animal health workers and Field veterinarians to collect near-real-time surveillance data from their immediate livestock keepers. The community-based animal health workers and Field veterinarians use smartphones installed the APPs for collecting field data (FAO, 2015; E. Karimuribo et al., 2016). However, delay of disease reporting cases is still a challenge because they could not capture surveillance data directly from livestock keepers who are at the grass-root of the animal diseases reporting chain (Namayanja et al., 2019a). These two mobile APPs deny livestock keepers to communicate and receive animal disease-related information due to lack of access. However, other studies emphasized that livestock keepers should be the primary source of animal diseases information because sickness always originates with their animals (Namayanja et al., 2019a).

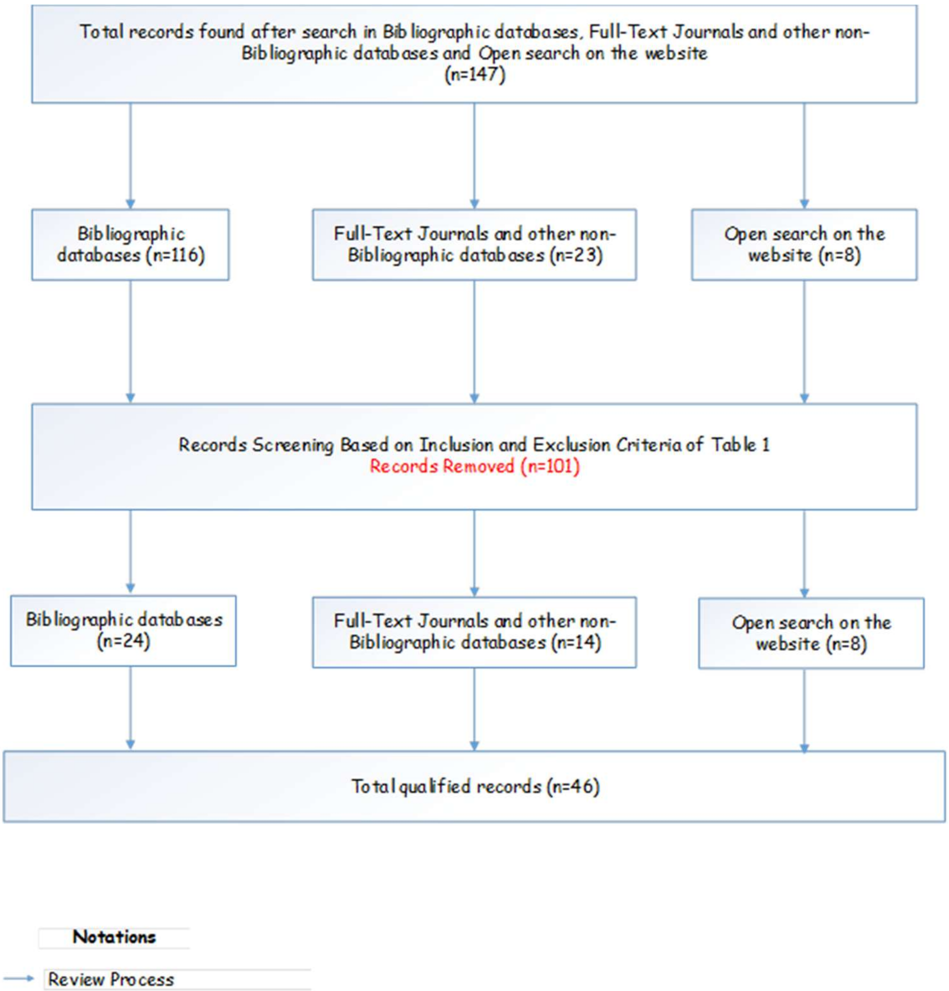


**Figure 1.** The flow of information through the different phases of a systematic review

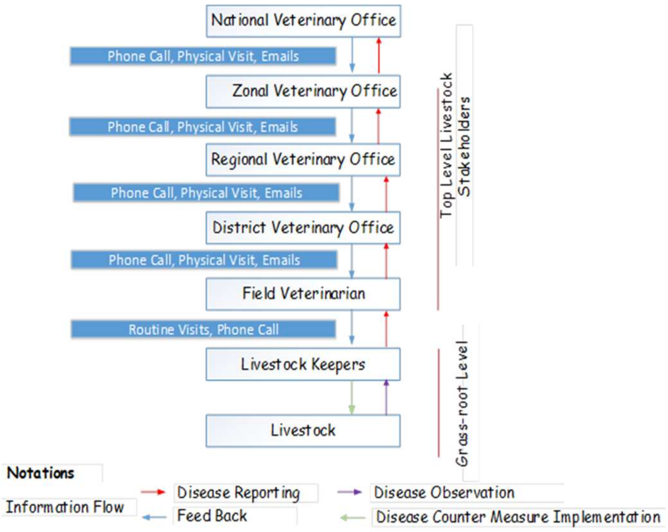


**Figure 2.** Information flow in the paper-based surveillance system

The EMA-i and Afyadata can be improved by adopting some of the functionalities of similar APPs available globally, such as Mobile phone-based syndromic surveillance systems for early detection and control of livestock diseases available in Kenya and Mobile phone-based Infectious Disease Surveillance systems in Sri Lanka (Robertson et al., 2010) (Namayanja et al., 2019b). Regardless of other valuable functionalities, the APPs still failed to accommodate livestock keepers among the users (Robertson et al., 2010; Wamwere-Njoroge et al., 2019). The APPs also utilize Community animal health workers to collect surveillance information on their behalf but with various names such as Community Disease Reporter in Kenya (Wamwere-Njoroge et al., 2019). Apart from surveillance of animal diseases, the study also observed that the Mobile-based surveillance systems have applications across multiple domains and disciplines, including but not limited to surveillance of human health etc. (Brinkel et al., 2014; Lungo et al., 2012; SearchHealthIT., 2021; Thirumurthy and Lester, 2012).

Apart from mobile-based systems, web-based systems also have been used in animal health surveillance globally (AU-IBAR, 2019; Bonnet et al., 2010; European Commission, 2020; FAO, 2021; Milinovich et al., 2014; OIE, 2021; ProMED-mail, 2018). In Tanzania, neither the government nor the agencies own a web-based animal diseases surveillance system. The existing web-based surveillance systems globally could be adopted or provide the Tanzania government or agencies with a blueprint to develop their web-based surveillance system. The excellent examples of such surveillance systems are the Animals Disease Notification System (ADNS) for European Union member's countries, the Livestock Management Information System (LIMS) under the SADC Epidemiology and Informatics Sub Committee (EIS) (Bonnet et al., 2010; European Commission, 2020). Also, there is an Animal Resources Information System (ARIS-AU-IBAR) under the African Union-International Bureau of Animal Resources (AU-IBAR, 2019). Similarly, there is a national information system for the notification of animal disease in Italy (SIMAN) which aims to communicate disease outbreaks and provide valuable tools to manage activities for emergency implementation (Colangeli et al., 2011). Likewise, there is the World Animal Health Information System (WAHIS), under World Organization for Animal OIE and FAO Empres-i global animal disease etc. (FAO, 2021; OIE, 2021). However, these systems still depend on input data from livestock stakeholders in the top-level of the disease reporting chain (veterinarians, laboratories, other healthcare provides, researchers etc.) and ignore those in the grass-root level (Livestock keepers). The systems developed using advanced technologies (web-based) which require skills and other resources like computers, smartphones and Internet connections to access them. In contrast, most livestock keepers, especially in developing countries, lack these requirements (Sankaranarayanan and Sallach, 2014). Therefore, it is difficult for them to report or access disease-related information.

Predicting occurrences of contagious animal diseases like Foot and Mouth Disease (FMD) and Contagious Bovine Pleuropneumonia (CBPP) is mandatory before they cause adverse impacts in livestock keeping communities and the country at large (Dion et al., 2011; FAO, 2018; Gloster et al., 2010; Kasanga et al., 2014; Kim et al., 2016; OIE, 2021). Various prediction models have been developed worldwide for animal diseases surveillance purposes (Bharaneedharan, 2020; Bradhurst et al., 2015; Gloster et al., 2010; Hunter et al., 2018; Kim et al., 2016; Woolhouse, 2011). Modelling provides a clear picture of disease spread mechanisms and suggests effective control measures (Hugo et al., 2017). Different modelling approaches such as Machine Learning Modelling, Agent-Based Simulation Modelling (ABSM) and Mathematical Modelling, also known as Equation-Based Modelling (EBM), have been used to develop such models (Gloster et al., 2010; Hunter et al., 2018, 2018; Kim et al., 2016). A traditional equation-based model (EBM) uses a system of ordinary differential equations (ODEs) to prescribe ratios of infection status in a population over time (Hunter et al., 2018). There is also a hybrid Modelling that combines more than one modelling approach (Bradhurst et al., 2015; Erraguntla et al., 2019). Sometimes, adopting one model from one place to another is a challenge due to the variation in the epidemiological structure of a particular place where the model was implemented. For example, using animal movement as among the variables when modelling the FMD transmission for domestic animals in Tanzania and Australia, one must understand that it is the animals' movement when transferred between farms in Australia while in Tanzania; it refers to the livestock keepers' movement with animals' herds when looking for pastures and water during the dry seasons. Also, some countries use the term transhumance movement with cattle's herds (Kim et al., 2016). As a result, different countries and agents developed animal disease prediction models for a specific location or place. For example, (Kim et al., 2016) developed a model for simulating the transmission of FMD among mobile herds in the far North Region of Cameroon only (Kim et al., 2016). Similarly, (Dion et al., 2011) developed the spatial explicitly multi-agent simulation (MAS) model for the spread of FMD between livestock and wild animals for a small area of villages located along the Kruger National Park fence in South Africa. At the same time, Bradhurst et al. (2015) developed a hybrid model for simulating Foot and Mouth Disease outbreaks for the whole country (Australia).

This review recognizes various mathematical models in Tanzania developed by researchers from different research and academic institutions. An excellent example is an Optimal control and cost-effectiveness analysis for the Newcastle disease eco-epidemiological model in Tanzania (Hugo et al., 2017). However, the models exist practical implementation to the real environment to predict real-time animal diseases outbreaks/incidents scenarios for intervention is a challenge. The models were just kept on the shelves. The Tanzania government and other stakeholders in the country prioritize and concentrate on the practical usage of electronic-based animal disease surveillance systems for timely sharing of surveillance data rather than prediction models which were also important components of any animal disease surveillance system (E. Karimuribo et al., 2016; Mwabukusi et al., 2014; Namayanja et al., 2019a; The United Republic of Tanzania National Audit Office, 2020). The lack of practical application of the existing animal diseases prediction models in the country is an unforeseen challenge since it was not mentioned in the audit report (The United Republic of Tanzania National Audit Office, 2020). To have proper information flow for animal disease control and timely intervention, this review recommends an Integrated Mobile Technology Animal Disease Surveillance Framework for sharing animal diseases surveillance data among livestock stakeholders, including livestock keepers in Tanzania (**Figure 3**). The framework will replace the paper-based surveillance mechanism used in the country for sharing animals' diseases surveillance data. The framework provides the common platform to livestock stakeholders with different systems' privileges to share animal disease-related information in time. The targeted stakeholders include regional bodies (e.g. African Union, Inter African Bureau for Animal Resources), international institutions (e.g. FAO, OIE), laboratories, and researchers (e.g. South African Centre of Infectious Disease Surveillance). Other stakeholders were the President's Office – Regional Administration, Local Government (PO-RALG) and Ministry of Livestock and Fisheries (MoLF) and livestock keepers. The framework also provides flexibility to add more stakeholders when necessary. The framework will enhance timely information sharing among livestock stakeholders by removing long chains for communicating diseases outbreaks/incidents. Livestock keepers are at the grass-root of the animal diseases reporting chain whereby diseases start from their animals, and the majority of them (725 out of 876) own feature phones which do not support the internet (**Table 3**) (The Conversation, 2019). Therefore, the framework provides them with the alternative way to access the information uploaded to the Integrated Mobile Technology Animal Disease Surveillance System (a part of the framework) using various mobile technologies such as Short Message Service (SMS), Unstructured Supplementary Service Data (USSD) and Robot Calls (Robocalls) (The Conversation, 2019). For example, the system will enhance diseases awareness to livestock keepers through periodically broadcasting (reminding) diseases awareness information to their mobile feature phones in SMS, Robocalls (Ahmed Kijazi et al., 2021; A. Kijazi et al., 2021; Mittal et al., 2021) (**Figure 3**). Similarly, the system will enable livestock keepers to access the same information at any time using USSD and SMS. Also, the framework will enable early diseases outbreaks detection by receiving diseases surveillance data simultaneously from different trusted sources which work independently (e.g. SACIDS through AfyaData App, FAO and OIE) (**Figure 3**).

Lastly, the animal diseases prediction models connected to the surveillance system will enable contagious disease (e.g. FMD) outbreaks forecasting as a means of preparedness before their larger negative impact on livestock keeping communities and country economy (**Figure 3**).

## Livestock Keepers Demographic Data

This study reviews livestock keepers' demographic data to propose suitable technologies to accommodate them as among the users of the proposed Integrated Mobile Technology Animal Disease Surveillance Framework in the country. Data were collected on the education level, mobile phone categories possessed by villagers/livestock keepers and mobile phone usage. The information was gathered from 19 villages from both Tanzania mainland and Zanzibar extracted from four different publications (**Table 3**) (Hashimu, 2018; Juma, 2019; Ahmed Kijazi et al., 2021; A. Kijazi et al., 2021). The villages practice both livestock keeping and crops production. Therefore, the mobile phones have been used to communicate livestock and crops related information among the villagers. Since data extracted from more than one source the sum or respectively variables frequencies have been considered for analysis. The data indicates that the number of villagers owning feature phones from all villages (725 out of 876) is higher compared to smartphones, 156 out of 876. The data also shows that 904 of the respondents' villagers/livestock keepers have different education levels including informal education (119), primary school education (312), secondary school education (329) and Tertiary/University education (144). The data also shows that villagers have experience of using different mobile services such as calling, Short Message Services (SMS) and browsing social media.

Since the majority of villagers own feature mobile phones (725 out of 876) which cannot browse the internet, their education level and mobile phone usage data, influence researchers to suggest suitable mobile technologies that could accommodate them among the users of the proposed an Integrated Mobile Technology Animal Disease Surveillance Framework. Therefore, they will be able to share animal diseases surveillance data among themselves and top-level stakeholders. The names of the suggested technologies and their implementations have been explained in the Implementation of SMS, USSD and Robocalls of an Integrated Mobile Technology Animal Disease Surveillance System section of this study, and in detail in two studies (Ahmed Kijazi et al., 2021; A. Kijazi et al., 2021).

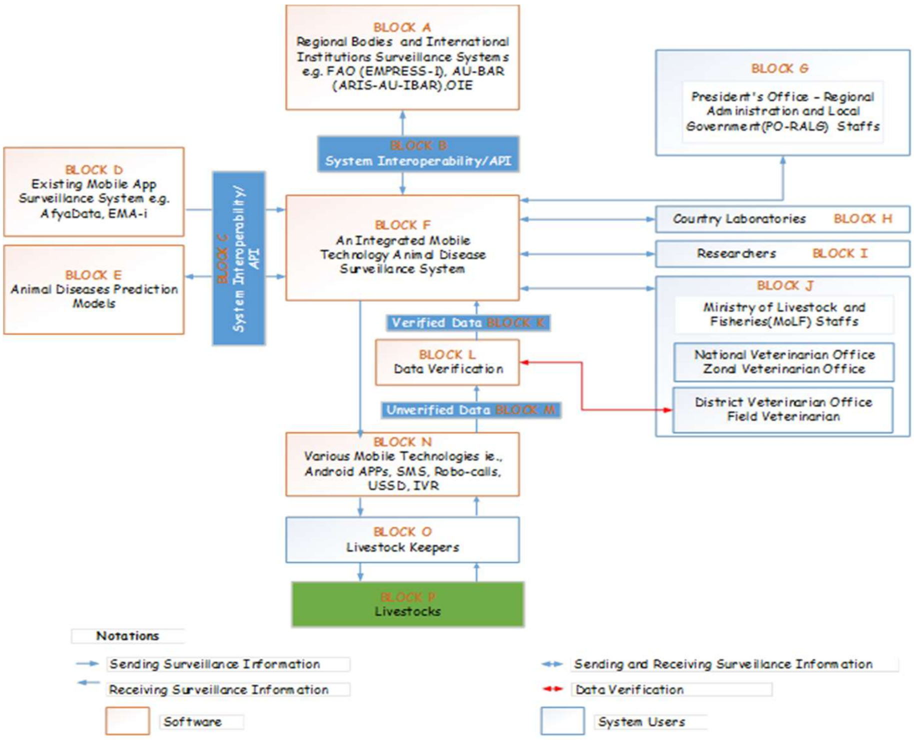


**Figure 3.** Integrated Mobile Technology Animal Disease Surveillance Framework

**Table 3.** Livestock keepers' demographic characteristics

| Section | Variables | Frequenci | Percent |
|---|---|---|---|
| A | **District Name: Gairo, Tanzania Main Land**<br>**Villages Involved: Kilama, Chogoali, Chakwale, Kilimani, Gairo town and Ibuti**<br>**(Ahmed Kijazi et al., 2021; A. Kijazi et al., 2021)** | | |
| | **Type of mobile phones owned (N=143)** | | |
| | Smartphone | 13 | 9 |
| | Feature phone | 139 | 91 |
| | Total | 152 | 100 |
| | **Level of education (N=171)** | | |
| | Informal education | 57 | 33 |
| | Primary school | 103 | 60 |
| | Secondary school | 10 | 6 |
| | Tertiary/University | 1 | 1 |
| | Total | 171 | 100 |
| | **Mobile phone usage (N=144)** | | |
| | Sending and receiving SMS | 114 | 39 |
| | Making and receiving calls (including Robocalls) | 141 | 48 |
| | Surfing the Internet | 10 | 3 |
| | Social network | 11 | 4 |
| | Other use | 19 | 6 |
| | Total | 295 | 100 |
| B | **District Name: Magharibi A, Zanzibar**<br>**Villages Involved: Mwera, Kianga, Dole, Kizimbani, Bumbwisudi, Mwakaje, Mfenesini, Chuini, Kama and Mbuzini**<br>**(Hashimu, 2018)** | | |
| | **Type of mobile phones owned (N=383)** | | |
| | Smartphone | 14 | 4 |
| | Feature phone | 365 | 95 |
| | Both types | 4 | 1 |
| | Total | 383 | 100 |
| | **Level of education (N=383)** | | |
| | Informal education | 62 | 16 |
| | Primary school | 153 | 40 |
| | Secondary school | 164 | 42 |
| | Tertiary/University | 4 | 2 |
| | Total | 383 | 100 |
| | **Mobile phone usage (N=177)** | | |
| | SMS | 95 | 53 |
| | Call | 72 | 41 |
| | Call and SMS | 10 | 6 |
| | Total | 177 | 100 |

| | | | |
|---|---|---|---|
| **C** | **District Name: Mpwapwa, Tanzania Main Land**<br>**Villages Involved: Tambi, Mlembule, Mwenzele**<br>(Juma, 2019) | | |
| | **Type of mobile phones owned (N=350)** | | |
| | Smartphone | 129 | 37 |
| | Feature phone | 221 | 63 |
| | Total | 350 | 100 |
| | **Level of education (N=350)** | | |
| | Informal education | 0 | 0 |
| | Primary school | 56 | 16 |
| | Secondary school | 155 | 44 |
| | Tertiary/University | 139 | 40 |
| | Total | 350 | 100 |
| | **Mobile phone usage (N=350)** | | |
| | Preference on receiving SMS | | |
| | No | 48 | 14 |
| | Yes | 302 | 86 |
| | Total | 350 | 100 |
| | Social Media and Access to Farm Input Information | | |
| | No | 299 | 15 |
| | Yes | 51 | 85 |
| | Total | 350 | 100 |

## Recommended and Integrated Mobile Technology Animal Disease Surveillance Framework

The study proposes an animal disease surveillance framework that accommodates animal diseases prediction models and various stakeholders for sharing surveillance data (**Figure 3**). The framework comprises an Integrated Mobile Technology Animal Disease Surveillance System that accepts and disseminate data to existing animal disease prediction models and mobile-based surveillance systems in the country, e.g. AfyaData and EMA-I, through system interoperability (**Figure 3**)(Respickius, 2016). The system also accepts and disseminate data to the regional bodies and international surveillance systems such as the Animal Resources Information System of the African Union-International Bureau of Animal Resources (ARIS-AU-IBAR), FAO-Empres-i and OIE World Animal Health Information System (OIE-WAHIS) (AU-IBAR, 2019; FAO, 2021; OIE, 2021). Apart from accepting and disseminating data to other existing surveillance systems, prediction models and regional bodies, through the mobile technologies such as Robocalls, Short Message Service (SMS), and Unstructured Supplementary Service Data (USSD), without the internet connection the system provides access to the majority of livestock keepers owning feature mobile phone (The Conversation, 2019; TTEC, 2021). Technically, SMS, USSD, Robocalls will benefit those with a primary school level education or above who believed they could read and write SMS, use the USSD menu and respond to voice calls (**Table 3**).

In contrast, Robocalls alone will benefit those with no former education and can not read and write SMS, use the USSD menu but can respond to voice calls. However, SMS, USSD and Robocalls will satisfy most livestock keepers because the majority own feature mobile phones (**Table 3**). Technologies provide flexibility to livestock keepers to report disease outbreaks/incidents to the system and to receive disease-related information from the system regardless of their demographic characteristics. Apart from livestock keepers the system also provides access to other top-level stakeholders through its web interface, i.e. Field Veterinarian Officers, District Veterinarian Officers, Regional Veterinarian Officers, Zonal Veterinarian Officers and National Veterinarian Officers, researchers and laboratories. Rather than sharing data among themselves through the system, top-level stakeholders also are responsible for registering livestock keepers, verifying diseases reported cases by livestock keeper and uploading disease-related information to the system, e.g. disease awareness information before being accessed by livestock keepers and the public in general (**Figure 3, 4, 6, 7 & 9**). In addition, the surveillance system integrates animal disease prediction models for forecasting disease disasters to prevent disease impacts on livestock keepers (Ashar et al., 2021). Animal disease prediction models play a significant role when dealing with contagious diseases like Foot and Mouth Disease (FMD), which requires more attention and prevention measures. Therefore, realising the importance and presence of various animal disease prediction models in the country, this study proposes their inclusion in the Integrated Mobile Technology Animal Disease Surveillance framework (**Figure 3**).

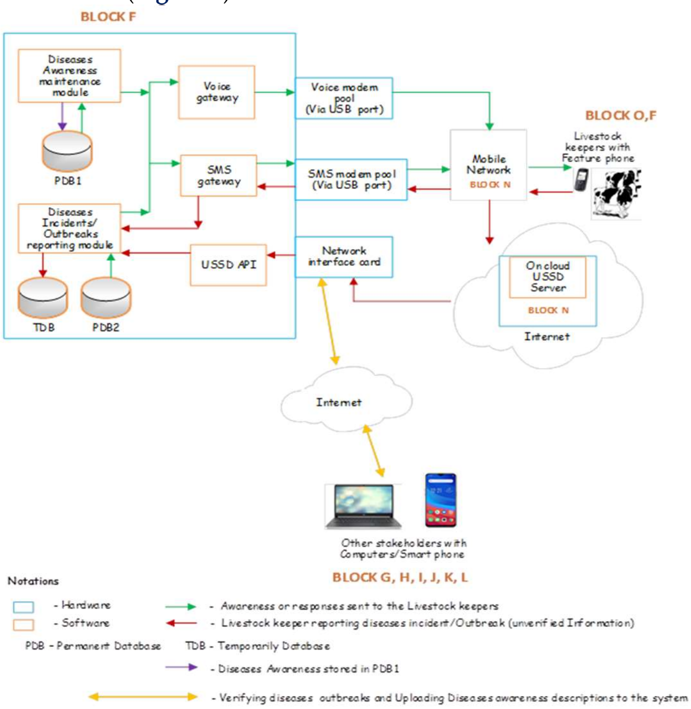


**Figure 4.** Architecture for the Implementation of SMS, USSD and Robocalls services

## IMPLEMENTATION OF SMS, USSD AND ROBOCALLS OF AN INTEGRATED MOBILE TECHNOLOGY ANIMAL DISEASE SURVEILLANCE SYSTEM

An Integrated Mobile Technology Animal Disease Surveillance System is a web-based system like other famous animal disease surveillance systems, but with extra functionality such as SMS, USSD code services, and automatic voice calls (Robocalls) (**Figure 3, 4, 6-9**).

### System Architecture

The system was developed using PHP hypertext processor, JQuery, HTML, MySQL database, Apache web server, JSON, and JavaScript. The MySQL database and Apache web server were available by installing the XAMPP software package. The SMS gateway and voice gateway is installed in the system for providing voice and SMS broadcast services (Diafaan, 2021; SMSDeliverer, 2021). The SMS modem and voice modem were attached to the server hardware via USB ports (**Figure 4**). The modems are connected to the SMS and a voice gateway through the software's setting menu. An Integrated Mobile Technology Animal Disease Surveillance System comprises two modules: (a) Animals diseases awareness maintenance module and (b) Animals diseases incidents/outbreaks reporting module.

### Descriptions for System Components

#### Diseases Awareness Maintenance Module

This module regularly broadcast diseases precaution measures, clinical signs and negative impacts in the form of SMS and voice to livestock keepers. The researchers, laboratories, regional and local VET officers store this information in permanent database 1 together with their broadcasting time interval (**Figure 9**). The data uploaded to the system is either the name of a prerecorded audio file (.wav) or the text descriptions of the disease awareness. However, the actual prerecorded audio file (. wav) is uploaded to the voice modem using the voice gateway software (SMSDeliverer, 2021). The module compares the last broadcast time of each stored diseases awareness with the operating system time. If the difference between them is greater than the assigned diseases awareness broadcast time interval, the system broadcast that particular diseases awareness to livestock keepers. The process repeats every 30 seconds. The text descriptions were broadcast to all livestock keepers in the form of SMS using SMS gateway through the SMS modem. Similarly, the voice file is sent as an automatic voice call (Robocalls) using a voice gateway through the voice modem.

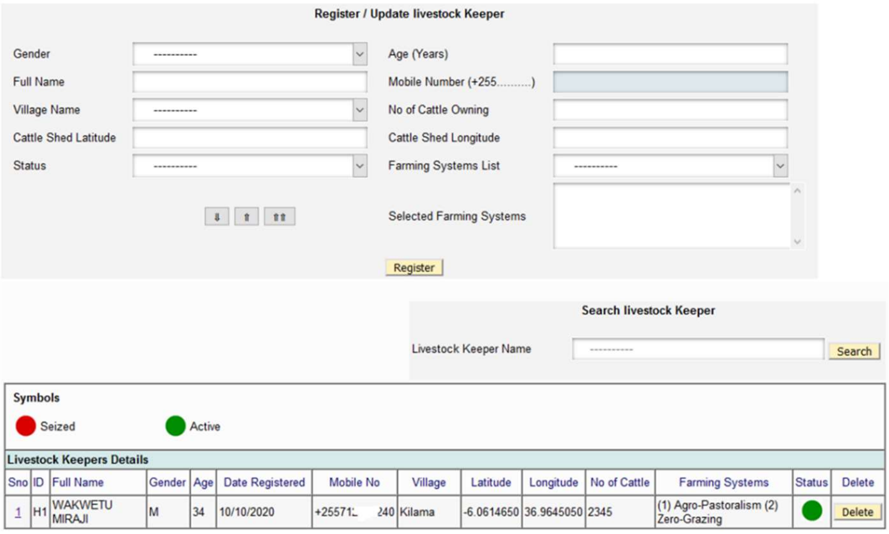


**Figure 5.** Livestock keeper's registration form

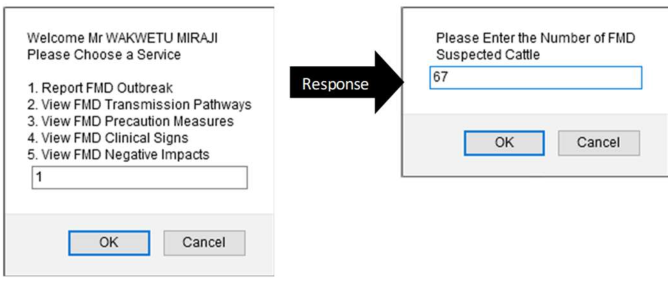


**Figure 6.** Reporting FMD outbreak using USSD menu

#### Diseases Incidents/Outbreaks Reporting Module

The livestock keepers my report the diseases outbreaks using USSD by dialling a specific USSD code e.g. *150.78#(**Figure 6**). When the request is initialized, a USSD menu will pop up with options (e.g. 1- Report FMD Outbreak, 2 – View FMD Transmision Pathways, 3-View FMD Precaution Measures) that allow livestock keeper to choose a service (**Figure 6**). Livestock keeper may report disease outbreaks by selecting repectively option e.g. Option number 1 for reporting Foot and Mouth Disease outbreaks (**Figure 6**). The alternative way is to send the village number to the system using SMS. Once the information received to the system is tagged as unverified and stored in the temporary database (TB) (**Figure 4 & 7**). The system captures mobile phone numbers of the livestock keepers whenever they report diseases incidents/outbreaks via USSD code or SMS. The veterinarians use the stored mobile phone numbers for tracing up the validity of the information immediately. If the temporary information is valid, the system transfers them to the permanent database 2 (PDB2) after the veterinarian clicks the confirmation button on the web page based on his privilege.

Consequently, the audio message and SMS sent to all livestock keepers, informing them about the outbreak and immediate precaution measures. Otherwise, the system deletes unverified information from a temporary database after the veterinarians click the discard button and feedback sent to only the one who reported the incident, informing him that the information was invalid. Anybody can view the number of unverified and valid incidents on the system home page.

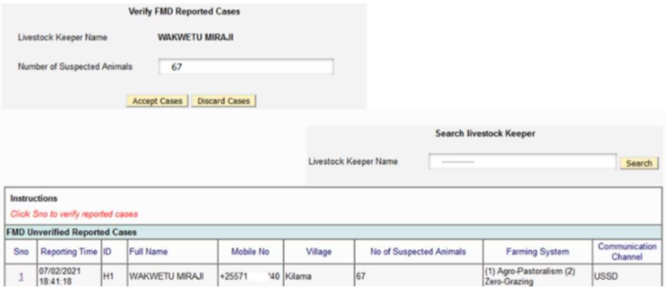


Figure 7. Verifying FMD reported cases

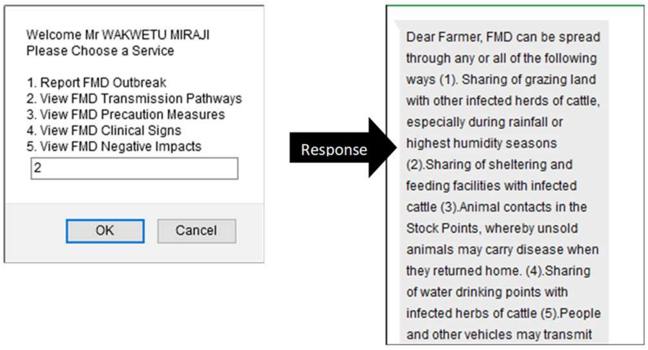


Figure 8. Accessing FMD transmission pathways using the USSD menu

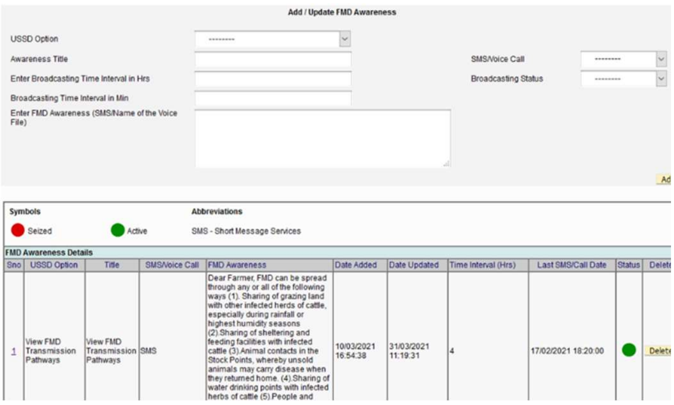


Figure 9. Uploading FMD awareness description to the system

### Voice Gateway

SMS Deliverer was used as a voice gateway for broadcasting voice (SMSDeliverer, 2021). Voice gateway provides automatic voice call services by broadcasting diseases awareness; diseases incident or outbreak prerecorded audio files to livestock keepers through the voice modem pool attached to the server via USB port (**Figure 4**). The voice gateway acts as a communication interface between the diseases monitoring system and the voice modem pool. The actual prerecorded audio files are stored in the modem using the voice setting panel of voice gateway software. The information system may broadcast a specific audio file by referring to its file name in permanent database 1 (PDB1) and database 2 (PDB2) (**Figure 4**). The modules use HTTP GET request to broadcast the prerecorded audio file by specifying the audio file name with the request. Therefore, the HTTP GET request acts like a simple API that connects the diseases monitoring system and voice gateway.

### SMS Gateway

Diafaan SMS Server was used as an SMS gateway. SMS gateway provides SMS services by broadcasting diseases awareness, diseases incident or outbreak descriptions to livestock keepers via SMS modem pool connected to the server (**Figure 4, 8 & 9**) (Diafaan, 2021). The SMS modem pool is connected to the server via a USB port. The SMS gateway act as a communication interface between the diseases monitoring system and the SMS modem pool.

### Voice Modem Pool

3G SIMCOM modem pool with 4 ports was used for voice broadcasting (China.cn, 2021). Any modem pool with the capability of SIMCOM modems can be used. Each modem contains a SIM card for accessing the mobile network. The SIMCOM are modems with the ability to execute "AT" commands and store audio files in (. wav) format. The prerecorded audio files were inserted into the modem using the voice gateway software (SMSDeliverer, 2021). The monitoring system plays the audio files by referring to their names in permanent PDB1 and PDB2 (**Figure 4**).

### SMS Modem Pool

Huawei modem E220 was used for routing SMS. The four Huawei E220 modems are connected using a USB hub to form a modem pool. Each modem contains a SIM card for accessing the mobile network.

### Feature Phones

Enables communication between livestock keepers and Integrated Mobile Technology Animal Disease Surveillance System

### USSD Application Program Interface (API)

The USSD application program interface is a part of the diseases incident/outbreaks reporting module. The API enables communication between the cloud USSD server and the system (USSD, 2021). The API periodically queries the newly reported outbreak information (number of suspected cases and reporter mobile phone number) from the USSD server and stores it in the temporary database.

### Smartphones and Computers

Smartphones and computers enable veterinarians to verify the reported outbreak information. Also, other stakeholders may use Smartphones and computers to access the system because it is web-based (**Figure 5, 7 & 9**).

### Sample Outputs

Only registered livestock keepers will access the system (**Figure 5**). Top-level stakeholders have the privilege to register livestock keepers particulars to the system. **Figure 6** indicates the mobile phone screen of the livestock keeper registered in **Figure 5**, reporting to the system 67 suspected Foot and Mouth Disease (FMD) cattle cases by selecting option number 1 of the USSD menu appearing after dialling a specific USSD code. Also, **Figure 7** indicates top-level stakeholders verifying 67 FMD reported cases to the system by clicking either accept cases or the discard cases button. **Figure 8** indicates livestock keeper mobile phone screen viewing FMD transmission pathways uploaded on the system by top-level stakeholders (**Figure 9**).

## CONCLUSION

The integrated animal diseases surveillance framework would provide a common platform for sharing surveillance data among livestock stakeholders in Tanzania. The platform would enhance timely information sharing between livestock stakeholders in the country. Thus, it will enable animal disease awareness maintenance, animal disease early detection and timely response. However, its smooth operation depends on the commitment of its components (third party application software, livestock keepers and Ministries) since they are operationally dependent on each other. Therefore, this study suggests that the Tanzanian government should impose a solid policy that governs the overall framework operation by providing directives to users and entities to enhance seriousness during its implementation. The policy should elaborate in detail on the technical, administratively and legal issues pertaining the framework operation to its users and entities. For example, administratively, the policy should explain the privileges of each user and entity on the data access. Similarly, technically the policy should describe how third-party applications (existing Mobile-based and Web-based animal diseases surveillance systems) would share data with the framework. Also, policy should legally explain the remedies if the user or an entity breaches the rules and regulations.

This study also observed the existence of valuable literature from research institution repositories. If the materials were shared through the proper channels, increasing their visibility would provide new solutions for the problems facing the Ministries responsible for animal diseases control or improve the existing solutions offered by the research institutions in the country. For example, the current animal diseases surveillance systems failed to include animal disease prediction modules regardless of the presence of various mathematical models from academic institutions describing the distribution behaviour of different animal diseases. However, it could be easily achieved by collaboration between experts/stakeholders through proper knowledge-sharing channels.

On the other hand, this study explained the implementation of the USSD code, Robocalls, and SMS functionalities, which are crucial for communication between livestock keepers and other top-level stakeholders. The implementation of other framework functionalities, including the interoperability between the existing animal diseases surveillance system and the proposed integrated mobile technology animal disease surveillance system, were left for more research. Lastly, this study advises other countries to examine their livestock keeping communities' demographics data which could provide valuable information for solving different challenges that hinders their livestock sector that would probably minimize unnecessary cost incurred when opting for more advanced solutions.

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