AN INVESTIGATION OF ICT-BASED MALARIA INTERVENTION FRAMEWORK FOR RURAL COMMUNITIES

By

ELLIOT MBUNGE

(21855551)

A thesis submitted in fulfilment of the requirements for the

Doctor of Philosophy in Information Technology in the Faculty of Accounting and Informatics at the Durban University of Technology

Supervisor: Professor Richard Millham

Co-supervisor: Professor Maureen Nokuthula Sibiya

Co-supervisor: Dr Sam Takavarasha Jr

Declaration

I**, ELLIOT MBUNGE**, student ID: **21855551**, declare that this thesis is the representation of my work that has neither been submitted to any higher institutions of learning nor other universities in any form except at the Durban University of Technology. Published literature and other sources used in this dissertation have been acknowledged and or referenced in the list of references.

________07/11/2022_______

Elliot Mbunge (21855551) Date

Approved for final submission

Supervisor ________________________ ___________________

Professor Richard Millham Date

Dedication

To my family and parents (Rackinosi Gozhorai Mbunge and Evelyn Mbunge), I dedicate this thesis to you.

Acknowledgements

I would like to express my greatest appreciation to my supervisors, Professor Richard Millham, Professor Nokuthula Sibiya and Dr Sam Takavarasha Jr for their tremendous guidance, comments, support, advice, and encouragement from the beginning of my study to completion. Without them, it would have been impossible to complete.

To my family and parents, your patience, emotional support, care, and words of encouragement during trying times helped me to progress and complete this study. I extend my greatest appreciation to friends and families, specifically Dr Bimha and his family for your support and prayers during my study.

I am forever thankful to the Department of Information Technology and the Durban University of Technology for allowing me to pursue my academic career. Without such an opportunity I could not be celebrating completing this study. I would like to thank staff members in the Department of Information Technology and the postgraduate coordinator and the entire staff members of the Faculty of Accounting and Informatics for your support.

Above all, I would like to thank almighty God for giving me the strength, courage and wisdom to carry out this study to completion.

List of Publications

This dissertation produced the following journal articles and conference papers published in DHET-approved journals and conferences:

1. Mbunge, E., Millham, R. C., Sibiya, M. N., & Takavarasha, S. (2021). Diverging Mobile Technology's Cognitive Techniques into Tackling Malaria in Sub-Saharan Africa: A Review. *Lecture Notes in Networks and Systems*, *232 LNNS*, 679-699. https://doi.org/10.1007/978-3-030-90318-3_54 [Springer]

2. Mbunge, E., Millham, R., Sibiya, M. N., & Takavarasha, S. (2020). Application of machine learning models to predict malaria using malaria cases and environmental risk factors. 2022 Conference on Information Communications Technology and Society (ICTAS), 2022, 1-5, https://doi.org/10.1109/ICTAS53252.2022.9744657. [IEEE]

3. Mbunge, E., Sibiya, M. N., Millham, R. C., & Takavarasha, S. (2021a). Micro-spatial modelling of malaria cases and environmental risk factors in Buhera rural district, Zimbabwe. *2021 Conference on Information Communications Technology and Society, ICTAS 2021 - Proceedings*, 52-58. https://doi.org/10.1109/ICTAS50802.2021.9394987 [IEEE]

4. Mbunge, E., Sibiya, M. N., Millham, R. C., & Takavarasha, S. (2021b). m-Health framework for improving malaria information dissemination in Buhera rural district amid COVID-19 and beyond. *2021 Conference on Information Communications Technology and Society, ICTAS 2021 Proceedings*, 59-66. https://doi.org/10.1109/ictas50802.2021.9395020 [IEEE]

5. Mbunge, E., Millham, R., Sibiya, M. N., & Takavarasha, S. (2021). Is malaria elimination a distant dream? Reconsidering malaria elimination strategies in Zimbabwe. *Public Health in Practice*, **2**, 100168. https://doi.org/10.1016/J.PUHIP.2021.100168 [Elsevier]

6. Mbunge, E., Millham, R., Sibiya, M. N., & Takavarasha, S. (2022). Modified UTAUT model: Modelling predictors for the adoption of mobile phone-based malaria interventions in vulnerable rural communities. *Scientific African.* [Elsevier]

7. Mbunge, E., Millham, R., Sibiya, M. N., & Takavarasha, S. (2022). Leveraging mobile health applications to improve malaria healthcare service delivery in resource-constrained rural communities in Zimbabwe: implications for practice and policy. *Human Behavior and Emerging Technologies* [Hindawi]

8. Mbunge, E., Millham, R., Sibiya, M. N., & Takavarasha, S. (2022). Machine learning techniques for predicting malaria: unpacking emerging challenges and opportunities for tackling malaria in sub-Saharan Africa. *12th Computer Science Conference 2023* [Springer]

Abstract

Malaria remains a significant public health challenge in many sub-Saharan countries. The United Nations through member states launched Sustainable Development Goal 3.3, to end endemic malaria by 2030. Despite these concerted efforts, malaria continues to decimate people, especially in malaria-endemic countries, including Zimbabwe. Malaria predominantly affects poor rural and resource-constrained areas where it places a very high burden on communities. In addition, the outbreak of coronavirus disease 2019 (COVID-19) tenaciously challenged the progress made in the previous years to combat malaria in endemic areas by forcing the reallocation of resources devoted to fighting malaria to fight COVID-19. This caused a drastic change in prevention and control measures. Indoor residual spraying, long-lasting insecticide-treated nets, and community behaviour change communication are among malaria control and prevention measures. Currently, hospitals and clinics use awareness campaigns, religious institutions, community meetings, community health workers, brochures, posters, billboards, newspapers, television, radio, and community dramas to convey malaria information. These traditional awareness strategies failed to achieve the anticipated results. More so, there is a non-existent technology-based framework for multi-sectoral linkages, collaboration, integration, and deployment of ICT-based malaria intervention in the Zimbabwean health system. This research addresses that gap by investigating a technology-based framework that supports the integration of feasible technologies to disseminate malaria information in rural communities.

This study applied convergent parallel mixed methodology, quasi-experimental design, document analysis and design science research (DSR) methodology. The DSR was utilised to guide the development, refinement, and deployment of the proposed prototype. The document analysis was used to determine the most feasible technology. Also, previous malaria cases from the District of Health Information System (DHIS) were used for mapping hotspot areas and predicting malaria in hotspot wards using Quantum Geographic Information System (QGIS) and machine learning techniques, respectively. The quasi-experimental design was utilised to gather information in two phases (pre-test and post-test). The pre-test stage focused on gathering prototype user requirements before developing the artefact. The post-test phase

concentrated on testing and assessing the adoption and acceptance of the proposed prototype. The acceptance and adoption of the proposed prototype was done through the modified unified theory of acceptance and use of technology (UTAUT) model.

The study revealed that mobile phones, radio, television, and social media platforms were the most common ICTs used to disseminate information. Among ICTs, mobile phones are the most prominent mobile technology used for bidirectional communication and mobile money transaction in rural communities. However, the absence of policies on mobile health, technological and infrastructure barriers, poor power supply, digital illiteracy, inadequate funding, language barriers, and religious barriers were factors hindering the adoption and utilisation of ICTs in resource-constrained rural areas. The findings of this research also revealed that machine learning techniques play an imperative role in predicting malaria in hotspot wards. The study applied logistic regression (LR), decision trees (DT) and support vector machines (SVM) to predict malaria in hotspot wards. LR performed better, with an accuracy of 83%, a precision of 82%, and an F1-score of 90% using environmental data and malaria incidences. These machine learning models can assist policymakers in developing and deploying malaria early warning digital tools and optimising the distribution of resources in sporadic areas.

The study modelled predictors for adopting mobile health interventions by healthcare professionals in Buhera rural community. The study utilised a modified UTAUT model and Smart-PLS to test several hypotheses. The study revealed that social influence, facilitating conditions, and effort expectancy facilitate the adoption of mobile phone-based interventions to create malaria awareness, reporting, and surveillance as well as sharing and receiving malaria data between satellite health centres. Among these predictors, facilitating conditions and effort expectancy influence health workers' attitudes to using mobile phone-based malaria interventions. Furthermore, the study developed a mobile health framework for disseminating malaria information in resource-constrained rural communities. The proposed framework consists of surveillance activities, mobile health interventions and health facilities. This is an additional uniqueness of this study as it incorporates feasible digital technologies to disseminate health information in rural communities within Zimbabwe's existing health

system structure. This includes the Ministry of Health of Child Care (National Malaria Control Programme), Provincial Medical Office, District referral hospital, and satellite health centres. However, the study also revealed that the adoption of ICTs in rural health systems faces several impediments such as network connection barriers, inconsistent power supply, unavailability and inaccessibility of ICT infrastructure, lack of technical support and training, digital literacy, language barriers, absence of active e-health policies, insufficient funding, bureaucracy and religious barriers. There is a need to develop a mobile health framework and policy to guide the development and deployment of mobile health applications, improve ICT infrastructure and network coverage in rural communities, develop community networks to improve internet access and connectivity, promote public-private partnerships and develop robust strategies for sustainable funding of m-Health projects and applications deployed to improve access to care, especially in resource-constrained rural communities.

List of Figures

List of Tables

List of Acronyms

ACT: Artemisinin-based combination therapy

ART: Antiretroviral therapy

ANN: Artificial neural networks

CHIRPS: Climate hazards group infrared precipitation with station data

COVID-19: Coronavirus disease 2019

EVI: Enhanced Vegetation Index

GSM: Global System for Mobile Communication Technology

GWPR: Geographically Weighted Poison Regression

GWR: Geographically Weighted Regression

HIPAA: Health Insurance Portability and Accountability Act

HMIS: Health Management Information System

IEC: Information and Education Communication

IRS: Indoor Residual Spraying

ITN: Insecticide-treated Nets

IPTp: Intermittent preventative treatment in pregnancy

LLIN: Long-lasting insecticidal nets

GIS: Geographic Information Systems

LST: Land surface temperature

m-Health: mobile health technology

MODIS: Moderate Resolution Imaging Spectroradiometer

MoHCC: Ministry of Health and Child Care

MoPSE: Ministry of Primary and Secondary Education

MRCZ: Medical Research Council of Zimbabwe

NMCP: National Malaria Control Programme

NDVI: Normalised Difference Vegetation Index

PMI: President's Malaria Initiative

POTRAZ: Postal and Telecommunications Regulatory Authority of Zimbabwe

RDT: Rapid diagnostic test

SBCC: Social and behaviour change communication

SMS: Short message service

s-GWLR: semi-parametric geographically weighted logistic regression

SMOTE: Synthetic minority oversampling technique

SVM: Support Vector Machine

TLV: Threshold Limit Value

SSA: sub-Saharan Africa

USSD: Unstructured Supplementary Service Data

VIF: Variance inflation vector

WDSS: Weekly Disease Surveillance System

WHO: World Health Organization

Table of Contents

CHAPTER 1: INTRODUCTION

1.1 Background

The incessant and drastic change in the digital world calls for the adoption of feasible and sustainable digital technologies in healthcare (Faggini et al., 2018) to improve operational processes, health literacy, service delivery, health digital awareness and information dissemination. Digital technology can act as a catalyst for sustainable development in both developed and developing economies in various sectors including health, education, mining, and telecommunication. Digital technologies may be termed as encompassing all Information and Communication Technology (ICT) that performs several functions including capturing, storing, processing and disseminating information electronically (Rouleau et al., 2017). The adoption of ICTs I s inevitable, especially in health systems because of the increasing demand to provide and ensure quality healthcare services delivery (Lo Presti et al., 2019) and well-being across all ages regardless of locality. In the realm of health, ICTs involve the use of telehealth, telemedicine, electronic health records (EHR) and mobile technology (McLay et al., 2020) to provide healthcare services. These modern digital technologies are transforming, redefining, redesigning and continuously offering unprecedented opportunities in the healthcare systems of both developing and developed countries (Fertleman et al., 2018). Modern digital technologies can substantially improve healthcare services delivery, health communication, health promotion, education and also bridge the health literacy gap.

Telemedicine is defined as the electronic information dissemination technologies that support virtual healthcare services delivery and ultimately improve access to care (Kichloo et al., 2020). However, telehealth and telemedicine are interchangeably used in the health system despite their obvious uniqueness in referents. According to Combi et al. (2016) and Traube et al. (2020), both technologies use electronic means to transfer health information in remote health centres. However, the distinguishing characteristic of telehealth and telemedicine is the reliance on the broad scope of remote healthcare services using ICTs. According to McLean et al. (2013), telehealth involves the utilisation of digital technologies to support health education, telemedicine and medical education over a distance, while Combi et al. (2016) describe telemedicine as a technology that uses advanced telecommunication technologies to provide health care services and health information across time, geographic, social and cultural barriers. To draw a distinction and understand the juxtaposition of telehealth and telemedicine, Kumar et al. (2013) and McLean et al. (2013) explicitly describe telemedicine as the diagnosis and treatment of patients who are geographically separated from healthcare providers, while telehealth focuses on the delivery and exchange of health information. Therefore, telehealth involves the transmission of health data and information including texts, images, videos and audio files over both short and long distances rather than moving care recipients, and health workers.

Modern digital technologies have created interesting and unexpected possibilities in many health systems by connecting users, patients, and healthcare professionals globally. However, the effective implementation of emerging digital technologies in developing countries, especially in remote rural settings, faces intransigent challenges due to technical difficulties, power outages, digital literacy levels, poor telecommunication networks, heavy investments required to acquire equipment, limited access to mobile phones, poor access to travel incentive in case of emergencies as well as legal obstacles (Akhlaq et al., 2016). Such problems have resulted in a resurgence of several diseases including cancer (Moodley et al., 2019) and malaria, particularly in resource-constrained areas as highlighted by Palombi and Moramarco (2018). Also, Espinoza (2019) states that resource-constrained countries are associated with a low gross domestic product (GDP), and a dearth of readily available cost-effective and sustainable information dissemination tools and adequate infrastructure to provide sufficient efficacy for disease prevention and control in marginalised remote areas.

Even though some countries introduced Health Information Systems (HIS) to collect, maintain, share, retrieve and secure patients' data for further processing to improve efficiency and quality of care, its adoption is still nascent in some sub-Saharan countries such as Zimbabwe (Khumalo & Mnjama, 2018). Health information systems help organisations and health institutions to create a synergistic relationship to plan, organise, control and initialise health system operations to improve patient care (Mohamadali & Aziz, 2017), enable concurrent access to health data and make recommendations for improving healthcare services (Serrano et al., 2020). However, Mohamadali and Aziz (2017) point out that despite the overwhelming benefits of HIS, some of the barriers such as lack of internet, lack of HIS integration standards and practice, lack of security and privacy, inadequate equipment and lack of HIS professionals still deter its full implementation and adoption.

1.2 The context of the research

The increased penetration of mobile technologies in Zimbabwe presents unprecedented opportunities in the health system to adopt and elevate digital technologies that support health awareness, health education, health communication, knowledge transfer and influencing individuals and the community's health behavioural change. ICTs are increasingly becoming an enabling fundamental tool to improve the healthcare system and address economic and social problems (Aceto et al., 2018). ICTs do not work in isolation; therefore, they should be integrated into the health sector to connect people and healthcare professionals in different locations. The integration of ICTs into the health system includes the use of a variety of electronic methods to manage patients' data, share and disseminate health information. The electronic methods encompass health information systems, clinical decision support systems, computerised databases for diseases, electronic medical record systems, telehealth, electronic prescribing, and electronic pharmacies. However, it is also difficult to integrate such electronic methods into the health system without a clear ICT integration and supporting health policy framework (Omotosho et al., 2019). This might cause some challenges in accessing and processing health data as postulated by Khumalo (2017) who argues that the paper-based health record system constantly gathers and stores data which is sometimes inaccessible and improperly formatted for further analysis.

Zimbabwe's Ministry of Health and Child Care (MoHCC) introduced the district health information system (DHIS) and service applications and products (SAP) to support electronic health and maintain patient records at the central hospital in Harare (Furusa & Coleman, 2018). The DHIS was rolled out in 2010 in all government hospitals to capture patients' details, as well as to analyse and survey disease prevalence. However, Furusa and Coleman (2018) further highlight that DHIS does not consider clinical care services including disease awareness, health promotion, disease prevention and control. A report from the MoHCC on Zimbabwe's e-Health Strategy 2012-2017 highlighted that there is a lack of guidelines to coordinate the development, implementation, and integration of e-health applications. Consequently, this leads to duplication of mobile health applications tested and deployed in various health centres which are sometimes incompatible with existing national health information systems. As a result, health service providers encounter several impediments such as multiple entries of patients' records, poor services provision, and inconsistent patient records formatting. In support, Waters et al. (2017) also noted that there are some inconsistencies in the standards and guidelines regulating the development and implementation of regional health information systems. This hinders the remote access and sharing of health data, as well as synchronisation of e-health applications which in turn substantially affects the planning and decision-making process as well as the tracking and monitoring of diseases at a regional level. In addition, a report from the National Health Strategy for Zimbabwe (2014) states that NHIS also experiences challenges including a lack of real-time mobile health applications integrated with the HIS to synchronise health data in real-time from the ward level to the national level. This affects the timely production of complete and reliable health information daily for improved health monitoring and surveillance of diseases.

Several companies in Zimbabwe, including Econet Wireless, introduced EcoHealth – which is a mobile phone health advisory service. Econet Wireless subscribers receive health tips via SMSs that are randomly distributed and not customised (Musesengwa & Chimbari, 2017). In addition to mobile health applications, in 2014, the Ministry launched the Frontline short messaging service (SMS) Weekly Disease Surveillance System (WDSS) which supports a bilateral mobile messaging system between health workers (Mbunge et al., 2020). The Frontline SMS WDSS transmits health data using text messages to the DHIS. Unfortunately, this platform is specifically used by healthcare professionals to perform administrative work in different healthcare centres (Furusa & Coleman, 2018; Masuku, 2019). The system does not support universal access and distribution of information between healthcare professionals and recipients of care. Apart from the yearly subscription costs of Frontline SMS WDSS, Furusa and Coleman (2018) state that Frontline SMS WDSS is not integrated with DHIS to enable real-time and concurrent sharing of information at the district level to ensure effective disease surveillance in the country.

The Ministry of ICT and MoHCC launched several pilot projects namely, electronic health records (EHR) and telemedicine in Mashonaland East in Uzumba-Maramba-Pfungwe rural district and Manicaland province in 2015 and 2016, respectively (Furusa & Coleman, 2018). The progress of these pilot projects was grossly affected by the economic situation exacerbated by the global recession, inflation, inconsistent monetary policy (Mhlanga & Ndhlovu, 2021) and political instability (Hove & Chenzi, 2020). Consequently, this affected the procurement of ICT infrastructure (Chidhau et al., 2021a) leading to the closure of some companies due to the lack of resources, brain drain of trained personnel (Moyo & Madziyire, 2020), and the decline in business confidence and financial illiquidity causing donors to withdraw from funding projects (Pride & Tatenda, 2017). This, therefore, poses tremendous challenges in disease prevention, monitoring, and control; especially in resource-constrained rural areas. In such areas, the outbreak of diseases such as malaria, cholera and other infectious diseases is inevitable. This is attributed to a lack of effective disease surveillance systems (Chitungo, Mhango, Mbunge, et al., 2021), poor sanitation and hygiene practices (Nhamo & Chikodzi, 2021), emerging health emergencies and natural disasters (Mukwenha et al., 2021), uneven distribution of health centres and healthcare professionals (Nhapi, 2019; Smythe et al., 2022) and poor ICT supporting infrastructure (Furusa & Coleman, 2018). Buhera district is a resource-constrained rural community located in Manicaland province which experiences malaria outbreaks. Most recently, Cyclone Idai caused devastation leading to further malaria and cholera vulnerability in Manicaland province (Mukwenha et al., 2021).

Therefore, this study aims to investigate digital technologies used to disseminate health information and create digital awareness pertaining to malaria in Buhera rural district, Zimbabwe. Thereafter, the study explores the use of feasible ICT-based malaria intervention in creating awareness in remote and resource-constrained areas in Buhera to improve communication through integration and incorporation of already existing technology including radio, television, mobile technologies, and internet-based interventions. This helps to accelerate technological innovation in healthcare service delivery in neglected and disadvantaged areas by bridging the existing communication gap between the villagers and healthcare professionals (Chiwara, 2012), and ultimately improves the awareness, malaria prevention and surveillance.

1.3 Research problem

A malaria report from WHO 2021 states that,

"*Globally, an estimated 241 million malaria cases and 627 000 malaria deaths were reported worldwide in 2020, showing a significant increase in global malaria cases as compared to 2019, with most of this increase coming from countries in the WHO African Region (228 million cases and 602 000 deaths).*"

Such an increase was exacerbated by recursive disruptions during the procurement of malaria commodities and temporary suspension of IRS activities (Nghochuzie et al., 2020) during the coronavirus disease 2019 (COVID-19) (Zawawi et al., 2020). The report further states that SSA reported high malaria incidences in 2020 (WHO, 2021).

Several milestones, policies and initiatives, such as Roll Back Malaria (RBM), Sustainable Development Goals, End Malaria and Elimination 8 Initiative, have been set in place to reduce the global malaria burden by 2030, and slow its catastrophic impact, especially in vulnerable communities (WHO, 2021). Such initiatives intensify existing and emerging malaria treatment, malaria control and interventions such as IRS, LLINs, intermittent preventive prophylaxis, development of strategies and digital tools for promoting positive behavioural change (Heuschen et al., 2021), malaria monitoring, reporting, surveillance, awareness and health promotion in sub-Saharan Africa (SSA) countries including Zimbabwe. Before COVID-19, there was positive progress in eliminating malaria in many SSA countries (WHO, 2021). However, Zimbabwe reported a significant rise in malaria incidences in 2020 as compared to 2018, of which most incidences were reported in Mashonaland East and Manicaland provinces despite concerted efforts to prevent this (Kusotera & Nhengu, 2020; Pellegrino et al., 2022). Malaria is preventable and treatable, but it remains the deadliest disease in the world, predominantly affecting people living in malarious resource-constrained areas in Zimbabwe (Gavi et al., 2021). A study conducted by Maseko and Nunu (2020) reported misuse of insecticide-treated nets especially in rural communities where LLINs are commonly used to catch fish, as selling nets, for granary purposes and as fowl runs to earn a living. The misuse of mosquito nets is orchestrated by the nature of social and economic challenges (Maseko & Nunu, 2020), lack of information, and lack of effective community engagement and awareness programmes (Larsen et al., 2018). Due to a lack of information, some people in rural communities do not believe that malaria exists. This is made evident by linking malaria signs and symptoms to witchcraft and consultation with traditional healers (O'Neill et al., 2015). Currently, hospitals and clinics use awareness campaigns, religious institutions, community meetings, community health workers (Prue et al., 2013), brochures, posters, billboards, newspapers, television, radio and community dramas to convey malaria information (Chiwara, 2012) and knowledge (Yaya et al., 2018). However, these awareness methods experience setbacks such as inadequate coverage, inequitable access (Tabassum et al., 2018), limited feedback (especially printed media, radio and television adverts) (Chiwara, 2012), the digital divide, printing costs, susceptibility to bad weather conditions (Yaya et al., 2018), movement restrictions especially during COVID-19 (Gavi et al., 2021), and illiteracy among others. Several studies including Mukora-Mutseyekwa et al. (2022) and Nyamambi et al. (2020) posit that language and illiteracy are among the communication barriers to conveying health-related information, especially printed posters, and charts. Such print media are usually written in foreign languages which probably leads to language discrepancies (Rugoho & Maphosa, 2017), literacy communication gaps (Murira et al., 2003) and linguistic differences in the rural populace (Meuter et al., 2015). Language barriers are a major deterrent to human knowledge transfer, especially in rural resource-constrained communities which ultimately results in miscommunication (Mukora-Mutseyekwa et al., 2022).

Therefore, traditional awareness strategies failed to reach the anticipated awareness level as indicated by Chiwara (2012). However, the adoption of feasible and emerging digital technologies in disseminating malaria information and creating malaria awareness is often overlooked. These technologies are key to connecting digitally disconnected vulnerable rural communities (Gavi et al., 2021). More so, there is a non-existent active mobile health framework for integrating and deploying emerging digital health technologies in the Zimbabwean health system. Also, Wouters et al. (2009), Moodley et al. (2019) and Pankomera & Greunen (2018) state that rural and marginal communities are usually affected by poor infrastructure, availability of sustainable technology, the digital divide, lack of proper m-Health policy and regulations, poor ICT governance and a high level of illiteracy. These challenges are intertwined especially in the Zimbabwean rural healthcare system due to the dearth of healthcare professionals (Dzinamarira & Musuka, 2021), poor digital awareness, uneven distribution of healthcare centres and unequal access to quality care (Smythe et al., 2022). Gavi et al. (2021) also highlighted the importance of integrating digital health technologies, especially mobile phone-based health interventions in rural health systems to alleviate malaria. The adoption of such technologies is still low in many SSA countries.

In addition to the lack of sustainable ICT-based information dissemination systems in resource-constrained communities, there is a need for mapping high malarial zones at the national and ward level to understand the spatial patterns of malaria cases (Gunda et al., 2017). Mapping malaria cases using emerging digital technologies helps to improve the allocation of resources at ward levels as the country tries to reach the pre-elimination phase in some provinces. However, there is very little literature published on the spatial patterns of malaria cases and correlated environmental data at the district scale in Zimbabwean rural communities that are vulnerable to malaria. Knowing and modelling malaria spatial patterns helps to identify and map malaria hotspots at the ward level and is imperative to predict malaria. Predicting malaria incidences in advance helps to know its devastating effects beforehand to effectively allocate resources, enhance malaria prevention and control measures, assist in strengthening malaria surveillance, and map malaria hotspot areas at the ward level.

1.4 Research aim

This study aimed to investigate an ICT-based malaria intervention framework to disseminate health information in rural communities.

1.5 Objectives of the study

Objectives of this research were to:

- Determine and analyse current strategies and information diffusion methods to help health promotion to manage malaria.
- Explore and implement the most feasible digital technology, which includes investigating mobile technology and alternatives, in order to bring about malaria health information dissemination and digital awareness, to reduce malaria incidences in rural communities.
- Develop an ICT intervention system to disseminate information in rural communities.
- Explore the views, attitudes and perceptions of healthcare professionals and communities towards the adoption and use of a low-cost malaria intervention system to disseminate malaria information.
- Develop a contextual m-Health framework for improving malaria information dissemination using feasible digital technology in resource-constrained areas.
- Map malaria hotspots and model micro-spatial patterns of malaria cases and environmental risk factors in malaria-endemic areas.
- Predict malaria outbreaks using malaria cases and environmental data in malaria-endemic rural areas.

1.6 Research questions

- What are the current strategies and information diffusion methods to help health promotion to manage malaria?
- How best to explore and implement the most feasible ICT technology, which includes investigating mobile technology and alternatives, for malaria health information dissemination and digital awareness, based on the previous investigation, to reduce malaria incidences in resource-constrained areas?
- How can a low-cost ICT intervention system be developed to enhance the secure transmission of health information in resource-constrained rural areas?
- What are the views, attitudes and perceptions of healthcare professionals towards the adoption and use of a low-cost malaria intervention system to disseminate malaria information?
- How can ICTs be integrated and adopted into Zimbabwe's health system?
- Can a contextual m-Health framework for improving malaria information dissemination be developed using feasible digital technology in resource-constrained areas?
- Are malaria cases linked to environmental risk factors in endemic areas and can these cases be modelled in micro-spatial patterns of malaria cases?

1.7 Significant contribution and uniqueness of the study

This study contributed to community development by designing, developing and implementing an ICT-based malaria intervention framework for rural communities. It was verified and validated within malaria hotspot areas and partially addresses problems, challenges and issues that led to the failure of past ICT systems that were deployed in the same context. The proposed ICT-based malaria intervention framework supports real-time and distant rural community interaction between people and health workers for further information processing, malaria monitoring, reporting and feedback. Furthermore, the proposed framework supports the customisation of messages to support the vernacular language as per population context and needs using mobile applications and short message services (SMS).

The previous ICT intervention systems were difficult to deploy due to the ever-growing population, complex socio-economic factors and most importantly, the exclusion of end-users' engagement in the development process. This was because of several factors including an unclear framework for integrating ICTs in healthcare, language barriers (Mukora-Mutseyekwa et al., 2022), unavailability of low-cost, feasible and customisable mobile health applications in healthcare service delivery (Zhou et al., 2015), lack of political will and funding (Chidhau et al., 2021a). This study partially addressed factors such as an unclear framework for integrating ICTs in healthcare, unavailability of mobile health applications to improve malaria healthcare services delivery in malaria hotspot areas and language barriers. This study developed a framework for integrating ICTs to improve communication in rural communities as well as building a malaria prototype mobile application that supports real-time malaria reporting and surveillance capacity.

Malaria reporting data can be further used to intensify malaria prevention, control, awareness, surveillance, clustering, mapping of malaria hotspots and prediction purposes. The unavailability of malaria data, the dearth of digital tools, inconsistent reporting and incomplete data ultimately affect the real-time mapping of malaria hotspots and the prediction of malaria outbreaks. Such challenges are prominent in rural communities because of poor ICT infrastructure (Chidhau et al., 2021a), digital literacy, intermittent network coverage (Furusa & Coleman, 2018), the digital divide, and inequitable access to healthcare (Zhou et al., 2015). In some cases, health workers utilise different data collection instruments to collect and store malaria data in different data formats, and sometimes there is limited sharing of health data across health systems (Zimbabwe’s E-Health Strategy 2012-2017). As a way of addressing that gap, the proposed ICT-based framework supports the inclusive participation of all stakeholders in the design, development, and deployment of ICT-based health digital tools in fighting malaria. The study further explores factors that promote effective integration of mobile phone-based health applications to improve rural healthcare services delivery, especially in resource-constrained areas. To achieve that, this study assessed and analysed factors that led to the failure of past ICT systems that were deployed in the same context and then explores the interplay between mobile phones and health workers that holds exceptional promise for the future development of feasible mobile phone-based health applications. This study also explores a framework for the integration and deployment of feasible mobile phone-based health applications in health systems.

Notably, recent technological advancements support the prediction and mapping of diseases as evidenced during the outbreak of COVID-19 (Agbehadji et al., 2020). However, there is limited literature on mapping malaria hotspots at the ward level by using reported malaria cases from the district health information systems. Some wards recursively record high malaria incidences and subsequently, these recorded incidences lead to high malaria cases at the national level (Takarinda et al., 2022a). Again, this study contributes significantly to this lack of mapping and predicting malaria by modelling micro-spatial patterns of malaria cases and then predicting malaria incidences in malaria hotspot wards. Since environmental risk factors significantly influence malaria outbreaks as indicated by Takarinda et al. (2022) and Maviza & Ahmed (2021), the study utilised reported malaria cases and environmental factors to develop a malaria incidences prediction model at the ward level. However, malaria intensity varies due to various factors such as inadequate resources, socio-economic factors, IRS activities, climatic conditions, malaria control measures adopted and also emerging pandemics such as COVID-19 (Manyangadze et al., 2021a; Takarinda et al., 2022a). Therefore, predicting malaria, especially in hotspots wards can effectively assist in allocating limited resources, updating malaria intervention policy, understanding the spatial variation of malaria (Manyangadze et al., 2021a), intensifying malaria awareness programmes, and optimising the allocation of IRS teams and equipment. Predicting malaria can tremendously assist the monitoring of malaria transmission at a local level and subsequently strengthen malaria control measures.

1.8 Research Hypothesis

To determine the perceptions of healthcare professionals towards the adoption and use of a low-cost malaria intervention system to disseminate malaria information, the research utilised the modified unified theory of acceptance and use of technology (UTAUT) to test the following research hypothesis:

The perceptions of healthcare professionals towards the malaria intervention system results in adopting and using technology to disseminate malaria information in resource-constrained areas.

The null hypothesis: The perceptions of healthcare professionals towards the malaria intervention system will not result in adopting and using technology to disseminate malaria information in resource-constrained areas.

1.9 STRUCTURE OF THESIS

Chapter 1: Introduction

This chapter describes the background of the research, the significance of the research study, the research problem, the research context, the research hypotheses and the structure of the dissertation.

Chapter 2: Literature review

This chapter provides a comprehensive analysis of ICT-based studies that were implemented by earlier researchers. Prior studies were reviewed to come up with a feasible and affordable ICT intervention system that met needs not met by other researchers. Furthermore, this chapter presents a comprehensive review of various digital health technologies applied in different countries to alleviate malaria in sub-Saharan Africa and identifies several research gaps for future studies. This chapter also presents machine learning concepts and their application in predicting malaria. Machine learning classification performance metrics are also presented in this chapter. In addition, several m-

Health frameworks for integrating digital interventions to tackle malaria in sub-Saharan Africa are comprehensively discussed in this chapter.

Chapter 3: Research Methodology

This chapter provides a thorough explanation of the research design and research strategy used to achieve research objectives, as well as data validity and reliability of data collected within this study. The research applied an interdisciplinary approach that combines design science research, parallel convergent mixed method and a quasi-experimental approach to guide the development of the proposed ICT-based malaria intervention framework for rural communities to improve communication, reporting, monitoring, and create malaria awareness. Furthermore, the study also analysed the existing literature to get more insights on previously deployed mobile health applications to tackle malaria in sub-Saharan Africa. In addition, the malaria dataset description, data pre-processing and tools for modelling malaria cases and predicting malaria outbreaks were comprehensively discussed in this chapter.

Chapter 4: Presentation of findings

This chapter focuses on the presentation of findings from the qualitative questionnaire and survey questionnaire issued to health workers and the community in the Buhera district. Also, this chapter presents confirmed malaria incidences from all health facilities in Buhera rural district. This chapter explains how research objectives were achieved by presenting findings gathered from the data collected from participants and malaria cases extracted from the Buhera district health information system. The findings in this chapter are used to determine the most feasible technologies to disseminate malaria information in Buhera.

Chapter 5: **Development and implementation of the ICT-based malaria intervention prototype**

This section focuses on the conceptual design including dataflow diagrams, Use Case diagrams, database design and context diagrams of the system. The architectural design includes the data capturing sub-system, SMS sub-system, malaria reporting sub-system, appointment sub-system, and the overall prototype. Each unit performs different functions and is further integrated into modules. Each unit is tested to check whether it conforms to user requirements. The methodology for the development of the prototype intervention system follows artefact development guidelines and principles of evolutionary prototyping methodology as per the design science methodology. Thereafter, this section focuses on the development tools and implementation of the proposed prototype. In addition to that, the technical requirements are discussed in this chapter.

Chapter 6: Prototype Evaluation and Adoption

This chapter explores the perception of health workers towards the use of the prototype to disseminate malaria information in resource-constrained rural areas. The prototype was tested and evaluated by health workers throughout the development phase as per design science principles. However, the overall evaluation of the prototype was done during the post-test phase of the quasi-experiment guided by a modified UTAUT model in Phase 2. To test the prototype, the study uses online survey questionnaires (different from the survey questionnaire used in Phase 1) to explore the perceptions of health workers towards the adoption of a low-cost malaria intervention prototype to disseminate malaria information. The modified unified theory of acceptance and use of technology (UTAUT) constructs are used to evaluate and assess the adoption of the proposed ICT-based malaria intervention by healthcare professionals to disseminate malaria information in the rural community.

Chapter 7: Mapping malaria hotspots and environmental risk factors

This chapter discusses the genesis of the DHIS, and the mapping of malaria incidences into their respective hotspot wards within the district. In addition, this chapter also presents the correlation and micro-spatial modelling of malaria incidences and the associated environmental factors in high malaria perennial hotspots - Chapanduka and Birchenough Bridge ward.

CHAPTER 8: Discussion of results

This chapter discusses the key findings of the study while addressing research objectives, and drawing recommendations for policymakers. The discussion focuses on the current strategies and information diffusion methods to help health promotion to manage malaria, the most feasible digital technology for tackling malaria, the development and piloting of the prototype, modelling predictors for the adoption of the prototype, and challenges affecting the adoption of ICTs in rural communities.

Chapter 9: M-health framework for integrating ICT-based malaria interventions in resource-constrained areas

This chapter presents the proposed mobile health framework for integrating ICT-based malaria interventions in resource-constrained areas.

Chapter 10: Conclusion, limitations and recommendations

This chapter presents the conclusion, recommendations, and future work of the study.

1.9 Summary of the chapter

This chapter provides a comprehensive background of the study, research context, research objectives and research questions. Additionally, this chapter explains the adopted research methodology and the structure of the dissertation. Furthermore, the chapter discusses concepts of ICTs in healthcare service delivery.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The previous chapter highlighted the background of the study, research aim and objectives, research context and the significance of the study. The purpose of this chapter is to review the existing literature that was implemented by the prior researchers to create awareness and dissemination of health information, especially in resource-constrained areas and disconnected communities.

2.2 Global and regional malaria burden

Malaria is an infectious disease that thrives in warm, tropical, and subtropical climates, causing severe illness and death (Gavi et al., 2021). A report from the Zimbabwe Presidential Malaria Initiative (2018) states that about half the world's population is at risk of malaria, with more cases occurring in many SSA rural and resource-constrained communities. The WHO (2021) malaria report states that,

> "*Globally, an estimated 241 million malaria cases and 627 000 malaria deaths were reported worldwide in 2020, showing a significant increase in global malaria cases as compared to 2019, with most of this increase coming from countries in the WHO African Region (228 million cases and 602 000 deaths).*"

The malaria burden is more prominent in the southern African region, though its intensity and transmission vary (Cock et al., 2019; Nkya et al., 2022). Within the Southern African Development Community (SADC) region, Eswatini, South Africa, Botswana and Namibia significantly reduced the impact of malaria and recently achieved previously set malaria elimination milestones (Raman et al., 2021). However, COVID-19 and imported malaria cases due to the constant regional movement of people potentially threaten previously achieved milestones. The increase in malaria cases attracted tremendous attention which resulted in the establishment of the Roll Back Malaria Partnership, Elimination Eight (E8) (Raman et al., 2021), National Malaria Programme (NMP), Global Technical Strategy 2016-2030, sustainable development goals, and other cross-border initiatives including

MOSASWA and Zim-Zam were established to mitigate cross-border transmission through synchronised and coordinated efforts against malaria in the SADC region (Moonasar et al., 2016). Globally, all nations through WHO launched Sustainable Development Goal (SDG) 3 targets 3.3 to end malaria by 2030 (WHO, 2021).

The Southern African region is accelerating toward malaria elimination by 2025, which resulted in the increase of domestic financing towards ending malaria by the Southern African Development Community, which has made remarkable progress in facilitating this paradigm shift (Raman et al., 2021). Several regional and cross-border initiatives such as E8, and MOSASWA have been established in the SADC region to address malaria transmission among mobile and migrant populations (Moonasar et al., 2016). In 2015, Elimination 8 secured a grant of $17.8 billion from the Global Fund to fight against malaria, acquired immunodeficiency syndrome (AIDS), and Tuberculosis in SADC's eight countries (Zelman et al., 2016). Swaziland reached pre-elimination in 2020 (Brooke et al., 2020; Dlamini et al., 2018), with Botswana, Namibia and South Africa following behind. In Zimbabwe, the transmission of malaria is highly heterogeneous and varies with seasonal changes (Muchena et al., 2018). The capability of malaria parasites' traits to adapt to environmental changes and resistance to insecticide caused the situation to deteriorate despite numerous interventions (Amoran, 2013). This requires the use of emerging digital technologies to analyse malaria parasite traits as they adapt to environmental changes to develop robust malaria prevention and control measures. However, COVID-19 and other diseases continue to eat into the resources initially allocated to fight malaria and consequently overburden weak health systems (Aborode et al., 2021; Pellegrino et al., 2022). More so, resistance to insecticide, climate change (Lubinda et al., 2021), breeding habitats, and community habits continue to complicate measures to control malaria and efforts to create awareness in hard-hit communities (Sangoro et al., 2021) and threaten social life and economic development in malaria-endemic countries including Zimbabwe (Sande et al., 2017).

Progress has been made in the past decades in malaria control, as elimination and eradication prompted the development of new interventions to detect, diagnose, treat, and prevent malaria. Such interventions involve innovative diagnostics (artemisinin-based combination therapy), vaccines (*P. falciparum* circumsporozoite protein), vector control interventions and improved methods for monitoring, surveillance and response. According to Hemingway et al. (2016), globally, there are more than twenty-five malaria vaccines in the pipeline, forty-seven medicines; and thirteen vector control products. These vector control products include LLINs, IRS, space sprays and larvicides; while numerous reference methods and subsequent-generation malaria diagnostic tools are in the development phase (WHO, 2021). Such advancement is led by global and regional partners to eliminate and eradicate malaria by 2030. This has led to continued progress, commitments, and optimism about ending malaria. Malaria-endemic countries have aggressively adopted malaria elimination and eradication interventions such as LLINs, IRS with insecticides, diagnosis and treatment with antimalarial drugs and seasonal malaria chemoprevention (Jamison et al., 2013).

2.3 Vector (mosquito) control strategies

The vector control strategies focus on preventing exposure to the risks that might cause malaria. They mainly focus on the susceptibility stage to minimise exposure to the vector (Tizifa et al., 2018). Vector control strategies such as indoor residual spraying and insecticidal-treated nets, together with case management are fundamental methods for reducing malaria transmission (Sande et al., 2017). Therefore, the following subsection presents vector control strategies.

2.3.1 Insecticidal-treated nets (ITNs)

Globally, ITNs have been used as an important primary strategy to prevent and control malaria (Kanyangarara et al., 2018; Murillo et al., 2019). ITNs provide the physical barrier that restricts direct mosquito-human contact, and they also contain permethrin which is toxic to the mosquitoes and kills them as well. ITNs can include both long-lasting insecticidal nets (LLINs) and Conventional Nets (CN). The use of ITNs is a cost-effective malaria intervention (Korenromp et al., 2003), and is known for reducing malaria incidences (Atieli et al., 2011) but their usage varies from one household to another. However, access to ITNs and the proportion of households with sufficient nets remains inadequate, mostly in SSA countries (World Malaria Report, 2017). Such discrepancies limit the potential impact of ITNs to manage malaria. In addition to ITNs household ownership discrepancies, socioeconomic factors including literacy, income, ignorance, and poverty as well as cultural factors such as beliefs, values, and religious practices influence the utilisation of insecticide-treated bed nets (Graves et al., 2011; Jombo et al., 2010). Other factors include allergic reaction to ITN chemicals (Aïkpon et al., 2020), the net's tendency to tear easily (Feachem et al., 2019) and sometimes increased room temperature that may lead to discomfort and suffocation (Fokam et al., 2017) which affect their purpose and utilisation. Also, the exploitation of insecticide-treated nets for deviant purposes is common in rural areas (Dhiman & Veer, 2014) and is detrimental to both people and the environment. Misuse of ITNs is a common practice in Zimbabwe, with some villagers resorting to using insecticide-treated nets to trap fish as shown in Figure 2.1, to create fowl runs, and for granary purposes (Maseko & Nunu, 2020). However, from an environmental perspective, treated mosquito nets contain an insecticide called *permethrin* which is toxic when it dissolves in water. *Permethrin* can affect aquatic life and other animals when consumed orally (Parent et al., 2011) and potentially can cause tremendous damage to the environment (DeLorenzo & Fulton, 2012).

Figure 2.1: Insecticide Treated Net Misuse, Source: (Yikoniko, 2015)

2.3.2 Indoor Residual Spraying (IRS)

This is the primary malaria prevention method that has been used on a large scale where people spray houses with insecticide to kill adult mosquitoes (Mharakurwa et al., 2004). IRS has been successfully used in some parts of Asia, Europe, America, and some parts of Africa to eliminate malaria (Choi et al., 2019; Pluess et al., 2010). Globally, indoor residual spraying protection declined to 2.9% in 2016 from 5.8% in 2010, following the use of artemisinin-based combination therapy (seasonal malaria chemoprevention), massive distribution of long-lasting insecticide-treated bed nets, intermittent preventive treatment of pregnant women, intermittent preventive treatment of infants (IPTi) and limited domestic and foreign aid funding which consequently led to budget restrictions (Winskill et al., 2019). In Zimbabwe, indoor residual spraying is monitored and regulated by the National Malaria Control Programme (NMCP) to reduce malaria density (Chimberengwa et al., 2015). In high malaria areas, IRS is usually done during the high malaria transmission period and rainy season in some parts of the country although this was later challenged by malaria resurgence and the lack of digital tools for real-time monitoring, reporting and surveillance (Sande et al., 2017).

2.3.3 Intermittent preventive treatment in pregnancy (IPTp)

Using intermittent preventive treatment in pregnancy as a malaria preventive measure has proven beneficial for both unborn children and pregnant women. The World Health Organization also recommends the use of intermittent preventive treatment in pregnancy with sulfadoxine-pyrimethamine (Azizi, 2020) and folic acid supplementation as a part of antenatal care services to prevent and treat malaria and anaemia during pregnancy in areas with moderate to high malaria transmission to combat the adverse effects of malaria in pregnancy (Henry et al., 2018). The evidence shows that the scale-up of malaria prevention interventions (IPTp and ITNs) in 25 malaria-endemic African countries has lowered neonatal mortality and low birth weight by 18% and 21%, respectively (Mushi et al., 2021). In Zimbabwe, ITPp is aimed to achieve a coverage of 85% of pregnant women attending antenatal service in the 30 moderate to high malaria-burdened districts with at least two doses of ITPp with Sulfadoxine-Pyrimethamine (IPTp-SP), except those on co-trimoxazole prophylaxis (Sande et al., 2017). These doses are generally administered in batches, the first dose is usually received at 16 weeks, the second dose is administered between 26-28 weeks and the third dose within 34-36 weeks after the gestation period (Sande et al., 2017).

2.4 Host protection strategies

Host protection strategies such as treatment, chemoprophylaxis, use of mosquito repellents, and vaccination. In places where mosquito vector biology and feeding behaviour are less conducive to current or available approaches, repellents are particularly useful for vector control and prevention (Aldila & Seno, 2019). However, sometimes people travelling to high malaria areas are encouraged to use chemoprophylaxis (Schlagenhauf & Petersen, 2008). Malaria chemoprophylaxis can be defined as the use of anti-malarial medication to prevent the occurrence of the symptoms of malaria (Schlagenhauf et al., 2010). The use of artemisinin-based combination therapy containing a combination of either artemether–lumefantrine, artesunate/amodiaquine (AS/AQ) /mefloquine/sulfadoxine-pyrimethamine, o rdihydroartemisinin–piperaquine is recommended treatment for malaria in sub-Saharan Africa (Kwenti, 2018). The following subsection presents artemisinin-based combination therapy.

2.4.1 Artemisinin-Based Combination Therapy (ACT)

ACTs were recommended by the WHO in 2001, as the first-line treatment where *Plasmodium falciparum* becomes resistant to other conventional antimalarial drugs (Bosman & Mendis, 2007). According to Pousibet-Puerto et al. (2016), ACTs combine an artemisinin derivative with a partner drug, which is effective to reduce the spread of drug resistance. In Zimbabwe, ACT was used to treat malaria (Sande et al., 2017) while the second line is artesunate-amodiaquine; and also oral quinine (with a combination of either doxycycline or clindamycin) is used as an alternative second-line treatment (Dube et al., 2019). Zimbabwe had been using antimalarial treatment drugs called *chloroquine* and *prophylaxis* but later faced high malaria drug resistance (Makono & Sibanda, 1999; Mharakurwa et al., 2004). Such high resistance has been prevented through a comprehensive national malaria strategic plan that incorporates other antimalarial drugs (Pellegrino et al., 2022). The strategic plan involves designing, developing, and advocating for national guidelines for the use of *chloroquine* and *prophylaxis*. The MoHCC deployed an efficacious new antimalarial drug called *Malarone* (Atovaquone-proguanil) as the recommended and effective antimalarial drug medication to fight drug-resistant species *Plasmodium falciparum* in Zimbabwe (Mharakurwa et al., 2021). However, branded Malarone is more expensive compared to the generic version of Malarone drug which is sold for USD $3 per tablet in pharmacies (Great Zimbabwe Guide, 2017). A generic version of Malarone is scarce, and inaccessible especially in some marginalised areas since a greater number of people are living below the poverty datum line (Pellegrino et al., 2022).

2.5 Malaria health policy and strategies in Zimbabwe

This involves designing, developing, and implementing rules and regulations for achieving malaria primary prevention goals. This entails the engagement of rural communities, non-governmental organisations, and government authorities in the early stages of the malaria policy formulation phase. This is because the use of IRS and ITNs has some implications for the environment (Parent et al., 2011), therefore, there is a need for great synergy between government authorities, non-governmental organisations, health experts and people living in malarial areas to prevent environmental damage.

Health policy decisions affect healthcare delivery in both urban and rural areas. Engagement, participation, and involvement of all stakeholders can assist in the formulation of sound malaria health policy. In Zimbabwe, in 2001, the MoHCC formed a malaria management arm called the National Malaria Control Programme (NMCP) with the mandate to develop malaria policy, and national malaria guidelines, among others (Chung et al., 2020). The National Malaria Control Programme regulates and monitors the implementation of malaria prevention, control and elimination activities and monitors disease trends (Zimbabwe Malaria Operational Plan, 2017). The successful implementation of the NMCP led to the development of policies, for instance, the National Malaria Strategic Plan was developed as a strategic plan to fight malaria between 2001 and December 2007 (Sande et al., 2017). Zimbabwe's several health policies in malaria prevention and health promotion are shown in Table 2.1.

Table 2.1: Zimbabwe malaria policies, Source: Sande et al. (2017)

Policy	Year
Zimbabwe National Health Strategy	1997-2007
National Malaria Prevention and Control Policy	2001-2007
National Malaria Control Programme Strategy	2008-2013 extended to 2017
Insecticide Treated Net Policy	2003 revised 2006
Zimbabwe Insecticide Nets Implementation Strategy	2009
Spray operator's manual	2007
Malaria treatment guidelines	2007
Malaria Monitoring and Evaluation Plan	2008-2013
National Malaria Communication Strategy	2007-2015
National Malaria Strategic Plan	2016-2020
Malaria Communication Strategy	2016-2020

As a developing country, Zimbabwe adopted and implemented several malaria interventions and case management strategies to eliminate malaria. However, malaria remains a burden in Zimbabwe even though there is the foreseeable prospect of eliminating malaria in some provinces (Muchena et al., 2018). Moreover, Hemingway et al. (2016) state that the adoption of malaria interventions without proper implementation and awareness strategies does not facilitate malaria prevention and elimination much in the long term. This jeopardises and underscores the fragility of malaria prevention's sustained success and progress. Several ICTs such as radio and television have been utilised in other countries to intensify malaria awareness, proper implementation, monitoring, and evaluation of interventions. The following sections provide an overview and comprehensive analysis of ICTs that have been deployed to fight elusive malaria.

2.6 Growth of ICTs

The widespread use of digital technologies presents unprecedented opportunities to fight elusive malaria as populations are expecting a transformative shift in the trajectory of malaria eradication and attainment of malaria milestones defined in the sustainable development goals. The pervasive and ubiquitous use of digital technologies especially mobile technology incessantly brings unprecedented opportunities in creating malaria awareness, monitoring malaria outbreaks, modelling climatic factors linked to malaria, and improve malaria monitoring and reporting (Mbunge et al., 2021). With these anticipated dynamic changes in malaria prevention and control, this subsection provides a detailed explanation of the significant roles of ICTs in malaria healthcare services delivery.

Globally, ICTs are becoming accelerators, amplifiers, and augmenters of change in many aspects of life through the provision and availability of computing devices and supporting infrastructure including telecommunications. Thus, ICT plays a significant role in both developed and developing economies to improve social-economic and health transformation through the integration of information media, thereby, bridging the digital divide, especially in rural communities (Farhadi et al., 2012; Jiang et al., 2017). This is exemplified by the significant increase in the availability, and upward trend in the access to and use of ICTs even in developing countries over the past decades (Avgerou et al., 2016). Indicatively, fixed-telephone subscriptions have consistently been decreasing while mobile cellular telephone and active mobile broadband subscriptions increased, from the year 2001 to 2018 as shown in Figure 2.2, 51.2% or 3.9 billion people of the world’s population were connected to the Internet and have access to fixed lines as of 2018 (International Telecommunication Union, 2018). Most importantly, mobile phone access and subscriptions are increasingly becoming predominant with an estimated 4.4 billion active mobile broadband subscriptions by the end of 2018 (International

Telecommunication Union, 2018). In sub-Saharan African countries, mobile phone usage and penetration outpaced fixed lines and present significant opportunities for mobile health, pervasive computing and inclusive access to healthcare services (Asongu, 2015). This reflects a vital step towards a more inclusive global information society.

Despite the positive milestone shown in Figure 2.2, concerns continue to emerge about new and growing digital inequalities (International Telecommunication Union, 2018) between countries, sexes, ages and regions. Avgerou et al. (2016) indicated that digital inequalities are fuelled by various factors including technical and financial challenges faced by telecommunication operators in expanding networks into more remote regions, making it difficult to ensure universal access to ICTs. Without universal access to digital networks and devices, poor people living in isolated, impassable, rural communities can experience difficulties in accessing malaria digital information which consequently affects milestones set to prevent and control malaria.

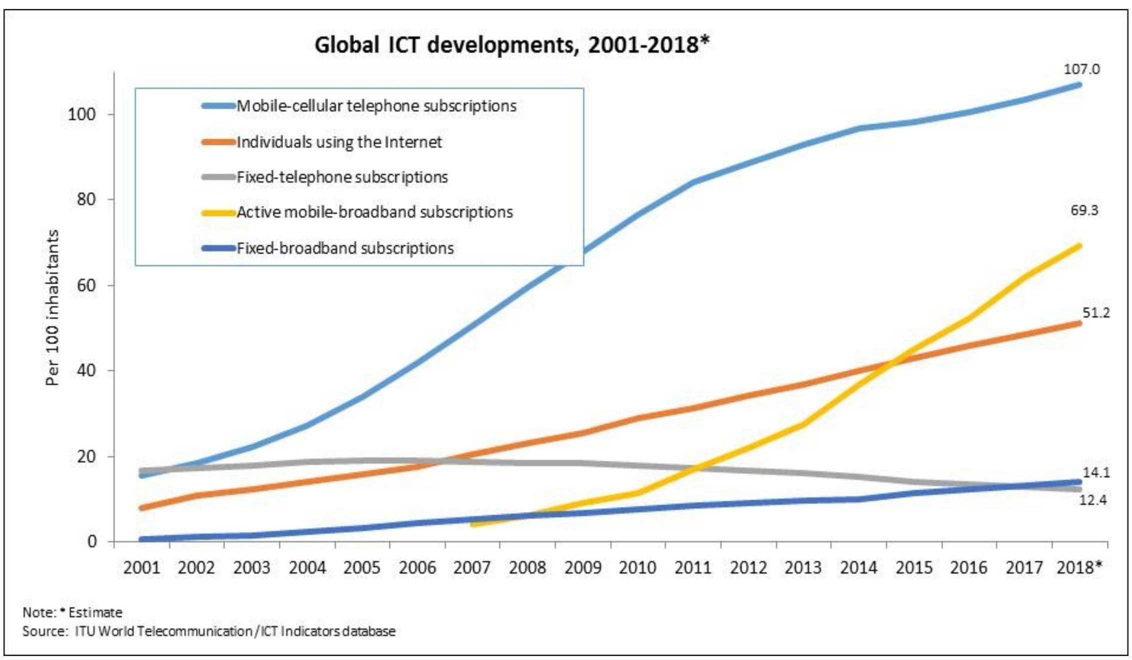

Figure 2.2: ITU 2018 Global ICT estimates (ITU, 2018)

However, mobile phone network infrastructure and signal coverage is increasing in more remote regions to improve network connectivity (van Deursen et al., 2019). Increasing mobile network coverage, especially in rural areas, can potentially reduce disparities in healthcare service delivery as well as the digital divide. Even though digital disparities still exist in rural areas, Dogba et al. (2019) highlighted that most countries in Africa are heavily investing in communication technologies such as telecommunications and broadcasting systems. The assimilation of these technologies into health systems resulted in a drastic increase in the adoption of mobile applications even in healthcare and electronic health (Ruxwana et al., 2010). Most of these mobile health applications (highlighted in Section 2.6) can be executed on mobile technologies. This is because mobile technologies are increasingly becoming ubiquitous and pervasive, hence becoming the most feasible technology to disseminate information in remote areas. Despite such improvements in the accessibility of mobile phones and network connectivity, the digital divide (Makri, 2019) and the mobile phone penetration gap between smartphones and feature phones still exist in many African rural communities (van Deursen et al., 2019). Therefore, there is heavy reliance on slow connectivity and feature phones for communication to accommodate communication bandwidth limitations and mobile phone costs. The mobile phone penetration gap between smartphones and feature phones affects the deployment of malaria interventions in different ways, including the need for developing multiple applications for different platforms that intend to serve the same purpose; inconsistencies in data standardisation and formatting and most importantly, diversion of funds that could be utilised for other malaria prevention control activities.

2.7 ICTs in healthcare

According to Aceto et al. (2018), ICTs are drastically changing various health systems in many countries in various ways – from how health information is accessed, communicated and stored; to remote monitoring and surveillance of patients and diseases. The accessibility and availability of ICTs can help bridge the information divide between health professionals and communities and ensure equitable access to health-related information. ICTs such as electronic health records (EHR), immersive virtual reality (VR), telemedicine, telehealth and mobile technologies substantially improve health communication, and health education, and also bridge the health literacy communication gap. For instance, immersive VR can be used for health professional education in resource-constrained countries to simulate physical reality in a virtual setting (Kyaw et al., 2019). However, limited evidence in the utilisation of VR to influence behaviour change and cost implications deters its adoption and use in rural communities (Fertleman et al., 2018). According to Kyaw et al. (2019), virtual reality technology requires a high bandwidth, huge capital investment and modern supporting technological infrastructure which might not be feasible to implement in resource-constrained countries because of dwindling funds. Resource-constrained countries are associated with a low gross domestic product (GDP) (International Telecommunication Union, 2018), uneven distribution of health centres and healthcare professionals, a lack of readily available cost-effective information dissemination tools (Zayyad & Toycan, 2018) and inadequate infrastructure to provide sufficient efficacy for disease prevention and control in marginalised remote areas (van Deursen et al., 2019).

2.8 Various digital technologies in healthcare service delivery

Notably, digital technologies have been at the forefront of delivering and improving healthcare services. Several digital interventions have been deployed to capture, store, process and disseminate malaria information in different countries. Such technologies include electronic health, telemedicine, telehealth, health information systems, mass media communication, social media platforms and mobile health applications. The following subsections present digital health technologies that have been used to tackle malaria.

2.8.1 Electronic Health

Electronic health (e-health) is the use of ICTs for health. e-health is defined by the WHO (2005) as the use of digital technologies to capture, process, and analyse health data to improve care, surveillance, monitoring, education, awareness, and health promotion. Thus, e-health integrates local, country, regional, and global partners with the salient goal of promoting and strengthening the adoption and use of ICTs in delivering health services (Silva et al., 2015). The evolution of e-health reached its pinnacle in 1999 – the remote delivery of healthcare services through Internet-based technologies (McLean et al., 2013). e-health technology involves applications such as HIS, electronic medical records (EMR), telemedicine and mobile health technology. These are very important applications that reduce healthcare costs, and provide access to updated health data and improved healthcare delivery (Akhlaq et al., 2016). From a strategic viewpoint, Zayyad and Toycan (2018) indicate that e-health provides tremendous benefits and opportunities such as the provision of electronic prescriptions, development of decision support systems, global sharing of health information and enhancing remote monitoring and administration of health services to improve access to care. However, Ross et al. (2015) conducted a study and posit that implementing e-health systems is a challenging and daunting task. This might be caused by the factors emanating from individuals, healthcare settings, and national health policy due to low e-health literacy; individuals' lack of knowledge of e-health benefits (Ross et al., 2015); interoperability; lack of evidence of cost-effectiveness (Ruxwana et al., 2010); and lack of skilled human resource and sustainable infrastructure (Zayyad & Toycan, 2018). Furthermore, Furusa and Coleman (2018) state that the security and privacy of patient's data, resistance to change, and legal, social and ethical barriers are some e-health implementation barriers. The following section explains the importance of telemedicine in healthcare as part of e-health.

2.8.2 Telemedicine

Telemedicine facilitates remote access to healthcare and health-related information irrespective of locality. The resurgence and adoption of telemedicine in the health sector have partially surmounted some challenges in education, training and awareness (Bashshur et al., 2020). This is because of improved network speed and coverage fuelled by the substantial growth of the digital communication network. Unfortunately, some areas remain unconnected because of the digital divide, which threatens the adoption of telemedicine in rural health facilities, thus exacerbating existing healthcare inequities. Also, the adoption of telemedicine in low-resourced settings faces intransigent problems due to technical difficulties (Doraiswamy et al., 2020), power outages, digital literacy levels, poor telecommunication networks (Chitungo, Mhango, Mbunge, et al., 2021), heavy investments in equipment (Bahl et al., 2020), poor access to travel incentives in case of emergencies as well as legal implications (Moodley et al., 2019). Alternatively, increased access to mobile technologies substantially reduced the digital divide in rural communities. A study conducted by Yoo (2013) and Watkins et al. (2018) indicated that access to mobile technologies dramatically improved access to care and healthcare services delivery in rural areas. The increasing adoption of mobile health applications in healthcare service delivery, especially in low-resourced communities shows promising results to improve access to care in various mobile health initiatives (Porter et al., 2019).

2.8.3 Telehealth

Another ICT technology that has changed several health systems globally is telehealth. Telehealth and telemedicine are interchangeably used in the health sector despite their obvious uniqueness in referents. According to Bashshur et al. (2020), both technologies use electronic means to transfer health information to distant sites, however, the distinguishing characteristic is the reliance on electronic information technology and telecommunication as a way of communication between health workers and patients. According to McLean et al. (2013), telehealth involves the use of ICTs to support health education, telemedicine and medical education over a distance, while Myers (2003) describes telemedicine as a technology that uses advanced telecommunication technologies to provide healthcare services and health information across time, geographic, social and cultural barriers. To draw a distinction and understand the juxtaposition of telehealth and telemedicine, McLean et al. (2013) explicitly describe telemedicine as the diagnosis and treatment of patients who are geographically separated from healthcare providers while telehealth focuses on the delivery and exchange of health information.

Therefore, telehealth involves the transmission of health data and information including texts, images, videos and audio files over both short and long distances rather than moving care recipients, and health workers (Doraiswamy et al., 2020). This involves the use of innovative telecommunication technologies and electronic information tools which support long-distance healthcare services, including patient care, education and communication.

Thus, according to Monaghesh and Hajizadeh (2020), telehealth is an umbrella term that includes mobile health, live video-conferencing, remote patient monitoring (RPM) and store-and-forward or asynchronous video. The ultimate goal of telehealth is to improve access to healthcare services using technological-based communication techniques. Video-conferencing supports live-streaming and bilateral audio-visual communication for people who live in different regional and geographic locations. According to Farrelly et al. (2007), store-and-forward technology is normally used to record health information using an electronic system, and then to forward medical information to a specialist in a remote location. It is usually practised in rural areas where there is unreliable internet connectivity. Remote patient monitoring is used for remote monitoring purposes by nurses and caregivers in different locations (Marcoux & Vogenberg, 2016). Mobile health, also known as m-Health, uses mobile technologies to transmit and exchange health information between care recipients and health workers over short and long distances. Globally, ICTs such as m-Health and mobile technology help to reduce increasing healthcare costs (Kushitor & Boatemaa, 2018) in both developed and developing countries. This is evidenced by the disparities in healthcare access and social determinants of health that fall disproportionately high and adversely on minority groups in LMICs.

Mobile technology and m-Health may help to alleviate health disparities in vulnerable populations. Telehealth is critical especially in both remote and rural areas because of inadequate health care, and a dearth of health workers who provide speciality care (Vidal-Alaball et al., 2020). Telehealth is evolving and has the capability of delivering affordable, quality and timely care to patients. However, developing countries face tremendous healthcare challenges in telemedicine such as limited medical resources supply (Bitar & Alismail, 2021), lack of ICTs infrastructure and uneven distribution of health centres (Dodoo et al., 2022) which limits their use, especially in remote and rural communities (Combi et al., 2016). Thus, the implementation of telehealth could be more meaningful to address healthcare challenges in resource-constrained areas.

For telehealth to address health care disparity between urban and rural densely populated areas there should be a smooth transition in the health sector. This can be achieved by exposing health workers to telehealth facilities during their educational experience to capacitate them with skills and knowledge to ensure a smooth transition (Koonin et al., 2020). Despite opportunities and many success stories of telehealth transforming healthcare in developing countries, Coleman and Delea (2013) state that telehealth also encounters various implementation challenges such as cost implications, technological readiness, adoption and financial barriers as well as security, privacy and legal issues. Due to these impediments, some countries in sub-Saharan Africa still rely on health information systems to capture and process health information (Dodoo et al., 2022). The following section presents the significance of health information systems in healthcare service delivery.

2.8.4 Health Information Systems (HIS)

With the high costs of establishing telemedicine and telehealth coupled with technological and infrastructural barriers (Bali, 2018; Bashshur et al., 2020; Chitungo, Mhango, Mbunge, et al., 2021; Vidal-Alaball et al., 2020), health information systems have been utilised as an alternative platform for capturing patient health data, diseases surveillance, monitoring and reporting in many health systems (Serrano et al., 2020). According to Dehnavieh et al. (2019), health information systems involve the integration and combined execution of healthcare activities and processes using information systems to deliver better healthcare services. Health information systems utilise technologically-based digital tools including computers, mobile devices and application programmes to collect save, process, and extract patient data and to create a link between caring for and managing patients' information (Alwan et al., 2016). Health information systems are powerful ICT-based platforms that enable the effective and efficient delivery of healthcare services by integrating all aspects of administrative, clinical care and activities within healthcare into a single system (Serrano et al., 2020). HIS helps to assess the health needs of the communities and can be also used for the planning and implementation of health interventions in both rural and urban areas. Kao et al. (2018) indicate that the HIS can be further utilised to assess the effectiveness of health programmes in a particular population and group. Effective evaluation of health programmes and integration of health entities through health information systems ensures legibility, administrative and medical error reduction (Bawack & Kala Kamdjoug, 2018), shrinking costs, easy access to information, the improvement of patient records and documentation (Rosewell et al., 2017), the enhancement of information integration, the improvement of hospital management and the bolstering of healthcare services (Mohamadali & Aziz, 2017). Health information systems allow for the sharing of information and reduce the risk of malpractice while observing the privacy of patients (Seebregts et al., 2018).

The adoption of such technology continues inexorably. Sadoughi et al. (2022) point out the need for HIS to address the complexity of hospital activities including managing ever-increasing patient data, communicating and educating patients, tracking and monitoring patients, and the demand to improve the quality of health data for future medical research. Despite the benefits and opportunities of HIS, Aziz (2017) states that HIS faces challenge such as a low adoption rate by healthcare professionals and policymakers due to low digital literacy levels, a perceived lack of return on investments, poor supporting ICT infrastructure, concerns of privacy and security and lack of global standards. Ruxwana et al. (2010) note that there is a need to balance standardisation, localisation and integration of health information and health information systems. However, insufficient training, inadequate availability of physical resources, limited human resources development planning, no accredited HIS training programmes and established HIS career paths, inadequate technical support at all levels, and limited or unavailable HIS versions control are major factors causing the underperformance of health information systems, predominantly in sub-Saharan Africa (Mbondji et al., 2014). Also, Mutale et al. (2013) indicate that there is a widening gap in the digital divide, especially in Africa's resource-constrained areas which led to the health information knowledge gap and bottlenecks in synthesising existing health data and information in health information systems. This is an obstacle to HIS' progress as it leaves the population and researchers trailing in health knowledge and information as well as other significant research outcomes, particularly in rural and poor-resource settings. Such challenges and obstacles may cause poor quality and disorganised health data collected by HIS (Kebede et al., 2014); inadequate skills for data explication, exposition and utilization (Bawack & Kala Kamdjoug, 2018); and unavailable or no policy guidelines on global sharing, interoperability and integration of health data and health information systems (Zayyad & Toycan, 2018).

2.8.4. 1 The role of Health Information Systems in healthcare service delivery

HIS can be utilised as diseases surveillance system, as indicated by Aziz (2017), for systematic gathering, processing and analysing patients' health data to strengthen surveillance while improving healthcare services delivery. According to Coleman and Delea (2013), HIS supports an inclusive surveillance effort to build an integrated, effective, and reliable disease reporting system through timely disease monitoring, investigation and continuous collection of early detection of outbreaks. For instance, HIS were used as a surveillance tool in Kenya to manage respiratory diseases and influenza (Aziz, 2017); to control infectious diseases and the emergence of new microbial threats in China (Gong et al., 2020; J. Wu et al., 2020); to survey human immunodeficiency virus (HIV) transmission (Clark et al., 2017; Cohen et al., 2014); to improve the availability of health data, and to monitor Ebola outbreaks in West and East Africa (Jalloh et al., 2021; Raab et al., 2021). In addition, in Papua New Guinea, health information systems have been used to strengthen malaria elimination by integrating a case-based malaria testing register geo-coded with household, village and health facilities (Rosewell et al., 2017) while in Vietnam and Thailand HIS are used for malaria surveillance purposes by detecting passive malaria cases (Erhart et al., 2007). Furthermore, there is significant progress in improving and transforming diseases surveillance approaches by incorporating and integrating HIS with disease-specific surveillance approaches to improve efficiency and interoperability (Dixon et al., 2021; Iskandar et al., 2021) and subsequently strengthen regional and international health data sharing and diseases monitoring (Inzaule et al., 2021). HIS can enhance malaria outbreak control, detection, surveillance, monitoring and malaria reporting as indicated by Dehnavieh et al. (2019). Thus, HIS continues to transform the way health data and diseases related information are disseminated by integrating digital health solutions. However, HIS is more focused on capturing, accessing, and managing health data and disease surveillance. Many SSA countries have been adopting alternative digital solutions to create health awareness and establish communication between health workers and patients to bridge existing inequalities in accessing healthcare. Therefore, the following section provides a detailed explanation of mass media digital communication that can be used to create awareness and health promotion.

2.8.5 Mass media digital communication platforms

Mass media plays an imperative role in tackling malaria by creating awareness, education and health promotion while maintaining social connections. For instance, during COVID-19, mass media has been utilised to sensitise people about the pandemic, to create awareness and to deliver the latest COVID-19 information to the public (Anwar et al., 2020). Mass media communication platforms present unprecedented opportunities to create awareness and engage with the public about malaria prevention and control strategies. According to Yaya et al. (2018), mass media digital communication tools including digital billboards, radio and televisions have been used in malaria-endemic sub-Saharan countries to create awareness and communication, and to influence healthy lifestyles. Radio broadcasting is considered a relatively affordable way of passing information on in most developing countries due to the accessibility and affordability of the radio in both rural and urban areas. For instance, Meena cartoons in Bangladesh were used to promote behavioural change programmes and to improve health literacy through mass media communication. Their effectiveness is not documented (Tabassum et al., 2018). In New York City in America, mass media tools have been utilised to promote tobacco cessation services including interventions to reduce the number of smokers through antismoking television advertisements (Farrelly et al., 2007). Malawi hosted an interactive health-talk radio programme to increase health awareness, promote health research, and also promote community participation in research while engaging health workers (Nyirenda et al., 2018). In addition, Nigeria also adopted mass media campaigns to create awareness about Ebola Virus (Eilu & Pettersson, 2019; Nelson & Namtira, 2017; Roy et al., 2020), and promote the regular use of ITN among pregnant women (Yaya et al., 2018). Some countries have been using mass media communication to promote awareness and manage human behaviour during epidemic outbreaks including Zika virus, Human Immunodeficiency

Virus/Acquired Immune Deficiency Syndrome (HIV/AIDS), Cancer, malaria and most recently, COVID-19 (Dubbelink et al., 2021; Hayes, 2020; Rai et al., 2022). Even though mass media platforms disseminate information, the audiences are exposed to misinformation (Hayawi et al., 2022), infodemics (Biradar et al., 2022) and also there is a paucity of feedback tools to assess the level and degree of awareness and accessibility (Xiangyu Wang et al., 2022). For instance, radio and television broadcasting lacks a comprehensive evaluation tool to determine whether the information is received and decoded in the perceived and intended manner (Ochieng et al., 2022).

In addition, Gibson et al. (2017) indicate that mass media digital communication usually contains generic content which does not address specific demographic groups because of limited knowledge about the recipients and undifferentiated audiences. Yaya et al. (2018) indicate that there is limited evidence on the effectiveness of mass media digital communication on malaria behaviour change in many African countries. Among other mass media communication platforms, social media has been recently used to share health information (Anwar et al., 2020). The following section presents the importance of social media in disseminating health information.

2.8.6 Social Media platforms

Social media is a subset of mass media communication platforms that are becoming indispensable tools in disseminating information. It addresses some inherent challenges faced by the existing communication platforms as it increases accessibility and interaction through creating online virtual groups (Rai et al., 2022). Social media platforms offer an alternative means of communication that promotes information transfer at scale and have proven to be exceptional media assets in elevating digital awareness, malaria surveillance, education as well as health communication (Hagg et al., 2018). Social media platforms can generate a large amount of data due to the collaborative nature of social media tools which support user-generated content to be shared among online virtual groups to create awareness (Lapointe et al., 2014).

Social media tools include media-sharing sites, social networking platforms, wikis, blogs, and micro-blogs, all of which connect people, foster user-generated content and share information through online virtual communities (Balatsoukas et al., 2015; Chou et al., 2012). Such tools allow healthcare recipients to share information that might lead to behavioural change through education and social networking. Globally, social media is becoming pervasive and prevalent across all ages despite the location, and social and cultural differences (Ventola, 2014). Social networking platforms such as Facebook, MySpace, Twitter and Google Plus; and professional networking platforms such as LinkedIn; media sharing platforms such as YouTube and Flicker, enable users to gather, share ideas and information and disseminate information in real-time (Xiangyu Wang et al., 2022). According to Ventola (2014), there are more than one billion Facebook users globally, more than two billion videos are viewed on YouTube, and each day 100 million active Twitter users send more than 65 million tweets. The continuous increase of social media subscribers and usage paves new ways of monitoring, tracking, surveillance and creating awareness around the outbreak of diseases. De Angelis et al. (2018) posit that social media platforms have become a paramount resource for patients to self-manage their health conditions and connect with health workers, especially during health emergencies where social distancing and movement restrictions measures are mandatory. Patients can disseminate health information, and consult health workers remotely using social media platforms (De Angelis et al., 2018) and in some instances, health workers can enhance health promotion (Laliberté et al., 2016).

In the realm of disease outbreaks, Lapointe et al. (2014) applied social media to create cancer awareness, while Lee et al. (2013) used Twitter data for flu surveillance. Social media enables users to collaborate, while facilitating information dissemination and also the coordination of distant members, thus allowing information sharing irrespective of the distance barrier. In Nigeria, Twitter was used to recruit volunteers, disseminate information, and facilitate discussion during the Ebola outbreak and Lassa fever outbreaks (Eilu & Pettersson, 2019). The campaign was spread on social media to facilitate Ebola awareness, education, community engagement and collaboration among healthcare professionals and researchers (Hagg et al., 2018). Also, social media was used to track earthquakes and cholera outbreaks in Haiti (Charles-Smith et al., 2015). And, social media platforms were used to spread information about the outbreak of the COVID-19 pandemic and monitor health behaviours in China (Y. Wu & Shen, 2021). Therefore, social media platforms can be used to detect fake news (Biradar et al., 2022), misinformation about the disease or vaccinations (Hayawi et al., 2022), track migration patterns of infected or quarantined people and map hotspots (Chakraborty et al., 2020; Khanday et al., 2021) to strengthen COVID-19 detection and prevention measures using data generated from different online social media communities.

In Zimbabwe, social media platforms are used for social networking and communication purposes but have not yet been formally approved as a platform to share health information. Nevertheless, the use of social media for health communication is not immune to security and privacy concerns as well as other ethical issues. Such ethical issues include potential violation of health communication protocols (Thapa & Camtepe, 2021), and the protection of the security and privacy of patients' data and policies (Ventola, 2014). Information from these platforms might be vulnerable and cause health data leakages (Hagg et al., 2018), and negative health behaviours and outcomes as indicated by Emily et al. (2018). Also, a study conducted by De Angelis et al. (2018) warns that unprofessional use of social media is becoming common among subscribers that make comments through media messages that exhibit sexism, discrimination, racism, misinformation, foul language and lack of respect for patients. These challenges disqualify social media from being a long-term feasible solution for disseminating health information. Therefore, some countries have adopted mobile health technologies to develop and deploy feasible mobile applications to create awareness and manage malaria data. The following section explicitly describes the significance of mobile technologies in healthcare service delivery.

2.8.7 Mobile technologies in healthcare service

Mobile technologies continue to revolutionalise health systems globally, bringing unprecedented opportunities in redefining healthcare services delivery to alleviate malaria.

Mobile technologies include wireless fidelity, Bluetooth, and data networking services for mobile phones as well as mobile applications. These technologies can be utilised to improve access to care. Mobile technologies cover a multitude of countless applications, such as health communication, monitoring, reporting, treatment adherence, recordkeeping, consultation between healthcare professionals and health surveillance (Silva et al., 2015). For instance, during COVID-19, mobile technologies have been used for information dissemination, fast-paced contact tracing, real-time data collection (Papadopoulos et al., 2020), convenient monitoring of health status and effective control, which contributes to mitigating and preventing the spread of infections (Budd et al., 2020). These functions could be also used to manage malaria in various ways including malaria case management, contact tracing of individuals with malaria and real-time data collection among others. Considering the high mobile phone penetration rate in sub-Saharan Africa (Lee et al., 2017a), mobile technologies are increasingly becoming the most feasible technology to disseminate health information in the African region. For instance, Reddy et al. (2021) note that there is a rapid increase in mobile phones and a favourable decline in the price of digital devices in developing countries which reduces the existing digital divide (Forenbacher et al., 2019). This is enabled by the advent of the latest and most advanced mobile communications including smart mobile computing devices, 3G, 4G and 5G mobile networks that continue to reshape mobile health services. A report from the Global System for Mobile Communications Association (GSMA) (2019) states that 5.1 billion people around the world subscribe to mobile services, accounting for 67% of the global population (Omboni, 2019). In Sub-Saharan Africa, mobile phone penetration has substantially increased in the previous years, with overall subscriber penetration reaching 44% in 2017, which is an increase from 25% at the start of this decade (Vinerean et al., 2022). This creates unprecedented opportunities to explore the extent to which e-health and m-Health can assist in alleviating impediments experienced by many health systems in delivering healthcare services mostly in resource-constrained communities. Silva et al. (2015) state that m-Health can be effective in healthcare monitoring, clinical patient data collection and administration, alerting and sending notifications, facilitating health awareness programmes, diseases surveillance, prevention, diagnosis and detection, and medical intake adherence.

Globally, several mobile applications in healthcare service delivery have been developed and piloted in various environments in both developed and developing countries to fight malaria (Vesel et al., 2015). They have also been used to enhance communication and health promotion because of their mobility and their technological capacity to circumvent health systems' limitations. The increasing use of mobile health applications has improved convenience in health care (Helbostad et al., 2017) and the remote monitoring of changes in health behaviour. From healthcare professionals' perspective, mobile health applications perform very important tasks including capturing patients' health data, remote patient monitoring, real-time health data processing, management and presentation which can further be used in clinical decision-making, policy formulation, health education and training (Ventola, 2014). From patients' perspective, mobile technologies act as an aid to bridge communication barriers and unequal access to health services, and they provide health information, along with improved access to point-of-care tools (Aungst, 2013) and patient outcomes. However, the lack of standards, policies, regulations and validation practices regarding the use of emerging mobile health applications in the health system discourages the adoption of mobile applications in health systems despite the tremendous benefits they offer (Manyati & Mutsau, 2021; Osei & Mashamba-Thompson, 2021). Further research to validate and standardise the development, deployment and integration of emerging mobile health applications is required.

Mobile health care increases adherence to community-based social and health services interaction (Osei et al., 2021), participation and engagement without placing an additional burden on clinical staff. Thus, mobile health care is a less costly and compelling tool for the delivery of health services and bridging the existing systematic gaps in access to care as attested by Moodley et al.(2019). But there are many inherent problems encountered by several health sectors in developing countries such as Zimbabwe, which include a shortage of health workers (Mashange et al., 2019), poor access to healthcare, lack of effective communication tools and lack of patient compliance. This can be mitigated through the wide deployment of ICTs such as mobile technology, telehealth and telemedicine which will establish communication between patients and healthcare professionals regardless of locality. Mobile health technologies are being adopted on a global scale, increasing opportunities to ensure inclusive access to care through mobile phone-based health applications. In support, WHO advocates the further development of feasible mobile health applications to ensure effective surveillance, management, and treatment of diseases, and prevention and control of non-communicable diseases (Opoku et al., 2017). Therefore, the benefits and challenges of mobile phone-based health interventions are explained in the following section.

2.9 Mobile phone-based health interventions: benefits, success, failure, challenges and disadvantages

A study conducted by Francis et al. (2017) shows that mobile technologies can extract and send health information to different health sectors and environments for health reasons. Githinji et al. (2014) used health information gleaned from mobile phones to track the outbreak and spread of malaria in Kenya, to reduce the response time to an outbreak by government authorities. Mobile phone calls were used as surveillance to track the spread of malaria in Kenya (Githinji et al., 2014; Oria et al., 2014). In rural areas of Bangladesh, new cases of malaria infections are reported via mobile phones (Prue et al., 2013). According to Zurovac et al. (2011), short positive text messages sent to health caregivers' mobile phones brought good results in guiding malaria outpatients to follow malaria treatment procedures in Kenya. Most recently in Kenya, immunisation programmes are facilitated through the use of mobile phone-based reminders coupled with incentives using a mobile health application called Mobile Solutions for Immunisation (M-SIMU) to improve immunisation uptake in Kenya (Gibson et al., 2017). In support of the short messaging system, Sarma et al. (2018) highlighted that text message reminders help patients and health workers in low-resource settings. Several m-Health and e-health applications such as the Malaria Buddy app, mSray application, Momala app, and Malaria System MicroApp were developed to detect, monitor and diagnose malaria (de Jager et al., 2019; Mbunge et al., 2021; Wallis et al., 2017). For instance, the University of Pretoria developed a satellite technology that notifies the user when approaching malaria risk areas, provides clinic and hospital coordinates as well as provides frequently asked questions with detailed answers using a mobile application called the Malaria Buddy app that monitors and controls the spread of malaria (de Jager et al., 2019).

Oliveira et al. (2017) developed a Malaria System MicroApp, which is a mobile-based diagnostic system to identify the plasmodium falciparum species from blood samples. The Malaria System MicroApp correctly identified 91% of 100 parasite-infected samples. However, the feasibility and sustainability of the Malaria System MicroApp were outweighed by malaria rapid diagnostic tests because of poor accessibility and the short battery life span of mobile phones. Larocca et al. (2016) posit that malaria mobile applications face various challenges including the reliability of the applications when deployed for parasite screening, inadequate monitoring and surveillance technologies, feasibility, sustainability and accessibility of technology in marginalised areas and difficulties in harmonising mobile health applications with other digital health systems. The use of m-Health surveillance systems in marginalised areas relies on the availability of supporting ICT infrastructure.

High-tech mobile technology solutions such as the MozzWear app, Sanford app (Kiskin et al., 2021; Sinka et al., 2021) and Malaria timelier notification app (Quan et al., 2014) had been tried but were shown to be ineffective due to the infeasibility and additional implementation costs that were involved. For instance, the MozzWear app was capable of detecting a mosquito sound within 10 centimetres away (with a detection accuracy rate of 68-92%), with an additional implementation cost of USD $20 (Kiskin et al., 2021). The Malaria timelier notification app requires a follow-up within 48 hours with reporting delays, and high telephone costs involved when reporting (Quan et al., 2014). However, cost implications and internet access are major barriers to the roll-out of mobile health applications nationwide (Manyati & Mutsau, 2021). South Africa's NMCP developed

MalariaConnect in Mpumalanga province, as a surveillance tool to report malaria cases using a mobile phone (Davies et al., 2019). However, these mobile phone-based malaria applications continue to show the possibility of reporting, monitoring, mapping hotspots and surveillance of malaria in real-time at the ward level despite the highlighted impediments.

The integration of mobile technology in healthcare service delivery benefits almost everyone across the spectrum. For instance, mobile technologies can reduce logistical inefficiencies in healthcare service delivery and improve communication and information sharing among health stakeholders (Vesel et al., 2015), especially in rural marginalised communities that experience a dearth of health workers (Beratarrechea et al., 2017), and a lack of feasible m-Health applications (Marufu & Maboe, 2017a). Despite the importance of mobile health applications to improve healthcare service delivery in resource-constrained areas, Watkins et al.(2018) highlighted that their adoption faces tremendous challenges such as lack of electricity, poor digital infrastructure, digital illiteracy, and lack of health information available in local languages (Manyati & Mutsau, 2021; Osei et al., 2021; Vinerean et al., 2022). In addition, challenges such as short battery life (Mosa et al., 2012), privacy and security issues (Bromwich & Bromwich, 2016; Hewitt et al., 2017), small user interface, lack of health data protection policy; and lack of guidelines and restrictions on mobile phone owners on what to install and restrictions on the terms of use especially when sending, receiving and accessing health-related data have been reported as major setbacks to adopt mobile phones in rural health systems (Wallis et al., 2017).

Moreover, the feasibility and sustainability of the piloted internet-based ICT interventions require a strong internet connection and supporting ICT infrastructure. For instance, the MozzWear app requires an additional implementation cost of USD $20 and daily airtime for internet connection (Kiskin et al., 2021). The Mobile Alliance for Maternal Action app supports a smartphone platform and requires active internet access which might not always be feasible in rural areas in low-income countries including Zimbabwe. For instance, a telemedicine pilot project cost USD $300 000 in 2016 when tested in 12 clinics and district hospitals in the Manicaland province. It required a reliable internet connection and was costly to sustain which subsequently affected the rolling out of the project nationwide. (Furusa & Coleman, 2018). Other factors such as interoperability and compatibility with feature phones, lack of funding (Chidhau et al., 2021a), brain drain of health workers, lack of skills, and the digital divide among others were major drawbacks of the past projects (Furusa & Coleman, 2018). Besides the yearly subscription cost and incompatibility with DHIS, the Frontline SMS WDSS, which is an SMS-based platform, is specifically meant for administrative work and does not support universal access and distribution of information between healthcare professionals and recipients of care as indicated by Chidawanyika et al. (2014). To bridge the existing gap between Internet-based intervention and the Frontline SMS system, the research explores an ICT-based intervention framework for disseminating health information in resource-constrained areas.

According to Yaya et al. (2018), the lack of knowledge about mobile technology-based platforms for malaria prevention and awareness in the public healthcare systems especially in resource-constrained areas is a major challenge. According to the Postal and Telecommunications Regulatory Authority of Zimbabwe (POTRAZ), a body mandated to issue licenses in the postal and telecommunications sector, most Zimbabweans have access to mobile phones. In Zimbabwean rural areas, mobile phones are a common and reliable channel of communication with at least one household member in 84% of households having a mobile phone. The mobile phone penetration rate is increasing gradually (Tsarwe, 2018). Mobile phones enable communication by using voice calls, mobile applications, and SMS. SMS is the most affordable two-way communication platform available in most Zimbabwean rural communities (Zhou et al., 2015). With the SMS platform, people living in malarial rural areas can send, leave, and receive messages at a very low cost as compared to internet-based channels (Oliver-Williams et al., 2017).

2.10 Technologies underlying mobile health applications

As stated by Klasnja and Pratt (2012), mobile-health applications rely on different technologies including technical capabilities, mobile operating systems and even mobile phone manufacturers. Mobile phones vary in technical capabilities (including basic voice calling and text messaging) to support third-party applications which allow access to the internet and establish connectivity with other smartphone devices. Smartphone devices such as iPhones, Blackberries, Windows phones and Android phones vary in terms of size, storage capacity and computational speed (Liu et al., 2011). These modern smartphones offer various services on top of voice calling and text messaging through advanced features, such as web searching, in-built sound recorders, installation of third-party applications, global positioning systems and high-quality cameras (Mosa et al., 2012). Because of these features, as well as processors, user-friendly operating systems, high resolution and large storage capacity, smartphones are increasingly becoming a powerful and intuitive tool in the healthcare system. Built-in applications, sensors and the ability to connect to wireless data service and with other devices have revolutionised the technology behind mobile-phone interventions, especially in healthcare systems (Boulos et al., 2011). In addition, the majority of these devices support universal service supplementary data technology, native applications and text messaging technology to deliver health services as discussed below.

2.10.1 Unstructured Supplementary Service Data (USSD) Technology

The USSD is a technology that establishes communication between the application programme and a mobile phone using text messages (Zhou et al., 2015). USSD technology is a real-time session-based communication using a global system for mobile communication technology (GSM). The GSM technology establishes the network and then allows the application programme and mobile phone to communicate bi-directionally by using codes or sessions to activate and de-activate the communication link. USSD protocol has been implemented in various fields to provide location-based services (Wouters et al., 2009), banking services, telecommunication services, marketing surveys, retailing services, agricultural services and health services (Perrier et al., 2015). For instance, the Ushahidi USSD application has been used as a crisis mapping system for reporting on political violence and activities, and assists during election time (Hirata et al., 2018).

USSD technology is cost-effective because it uses the existing global system for mobile communication infrastructure (Lakshmi et al., 2018). Besides, USSD technology is responsive, faster and interactive. This is because USSD technology supports real-time session-based services with several interactive options which can be customised to meet users' demands as compared to the SMS platform that uses the store and forward technique to send the message. In terms of operational costs, USSD is less costly compared to SMS technology, since each text message attracts a relative amount of charge (Lakshmi et al., 2018).

2.10.2 Native applications in healthcare services delivery

Mobile smartphones support the installation of third-party applications on mobile platforms such as iOS, Android, Symbian, Blackberry, WebOS, and Windows (C. Liu et al., 2011). This allows programmers to design, build and develop special-purpose applications through the use of programming interfaces called application programme interfaces (API). Mobile applications function through mobile application distribution platforms called mobile operating systems. In general, three mobile operating systems support mobile applications namely, Apple iOS, Android OS and Windows owned by Apple Inc, Google Inc and Microsoft Corporation respectively (Saxon, 2016).

The concept of smartphones was introduced in the 1970s (Green et al., 2018) and first released a Simon primitive smartphone in 1992 (Oehler et al., 2010) but it was impaired by high cost, limited functionalities and lack of applications. Later on, after thorough research, Handspring developed palm-based medical applications for a phone handset in 2001 (Moodley et al., 2013). In 2002, BlackBerry was launched with numerous medical wireless information services such as electronic mail, text messaging, and web browsing capabilities. In 2006, high-tech companies leveraged the capabilities of the previous smartphone which gave birth to Blackberry, Windows Mobile, Symbian, and Palm OS-based smartphones (Oehler et al., 2010). In 2007, the first-generation iPhone was launched, which include improved features such as Safari web browser, 8 gigabytes storage size and media player, and these functionalities paved a way for the iPad in 2010 (Yoo, 2013). The iPad 2010 supported the installation of native applications such as SMS, YouTube viewer and Google maps but still, it was of limited medical utility. According to Liu et al. (2011) and Fougerouse et al. (2017), Apple's iOS mobile devices including iPhone and iPad support more convenient and richer user experiences, as evidenced by the rapidly increasing number of m-Health applications with over 259 000 health-related applications in Apple's App Store. Apple supports the software developer's kit which enables mobile health application developers to link their apples with Apple Libraries and push the application to the cloud, Apple's App Store.

According to Ventola (2014), the first HTC Dream smartphone with a user-friendly intuitive touchscreen and advanced features running on the Google Android operating system was launched first in 2008. Google further developed the Samsung Galaxy series in the preceding year to improve the HTC dream. Just like Apple, Google launched Google Play Store to allow health stakeholders including healthcare professionals and patients to have access to various health applications (Payne et al., 2012). Google also provides cloud-based storage services (Google Drive) that support uploading, sharing, downloading and management of health information which can be accessed in parallel and simultaneously with multiple devices irrespective of geographical location. Google Drive is directly linked to G-suite to store patient data files in a cloud repository with respect to health insurance portability. It is Accountability Act (HIPAA)-compliant. In addition, Google released Android Studio as a platform that allows Android developers to build Android-based mobile applications (Papageorgiou et al., 2018). For example, developers can develop android-based health applications that meet user requirements and specifications.

Several Android-based health applications including healthcare monitoring systems (Kao et al., 2018; Lou et al., 2013), tracking systems and chronic disease self-management (Park et al., 2016) have been developed and implemented to improve the quality of care. However, mobile health applications make use of unsecured Internet communications and third-party servers, especially the applications store for iOS (Apple App Store) and Google Play store (Android), which makes them vulnerable when handling sensitive health data for both patients and health workers. Papageorgiou et al. (2018) also state that mobile health applications from Google Play including Epocrates, Self-help Anxiety Management, Clinical Advisor and iCardio collect a vast amount of health data from the patient such as mental health information, location tracking, social interactions, patient health behaviour and activities without proper security and privacy guidelines that suit dynamic markets. The guidelines should promote the growth and proper implementation of mobile health applications in the healthcare system without causing a cavalier attitude towards personal health data. In addition, Bhuyan et al. (2017) and Hussain et al. (2018) argue that despite the use of sandboxing and permissions as security mechanisms, Android mobile health applications are still plagued by severe security and privacy issues. To alleviate security and privacy risks associated with health data, several high-tech companies including Microsoft developed mobile health applications that secure patient health data through standalone data repositories.

Microsoft Corporation released a health application called Microsoft HealthVault, which is a personal health record that involves a standalone data repository with an integrated application ecosystem (Do et al., 2011). Microsoft HealthVault provides web interfaces that encourage patients to participate in the health system in two ways: storing their health data electronically and searching for health information (Sunyaev, 2013). It is sometimes called consumer healthcare or personal healthcare due to its flexibility of allowing patients to remotely (online) store health data, manage their records and upload medical data from wearable devices. This results in yielding a larger amount of health information, which can be further used for research, treatment and diagnosis purposes since the information can be shared with other health management web portals. Even though Microsoft Health Vault claims to support clinical document architecture, it does not support the messaging scheme to connect the patients with healthcare professionals (Vogiatzaki & Krukowski, 2019). Despite the benefits of using mobile health applications, their effective implementation and utilisation depend on the availability of smartphones, which is not always the case with some underprivileged people in resource-constrained rural communities. In such circumstances, text messaging might be useful to create awareness and health promotion because of the pervasiveness and ubiquitous of mobile phones. The following section explains the significance of text messaging technology in healthcare.

2.10.3 Text messaging technology

Given the increasing use of cell phones and text messaging in sub-Saharan Africa, there is an increasing need to explore its potential use to improve healthcare utilisation and adherence. The widespread use of text messaging can potentially lead to improved delivery of health services and better health outcomes (Zurovac et al., 2011). Text messaging is regarded as the most common digital method of communication in resource-constrained areas (Zurovac et al., 2012). SMSs can be broadcasted in bulk using an SMS gateway provided by mobile telecommunication companies that use GSM technology. This is a tremendous opportunity to reach out to a larger audience. SMS requires minimal skills and offers convenience because of its asynchronous character. Several studies used SMS in healthcare to perform different tasks including malaria surveillance, sending reminders (Gibson et al., 2017), creating awareness, reducing stock-out (Githinji et al., 2013), follow-ups (Sarma et al., 2018) and monitoring treatment adherence (Quan et al., 2014).

However, sending SMS has its limitations and drawbacks such as the cost per SMS and the content of one SMS being limited to 160 ASCII characters (Barron et al., 2018). This technology offers one-way communication, unlike USSD technology. However, Källander et al. (2013) and Barron et al. (2018) posit that the integration of USSD technology and SMS can bring positive results when deployed after understanding the embodiment of challenging factors hindering the use of mobile health applications in healthcare service delivery. In addition, SMS-based malaria interventions cannot capture, process, analyse, and predict malaria outbreaks using existing malaria data from various sources such as district health information systems, and meteorological departments among others. To counter this major drawback, several scholars applied machine learning techniques to predict malaria at the national level using malaria data from various data sources, as explained in the subsequent section.

2.11 Machine learning concepts and their application in predicting malaria

Machine learning (ML) is a subset of artificial intelligence that learns from experience and extracts valuable patterns from large, unstructured, and complex datasets to predict future incidences (Harvey et al., 2021). Machine learning models are generally trained and learn from data using either supervised or unsupervised learning techniques. Unsupervised learning focuses on uncovering structure within a dataset without prior knowledge of how the data are organized, thus expected output is unknown (Mariki et al., 2022). In contrast, supervised learning relies on prior knowledge and labelled training data to make predictions or classify labelled data (Lee et al., 2021). Therefore, supervised machine learning predicts the value of response labels of either categorical or continuous values based on the input dataset.

Predicting malaria outbreaks is increasingly becoming essential in forecasting, treating and preventing malaria in malaria-endemic areas to optimise the distribution of limited malaria commodities (Brown et al., 2020). Thus, machine learning can assist to predict malaria with high precision using a dataset that would ordinarily present challenges with manual computations (Okagbue et al., 2021). This can also assist policymakers to expedite the development of early warning systems to monitor the spread of malaria and subsequently strengthen malaria prevention and control measures. In addition, malaria prediction models help to plan, organise, expeditiously allocate resources and operationalise malaria control and vector management giving priority to the predicted high malarial zones. However, despite the important application of machine learning (ML) models in predicting malaria in endemic areas, the adoption and implementation of ML to alleviate malaria are still nascent in many sub-Saharan African nations. Among other benefits, predicting malaria can significantly assist in effectively allocating resources, developing malaria early systems, and enhancing the understanding of malaria trends, distribution, and hotspots at the ward level. However, the application of machine learning models in malaria surveillance systems has been tremendously affected by scanty and inaccurate quality data due to inconsistencies in malaria data collection methods and data formats. Despite these impediments, machine learning techniques have been applied to solve various malaria-related problems such as malaria detection, diagnosis

(Okagbue et al., 2021), mosquito identification, malaria outbreak (Harvey et al., 2021) and forecasting malaria transmission (Nkiruka et al., 2021).

2.11.1 Machine learning models for predicting malaria

Several machine learning models have been used to predict malaria in various malaria-endemic countries. Such models include support vector machines (SVM), decision tree (DT), random forest (RF), Extreme Gradient Boosting (XGBoost), logistic regression (LR), K-Nearest Neighbours (KNN), and Naïve Bayes as shown in Table 2.2.

Table 2.2: Machine learning-based malaria prediction models

Reference	Prediction models	Data sources	Performance metrics			
			Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
(Kalipe et al., 2018a)	RF, DT, SVM, Naïve Bayes, KNN and XGBoost	Meteorological Centre, India	KNN:86.21, RF:93.94, SVM:92.69, XGBoost:96.26, LR:92.44, Naïve Bayes: 91.69	KNN=92.9, RF:85.42, SVM:91.14,XGBoost: 91.8, LR:90.44, Naïve Bayes: 88.36	KNN=50.48, RF:92.28, DT:42, SVM:79.42, XGBoost:93.89,LR:79.1, Naïve Bayes: 78.14	Not used to assess the performance
(Yadav et al., 2021)	DT, RF, NB, LR and SVM	Clinical data, Senegal	DT: 97.8, RF: 97.24,	NB:96, LR: 93, DT:92, RF: 92, SVM:93	NB:5, LR: 62, DT:85, RF: 85, SVM:86	NB:10, LR: 75, DT:88, RF: 89, SVM:89
(Mohapatra et al., 2021)	Decision Tree	Malaria cases, rainfall, temperature, humidity, Odisha, India	71	Not used to assess the performance	Not used to assess the performance	Not used to assess the performance
(Lee et al., 2021)	SVM, RF, Gradient boosting, CatBoost(CB) and multilayered perceptron, AdaBoost	Parasitic disease dataset using BioPython from Center for Disease Control and Prevention	SVM: 91.5 RF: 90.3 MLP: 90.9 AdaBoost: 89.4 GB: 89.1 CB: 90.9	SVM:00 RF: 25 MLP: 28.6 AdaBoost: 21.1 GB: 22.7 CB: 25	SVM: 00 RF: 16 MLP: 16 AdaBoost: 16 GB: 20 CB: 12	SVM: 00 RF: 19.5 MLP: 20.5 AdaBoost: 18.2 GB: 21.3 CB: 16.2
(Harvey et al., 2021)	Random Forest	IeDA database	95	83	99	Not used to assess the performance

(Nkiruka et al., 2021)	XGBoost, SVM, Naïve Bayes and LR	Climate factors and malaria incidences	XGBoost: 86, SVM: 72, Naïve Bayes: 70 and LR: 77	Not used to assess the performance	Not used to assess the performance	Not used to assess the performance
(Muhammad & Varol, 2021)	Decision tree	Clinical malaria data	77	Not used to assess the performance	Not used to assess the performance	Not used to assess the performance
(Zacarias & Bostrom, 2013)	SVM and RF	Malaria cases, IRS data and climatic factors	SVM: 95 RF: 90	Not used to accessing the performance	Not used to assess the performance	Not used to assess the performance

Support Vector Machines is a supervised algorithm that learns by analysing data used for classification and regression analysis purposes, thus assigning labels to objects (Lee et al., 2021). Support Vector machines can classify both linear and non-linear data by mapping each input data into an *n*-dimensional feature space, where *n*, is the number of features. The classes of data input are then separated by a hyperplane to maximise the marginal distance and minimise classification errors in both classes (Zinszer et al., 2012). In linear SVM, the plane can be split by a line and then the marginal distance for a class is determined by the distance between the nearest input label of the same class and the decision hyperplane. SVM also solve nonlinear regression problems by transforming support vectors into higher dimensional feature space, which is introduced by kernel functions. In this context, support vectors refer to training points that are nearest to the separating function. The kernel functions map nonlinear regression problems into separable entities by mapping data into better representational space. For instance, Sharma et al. (2015) applied SVM and artificial neural networks (ANN) to predict malaria outbreaks with environmental data such as temperature, humidity, rainfall, and malaria-positive cases. From their study, SVM recorded a root mean squared error (RMSE) of 0.12 as compared to artificial neural networks which had an RMSE of 0.47. However, SVM requires manual feature extraction and is unsuitable for discovering multifaceted correlations in malaria data though it seems to be the best prediction model. Therefore, SVM cannot be easily integrated alone without other optimisation algorithms and process malaria data with unbalanced dimensions because it may affect the prediction results. To solve this problem, Sudheer et al.(2014) applied SVM coupled with the firefly algorithm to determine malaria transmission, and compared it with other models such as SVM, ARMA and ANN. From their study, SVM with the firefly algorithm outperformed other models with the normalised mean square error of 0.21, and 0.32 for SVM, 0.34 for ANN, and 0.39 for ARMA (Sudheer et al., 2014).

A decision tree is a tree-like structure that uses several questions with binary answers. Each answer to a new question leads to a new yes or no answer in the form of nodes until finally, a prediction can be made. Each node represents the splitting rule for a feature to classify the target value. In Mozambique, Zacarias & Bostrom (2013) applied decision trees to predict malaria incidences using a combination of IRS datasets, malaria cases and climatic factors. However, decision trees suffer from misclassification errors of the multiclass variables since the splitting criterion is based on the normalised information gain (Wang et al., 2019). Thus, a decision attribute for splitting the data is chosen based on information gain (Zhu et al., 2009). An attribute with the highest normalised information gain is chosen to make the decision.

Random forest (RF) is a supervised machine learning ensemble classifier that consists of many decision trees (Kalipe et al., 2018; Zhang et al., 2022). The class that is most frequently predicted across all trees in the forest is chosen as the predicted class by the random forest (Pourhomayoun & Shakibi, 2021). It combines decision trees with ensembles of classification or regression trees, which are created by employing bootstrap sampling on the training set and random feature selection during tree induction (Zacarias & Bostrom, 2013). It is a machine learning method composed of many Decision Trees that use randomly picked data attributes as their input. The forest generation process constructs a collection of trees with controlled error variance. The resulting prediction can be decided by a selection scheme, such as averaging or majority voting (Breiman, 2001). Buczak et al. (2015) and Zacarias & Henrik (2013) applied a random forest to predict malaria incidences in South Korea and Mozambique, respectively. Zacarias & Henrik (2013) noted that the mean square errors of RF were higher than SVM. This shows the applicability of SVM in predicting malaria incidences, especially in malaria-affected zones.

Adaptive Boosting (AdaBoost) is a boosting algorithm introduced by Freund and Schapire to solve classification problems (Sornsuwit & Jaiyen, 2019). The algorithm is generally integrated with other machine learning classifiers to improve performance. The Adaptive boosting algorithm trains a classifier into input data and adjusts the weights of misclassified data, while additional copies of the classifier are fitted to the same data (Feng et al., 2020; Walker & Jiang, 2019). This process is done iteratively till it achieves the best performance. A study by Bui et al. (2018) applied GIS, support vector machine, artificial neural networks and AdaBoost to understand malaria spatial variations in Vietnam and further assessed the performance of these techniques using statistical evaluation metrics such as mean absolute error and root mean square error.

Logistic regression (LR) is the most prominent and powerful supervised machine learning classifier used to solve binary classification problems (Yadav et al., 2021). It is based on the logistic representation of a binary dependent variable and explanatory variables as feedback to calculate the probability of a particular class label (Fashoto et al., 2021). Logistic regression finds the probability that a new instance belongs to a certain class and the outcome lies between 0 and 1 (Uddin et al., 2019). Therefore, a threshold needs to be assigned to separate the two classes. For example, if a probability score is greater than 0.5, logistic regression classifies it as 1, otherwise 0. The next subsection presents performance evaluation metrics for assessing machine learning-based malaria prediction models.

Multilayer perceptron is a machine learning classification algorithm that uses a supervised training method. Multilayer perceptron (MLP) consists of the input layer, hidden layer and output layer (Lee et al., 2021). The input layer receives input data, while the hidden layer consists of hidden neurons that compute associations in sample data and pass the results to the output layer. The purpose of the output layer is to generate results. The MLP is generally trained using a supervised learning algorithm until the error rate becomes sufficiently small. As shown in Table 2.2, Lee et al. (2021) applied MLP to predict malaria using clinical data and the model achieved an accuracy of 90.9%, precision of 28.6%, recall of 16% and F1-score of 20.5%. This shows that MLP generally performs poorly when predicting malaria with a small dataset.

2.11.2 Malaria prediction models performance evaluation metrics

Prediction models are generally assessed after a computing model training and testing process. In the past, the performance of machine learning models was centred on accuracy (Sokolova & Lapalme, 2009). However, accessing prediction models using accuracy only proved insufficient and sometimes misleading due to different factors including the type of the problem being solved (Lahmiri et al., 2018), and the structure and size of the dataset (Kalipe et al., 2018a). In addition, Seliya et al.(2009) noted that there is no general consensus on the best machine learning evaluation metrics because values generated in the confusion matrix (especially binary classification) determine the false positives, false negatives, true positives and true negatives. Thus, the performance of machine learning models to solve binary, multilabel and multiclass classification problems can be assessed using machine learning classification performance metrics such as precision, recall, accuracy, and F1-score (Erickson & Kitamura, 2021). These classification metrics capture important aspects in the model evaluating space. Binary classification ensures that the input is classified into one, and only one, of two non-overlapping classes (Sokolova & Lapalme, 2009).

Predicting malaria outbreaks is a binary classification problem that can be solved by applying machine learning classification models. The performance of machine learning classification models can be assessed by using classification performance evaluation metrics (Alaa Khaleel & Al-Bakry, 2021). The study tries to address a classification problem by predicting malaria (malaria or not) in malaria hotspot areas, hence the use of classification performance evaluation metrics such as precision, recall, accuracy, and F1-score. These performance measurement metrics are calculated using the confusion matrix of each machine learning model. The parameters of the confusion matrix consist of True Positive (TP), False Positive (FP), True Negative (TN) and False Negative (FN). True positive is the number of positive target variable instances that have been correctly predicted as positive (Kalipe et al., 2018b). False positive is the number of negative target variable instances that have been wrongly predicted as positive (Uddin et al., 2019). True negative is the number of negative target variable instances that have been correctly predicted as negative (Alaa Khaleel & Al-Bakry, 2021). A false negative is the number of positive target variable instances that have been wrongly predicted as negative (Yadav et al., 2021). Machine learning performance evaluation standards such as recall, precision, accuracy, and F1-score can be calculated using the confusion matrix. These metrics are paramount to assessing the performance of machine learning models. These evaluation metrics are explained below.

A recall is also known as sensitivity; it evaluates how many positive targets are lost in the prediction. It is calculated as follows.

$$Recall = \frac{TP}{TP+FN} \quad (1)$$

Precision is also known as positive predictive value; it helps evaluate how many positives are superfluous in the result and thus cannot be trusted. It is calculated as follows.

$$Precision = \frac{TP}{TP+FP} \quad (2)$$

Accuracy is the ratio of correctly predicted observations over the total observations (Gonzalez-Cuautle et al., 2020). It is calculated as follows.

$$Accuracy = \frac{TP+TN}{TP+FP+FN+TN} \quad (3)$$

F1-score is a function of precision and recall and it is needed to maintain a balance of precision and recall results. It is calculated as follows.

$$F1 - score = \frac{2*TP}{2*TP+FP+FN} \quad (4)$$

2.11.3 Data sources for predicting malaria

As shown in the previous section (Section 2.11.1), the growth and maturity of this parasite mostly depend on climatic factors, which include temperature, rainfall, and relative humidity. Thus, any change in climate factors would certainly exert an effect on the mosquito ecology. Therefore, the correlation between climatic and environmental risk factors and malaria incidence has been a predominant research focus (Nkiruka et al., 2021). Although many studies have indicated that climate and environmental change may influence the distribution of malaria, there is a paucity of information on its trends and association with climatic variables in Zimbabwe, especially at the ward level (Gunda et al., 2017). For instance, rainfall and temperature influence seasonal malaria transmission. Rainfall is responsible for creating mosquito breeding sites while temperature regulates the rate of development of the mosquito larvae and influences mosquito survival rates. In addition, Gunda et al.(2017) argue that rainfall, temperature and altitude are key factors in determining the habitat suitability of malaria vectors, including *Anopheles* (common in Zimbabwe), as well as determining malaria incidences. Also, Manyangadze et al.(2021b) state that enhanced vegetation index (EVI), normalised difference vegetation index (NDVI), and normalised difference water index (NDWI) influence seasonal and spatial variation in malaria transmission in Zimbabwe.

Several scholars utilise climatic and environmental data to predict malaria. For instance, Zinszer et al.(2015) apply the autoregressive integrated moving average (ARIMA) model to forecast malaria using clinical predictors and environmental data in Uganda. The environmental data used in the study include day and night land surface temperature (LST) from MODIS (MOD11A2) using 8-day composite images at a 1 km × 1 km resolution, enhanced vegetation index (EVI) from MODIS (MOD13A1) using 16-day composite images at a 0.5 km × 0.5 km resolution, and rainfall estimates with a spatial resolution of 0.25° × 0.25° or 27.8 km × 27.8 km (at the equator). For instance, Yadav et al.(2021) apply machine learning models such as random forest, support vector machine with Gaussian kernel and artificial neural networks to predict malaria using clinical data such as signs and symptoms in Senegal. Also, Nkiruka et al.(2021) utilized machine learning to predict malaria incidences at the national level using data from the National Centre for Atmospheric Research. They researched sub-Saharan African countries such as Burkina Faso, Cameroon, Mali, DRC, Niger Republic, and Nigeria. However, their study did not have adequate datasets for confirmed malaria incidences to stratify malaria seasons to enhance real-time prediction. Also, Harvey et al. (2021) applied time series to predict malaria epidemics in Burkina Faso. In Ethiopia, Chekol & Hagras (2019) predicted malaria incidences three months ahead by using an adaptive neuro-fuzzy inference system and support vector regression. These models were trained and tested using climatic data such as monthly rainfall, average temperature, relative humidity, and monthly malaria data. To improve the performance of machine learning models, Harvey et al. (2021) utilised the synthetic minority oversampling technique (SMOTE) to address the class imbalance problem and then applied a support vector machine, random forest, multi-layered perceptron, AdaBoost, gradient boosting, and CatBoost to predict malaria using both clinical information and parasitic disease dataset. Class imbalance occurs when instances of one class outnumber the instances of other classes which can affect the performance of machine learning problem (Gonzalez-Cuautle et al., 2020). This is because the classifiers, which learn from a minority class with very few instances, tend to be biased towards a high accuracy in the prediction of the majority class (Seo & Kim, 2018). Several techniques such as over-sampling the minority class, under-sampling the majority class, and using hybrid methods have been utilized to balance class distribution. Undersampling the majority class is the most native method of dealing with class-imbalance problems by eliminating of majority class which consequently leads to discarding potentially useful data that could be important for classifiers (X. Y. Liu et al., 2009). Therefore, to avoid discarding important useful malaria data, this study utilized a synthetic minority oversampling technique (SMOTE) to address the class imbalance problem by changing class distributions (Guo et al., 2008). The synthetic minority oversampling technique is the most popular over-sampling method due to its simplicity (T. Zhu et al., 2017), computational efficiency, and superior performance. SMOTE generates a synthetic example rather than replacement with replication. This technique identifies more specific regions in the feature space for the minority class (Elreedy & Atiya, 2019). However, SMOTE is applicable for binary classification problems with a continuous feature space (Wang et al., 2019). For instance, predicting malaria outbreak is a binary classification problem. A study conducted by Lee et al.(2021) applied SMOTE to solve data imbalance problem and predict malaria using clinical information.

2.12 m-Health frameworks for integrating ICT-based malaria interventions in sub-Saharan Africa

Mobile health services especially mobile health applications seek to increase universal access to healthcare, particularly in rural communities to reduce existing inequalities and poor access to health services and facilities. Several scholars developed different frameworks (see Table 2.3) to provide various functionalities including strengthening health systems, improving service delivery, improving the performance of health workers, and adopting emerging technology (Mbuthia et al., 2021). Despite these functionalities, existing inequality and poor access to healthcare (Mbuthia, 2020), especially in resource-constrained rural areas is now a global health concern that incessantly affects progress to ensure universal access to care. As a result, WHO and member states formulated sustainable development goals, emphasizing the need for improving universal health coverage while promoting good health and well-being (Manhibi et al., 2022). One of the important set milestones is to end the epidemics of AIDS, tuberculosis, malaria and other communicable diseases by 2030. This can be realised by improving access to care, improving health communication, investing in healthcare, creating awareness and adopting feasible emerging digital health interventions including mobile health applications, radio, television, digital billboards and mobile phones. Empirical evidence from several studies including Chawurura et al.(2022), Chigwedere et al.(2022),Khatun et al.(2016) and Pankomera & van Greunen (2018) show that access to care is high in urban areas as compared to resource-constrained rural areas because of easy access to health facilities and health workers as well as increased utilisation of digital health platforms. However, the uptake and accessibility of these interventions and services are substantially low in resource-constrained rural areas (Mbuthia et al., 2021). To improve access to healthcare, several scholars developed different mobile health frameworks, with little focus on malaria digital interventions as shown in Table 2.3.

Table 2. 3: m-Health frameworks for improving access to care

References	Functions	Application	Country	Limitations
(Mbuthia et al., 2021)	• Improve health communication	Postnatal care (PNC)	Kenya	No prototype was used to validate the framework based on available evidence
(Pankomera & van Greunen, 2018)	• Implement m-Health technologies	General care in resource-constrained settings	Malawi	Experts theoretically validated the framework
(Mwendera et al., 2017)	• Improve and promote the utilisation of malaria research for policy and practice to reduce malaria	General health setting	Malawi	The framework does not include the use of ICTs in malaria research
(Thobias & Kiwanuka, 2018)	• To improve health information access for antenatal care using SMS	Pregnant mothers	Tanzania	No real-time bidirectional communication between health workers and pregnant mothers.
(Mark & Ngwira, 2011)	• Planning, management of patient records and basic diagnostic support	General health setting	African states	The framework is generalised to African states to collect patients and resource allocation and utilisation. However, each African state has its ICT infrastructure and health policies which can differ from each because of factors such as network penetration, mobile technology usage, and policies among others.
(Ndayizigamiye & Maharaj, 2016)	Adoption of m-Health projects in Burundi	m-Health	Burundi	The framework assesses Burundi's readiness to adopt m-Health into the health system focusing more on perceived challenges
(Mukami et al., 2019)	Mitigating the determinants of maternal and neonatal mortality	Maternal and neonatal	Kenya	The framework does not specify the kind of ICT technology to be used and assumes that due diligence towards the implementation of the technology has been conducted. Also, the framework does not cluster maternal healthcare services based on highlighted extrinsic variables and underlying factors.

(Agbehadji et al., 2019)	Delivering basic healthcare services to the aged person using mobile technology	Aged Persons	Ghana	The framework focuses only on the provision of care to aged persons by utilising mobile phone platforms.
(Matingwina & Raju, 2017)	Disseminating Health Information and promoting health among university students	University students	Zimbabwe	The framework only focuses on providing health information to university students from health workers.
(Leon et al., 2012)	Assessing the health system challenges to scaling up m-Health projects	General health setting	South Africa	The framework focuses on operational, organisational, technological and financial challenges for improving and scaling up of m-Health projects.

Mobile health frameworks shown in Table 2.3 have several setbacks exacerbated by the outbreak of COVID-19, and the need to achieve health goals by promoting the adoption of emerging digital health technologies to support virtual care. Therefore, the following subsection provides a comprehensive explanation of the challenges encountered and existing research gaps.

2.12.1 Identified challenges and research gaps

A framework proposed by Thobias & Kiwanuka (2018) only considers one form of communication, the SMS platform, which might not be the only feasible platform for other settings. Pregnant mothers are expected to regularly visit health facilities for regular check-ups, which is the best practice under normal circumstances, however, because of COVID-19, alternative means are required to improve care services delivery.

The literature also revealed that several m-Health projects have stagnated, not scaled up to other locations and in some instances, stalled at the pilot phase due to a lack of funding to sustain them (Pankomera & van Greunen, 2018). Some further challenges encountered when implementing m-Health frameworks and projects in resource-constrained areas include inadequate digital skills training (Ndayizigamiye & Maharaj, 2016), lack of human skills and development, lack of political will, language barrier, low digital literacy levels, low socioeconomic status (Marufu & Maboe, 2017b), inconsistent power supply (Mbuthia, 2020), perceived implementation costs, lack of standards for data, security (Chawurura et al., 2022), and architecture for interoperability, poor digital infrastructure to support m-Health projects (Manhibi et al., 2022), lack of coordination and poor ICT governance (Pankomera & van Greunen, 2018). The literature also revealed that there is a lack of robust policies, regulations and guidelines (Batani & Maharaj, 2022; Chigwedere et al., 2022) as well as m-Health frameworks guiding the integration of feasible and sustainable feasible digital technologies for improving malaria healthcare service delivery in resource-constrained rural communities despite the high penetration of mobile phones in sub-Saharan Africa.

In some developing countries including Zimbabwe, there is a lack of mobile health frameworks for improving access to care, and providing quality care effectively, especially in resource-constrained areas (Batani & Maharaj, 2022; Chigwedere et al., 2022). The dearth of resources exacerbated by the outbreak of COVID-19 requires the adoption of emerging mobile health technologies to meet three goals of healthcare institutions – access, quality and efficiency (Batani & Maharaj, 2022). Realizing these goals, especially in resource-constrained rural communities is an unlikely ambition without adopting and integrating feasible digital technologies in health systems to ensure universal healthcare and effective delivery of healthcare services (Marongwe et al., 2022a). For instance, creating awareness, improving access to care, facilitating remote consultation (Batani & Maharaj, 2022), disseminating health information between health workers and the community, and bridging health inequalities (Chawurura et al., 2022; Marufu & Maboe, 2017b), monitoring diseases effectively, surveillance and mapping require effective adoption and utilisation of feasible digital health systems. The adoption of digital health systems attracted considerable interest from researchers and policymakers mainly concentrating on digital health readiness (Batani & Maharaj, 2022), factors influencing adoption and potential benefits (Furusa & Coleman, 2018), improving maternal care (Dabengwa et al., 2022a; Nyati-Jokomo et al., 2020a), and security and ethical issues (Mbunge et al., 2021).

Therefore, it is imperative to address that research gap by considering the health needs of vulnerable communities, and perceptions of health workers, crafting enabling policies for integrating emerging feasible digital health interventions as well as enabling resources and digital infrastructure. These factors are paramount when developing mobile health frameworks. As evidenced in the literature, currently in Zimbabwe there is no published m-Health framework for integrating feasible digital technologies to improve healthcare service delivery, especially in resource-constrained rural areas to tackle malaria.

Therefore, there is a need for developing a mobile health framework to integrate emerging digital technologies for improving access to care and health information dissemination in resource-constrained rural areas. This study sought to address this gap by developing m-Health for integrating feasible digital technologies to improve malaria healthcare service delivery in malaria-endemic rural communities.

2.13 Accessibility of digital communication technologies in Buhera rural district

Buhera rural district is one of the partially disconnected rural communities with regard to telecommunication connectivity. The increasing demand for the use of adequate digital infrastructure resulted in the introduction of the community network, Murambinda Works (Gwaka et al., 2022). Murambinda Works is located at Murambinda Growth Point in Buhera District under Manicaland province. The prime goal of Murambinda Works is to provide sustainable internet access through community networks to rural communities even though they are under-resourced.

As telecommunication companies continue to be disinclined to provide full digital coverage in rural communities, the populace living in marginalised areas continues to be alienated. Notwithstanding this, the Zimbabwean Government through the Postal and Telecommunications Regulatory Authority of Zimbabwe (POTRAZ) tor is advocating to improve access to ICTs in rural areas through the formulation of favourable policies that promote investment in community networks (Gwaka et al., 2018). TelOne is one of the internet service providers working towards establishing fibre optics to increase the internet speed of Murambinda Works. Currently, there are three competing mobile operators, Telecel, NetOne and Econet wireless. Amongst them, Econet is a leading network service provider based on the number of subscribers, providing mobile services including voice calls, text messages, internet access and mobile money transfer. Community networks help to bridge the telecommunication gap and digital divide, thereby creating an enabling environment to disseminate health information in underserved rural communities (Gwaka, 2017). The digital divide exacerbates the already wide disparities in accessing digital information (Maphosa, 2018), and such deviations have an impact on digital awareness and digital health service delivery. More so, there is a mutual correlation between access to health information and health behaviour.

Even though television and radio broadcast health information during a disease outbreak, they suffer from attenuation in distant rural communities. Currently, ZIFM Stereo, Power FM, Radio Zimbabwe and Star FM Radio are the largest radio stations based on listenership. Some radio stations could not withstand the political instability and prevailing economic challenges in the country (Maphosa, 2018), and had to close. The monopolisation of broadcasting services has been affecting the issuance of television broadcasting licenses which has resulted in Zimbabwe Broadcasting television as the sole broadcaster (Mabweazara, 2013).

As a result, some digitally disconnected, impoverished and vulnerable communities might not have full access to malaria information as indicated by Kaindoa et al.(2018). A study conducted by Tsuyuoka et al. (2004) shows that educating communities about the importance of vector control and elimination strategies contribute significantly toward the cessation of malaria. Therefore, health promotion, education, community engagement and behavioural change can significantly complement existing malaria prevention and control measures. Integrating and incorporating already existing strategies with feasible and affordable mobile interventions aids communication, educating communities and disseminating malaria information in remote and marginalised areas. The use of mobile intervention to piggyback on existing infrastructure and people's familiarity with mobile technologies enhances the coordination of healthcare activities such as the provision of care, education and communication in vulnerable communities regardless of the locality. In the meantime, traditional awareness methods including community groups, community health workers, dramas, brochures, flyers, religious institutions, and public shows have been used to create awareness and community engagement (Musesengwa & Chimbari, 2017; Prue et al., 2013). However, brochures and flyers face challenges such as printing costs and unexplained medical jargon (Anwar et al., 2020; Chiwara, 2012). Community health workers and healthcare professionals are grossly affected by limited resources, poor road networks, and also geographical distances between health centres and recipients of care (van Deursen et al., 2019; Zayyad & Toycan, 2018). In some instances, ICTs such as radio, digital billboards television, social media platforms and mobile phones are roped in to enhance awareness in Zimbabwe, but their effectiveness is yet to be measured (Chiwara, 2012).

2.10 Identified research gaps in integrating mobile applications for tackling malaria in sub-Saharan Africa

Based on the literature, mobile phones have been utilised as a low-cost and feasible technology to provide malaria healthcare services in sub-Saharan Africa (Osei & Mashamba-Thompson, 2021). There is a substantial increase in the development and deployment of smart applications to fight against diseases such as malaria as mobile phones become ubiquitous. These applications can be used to support malaria eradication through SMS, application development and voice calls. Adopting mobile phones as part of malaria strategies is the best chance to alleviate some of the impediments faced by traditional malaria prevention and control methods especially when creating malaria awareness. Such technology can reach more people in resource-limited settings if there is supporting infrastructure than the traditional malaria awareness methods such as fliers, charts and community gatherings. However, the effectiveness of emerging digital technologies, such as mobile phones, to enhance awareness has yet to be effectively measured especially in high malaria-endemic and resource-constrained areas.

The literature also reveals that SMS and USSD mobile phone services have been predominantly used for reporting malaria (cases and deaths), sending alerts and communicating among healthcare professionals working in high malaria-endemic areas. However, these technologies experience several challenges such as poor network coverage (Nema et al., 2021), high SMS charges, digital divide (Grobbelaar & Uriona-Maldonado, 2020), digital illiteracy, increased health workers' workload (Kao et al., 2018) and poor access to mobile phones among others. In addition, SMS technology does not provide malaria services in real-time which consequently affects its utilisation in malaria surveillance and monitoring.

More so, the literature also reveals that there is a lack of data-driven, customised and adaptive mobile applications for tackling malaria (Morris et al., 2021). Such smart applications can make short-term local malaria predictions and assist in decision-making as well as optimise the allocation of limited resources (Brown et al., 2020) and automated malaria screening (Rajvanshi et al., 2021). Some routine activities such as checking malaria commodities (IRS and ITNs) stock levels, mapping malaria cases, predicting potential malaria outbreaks, and reporting cases through alerts and SMS can be automated by developing and integrating data-driven and adaptive malaria smart applications.

In addition, the literature also reveals that multiple malaria smart mobile applications have been developed and deployed to address almost similar problems in the same context. For instance, in South Africa, different applications including the mSpray mobile-based application (Eskenazi et al., 2014), timelier notification (Quan et al., 2014), MalariaConnect (Davies et al., 2019), and DHIS (Dehnavieh et al., 2019) have been implemented to improve malaria services. In Kenya, SMS for Life (Githinji et al., 2014; Otieno et al., 2014), and SMS reminders (Zurovac et al., 2012) were rolled out to remind patients about malaria adherence guidelines at different intervals. Thus, the integration of malaria applications can assist to track and monitor patients' drug adherence as well as managing progress made to eliminate malaria. Therefore, there is a need for developing standards and guidelines to minimise duplication of malaria mobile applications that intend to achieve relatively similar objectives. The literature also noted that there is a need to modify and update existing mobile health policy to incorporate emerging digital health technologies (Mohammed et al., 2019), implementation standards as well as guidelines for the development of malaria mobile applications (Moore et al., 2021).

2.14 Summary of the chapter

This chapter provides a comprehensive analysis of malaria prevention and control measures focusing more on global malaria status. Digital health technologies deployed to tackle malaria are presented in this chapter. In addition, this chapter also provides a comprehensive analysis of the existing literature regarding opportunities, benefits, challenges and impact of health information, electronic health and mobile health applications previously deployed to tackle malaria. After a comprehensive analysis of existing literature, this chapter presents the identified research gaps in integrating mobile applications to tackle malaria in sub-Saharan Africa.

CHAPTER 3: RESEARCH METHODOLOGY

The previous chapter focused on the comprehensive analysis of prior literature relevant to the study. The literature review was to establish the relevance, benefits, applicability, affordability, sustainability, and feasibility of the study by comparing it to previously implemented ICT-based malaria interventions in the context of health information dissemination, especially in neglected and underserved rural communities.

3.1 Introduction

This chapter illustrates how study objectives and research gaps identified in the previous chapters were addressed. It explains the methodology, research design, research approach, paradigm, sampling process, recruitment process, data collection instruments and techniques applied to carry out the study. Also, in this chapter, the researcher illustrates how the proposed malaria intervention was designed, developed, tested, and evaluated. The study applied two approaches, namely design science research and convergent parallel mixed method. The design science research was utilised to design and develop an intervention, and the convergent parallel mixed method was applied to elicit user requirements and to deploy and evaluate the intervention to the targeted population. It was also used to develop a contextual m-Health framework for integrating feasible ICT-based malaria interventions in resource-constrained communities. To ensure that these approaches complement each other, the researcher applied a quasi-experiment as the research approach, to elicit user requirements and specifications during the pre-test phase, and to evaluate the intervention during the post-test phase. The following subsection discusses the research paradigm applied to achieve the study objectives.

3.2 Research Paradigm

Creswell and Clark (2013) define a research paradigm as an all-encompassing system of interrelated practice and thinking that shapes the nature of enquiry along with ontological, epistemological, and methodological concerns that can adopt one or more research paradigms such as constructivism, pragmatism, positivism, interpretivism and postpositivism. The constructivism research paradigm deals with reality as a construct of the human mind, thus making reality perceived to be subjective (Morgan, 2014). This paradigm is related to relativism and pragmatism. As indicated by Bisman and Highfield (2013), constructivism is not entrenched within the ontology of the world but within the acceptance and belief in multiple social realities that point to the conclusion that knowledge is relativistic. According to Goldkhul (2012), the pragmatism research paradigm focuses on change and the interplay between action and knowledge. It originated from American pragmatism (Morgan, 2014) in which actions and change remain in the constant state of becoming a process of action. The positivist research paradigm is associated with discovering hidden truths or facts from numerical and measurable data (O'Neil & Koekemoer, 2016) and then using empirical means to present facts. The interpretivism research paradigm is associated with the thought of Max Weber (Goldkhul, 2012) which states that reality is multifaceted and complex. This is a phenomenological approach to gaining a better understanding of people's experiences. The school of thought of interpretivism is that the truth is nuanced and subjective because it is determined by the experiences and views of the participants, and the values and objectives of the researcher (Bonache & Festing, 2020). So, interpretivism reflects a social reality which means it is the understanding of human beings in social experiences. The human mind interprets views, opinions, and experiences. This relates to the study's search to discover hidden truths on why current and previous interventions fail to disseminate malaria information in rural communities. Also, based on participants' previous experiences and views, the study developed a prototype, which was later deployed to the target population for evaluation. Therefore, the study applied positivism and interpretivism research paradigms as empirical means to present facts. To achieve this, the study applied two methodologies namely, convergent parallel mixed methods, and design science research methodology to:

i) Elicit user requirements and specifications from the target population while analysing their experiences, attitudes and views towards the current and previous interventions used to disseminate malaria information.

ii) Design and develop ICT-based malaria intervention (prototype) to disseminate information.

iii) Test and evaluate the proposed prototype in the target population.

3.3 Research Design

The study adopted a convergent parallel mixed methods approach which converges qualitative and quantitative data collection techniques to gather user requirements and prototype specifications and to ensure a comprehensive analysis of the study. The convergent parallel design as illustrated in Figure 3.1 refers to the equal prioritization of qualitative and quantitative methods within a single study whereby qualitative and quantitative strands are implemented concurrently within a single phase of the study. The qualitative and qualitative strands are analysed independently, however, both results are mixed to formulate the overall interpretation of the study (Creswell & Clark, 2013). This was done in two phases of the quasi-experimental approach, that is, the pre-test phase and the post-test phase. During the pre-test phase, the study addressed the following objectives:

- To explore and analyse current strategies and information diffusion methods to help health promotion to manage malaria.

- To explore and implement the most feasible digital technology, which includes investigating mobile technology and alternatives for malaria health information dissemination and digital awareness, based on the previous investigation, to reduce malaria incidences in rural communities.

The rationale for convergent parallel mixed methods was that the researcher collected both quantitative and qualitative data during the same time (pre-test phase) and then combined the information to compare, relate and then analyse to get an overall interpretation of results

(Figure 3.1). This was done to gather more user requirements and specifications to ensure inclusive participation from all stakeholders. The quantitative part of the convergent parallel mixed method quantified and determined the relationship between quantitative variables and UTAUT constructs, while the qualitative aspect serves the purpose of exploring participants' experiences, opinions and views towards the current malaria interventions used to disseminate malaria information in the community. The fact that this research sought to explore mobile technology as the most feasible digital health intervention to disseminate malaria information in the rural community made this study adopt convergent parallel mixed methods and a quasi-experimental research approach. These approaches complement each other to provide a comprehensive gathering of user requirements and specifications as well as to evaluate the performance of the proposed prototype.

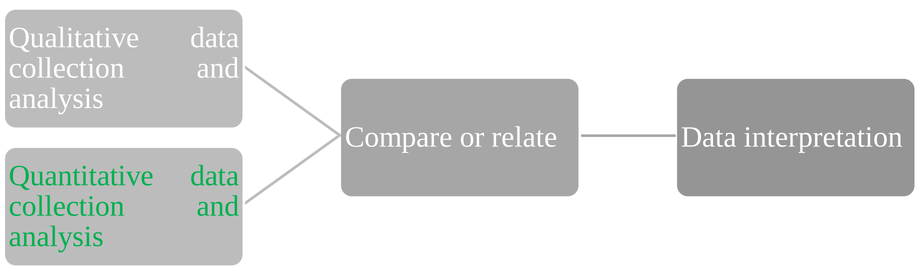

Figure 3.1: Convergent parallel design (Creswell and Clark, 2013)

3.4 Research Methodology

Creswell et al. (2016) define research methodology as a set of processes used to collect, analyse data, and interpret results to either reject or accept a claim. It is a systematic way of addressing the research problem by clearly defining logical steps such as the research process, techniques, tools, and procedures to be used. Therefore, research methodology is a plan of action that links methods, techniques, and procedures to study objectives and outcomes (Creswell, 2015). The study adopted an interdisciplinary approach that combines design science research and a parallel convergent mixed method. Design science research methodology was utilised to design and develop a prototype, while the parallel convergent mixed method was used to:

i) Gather user requirements and determine the most feasible technology.

ii) Design, develop, deploy, and assess the adoption of the proposed malaria application in the Buhera rural community.

By using this approach, two methodologies were applied in two phases based on the quasi-experimental design as shown in Table 3.1.

Table 3.1:Phases, Stages of implementing the proposed methodology

Phase	Stages	Methodology
Phase 1: Pre-test	Stage 1: Elicit user requirements and specifications from the target population.	Convergent parallel mixed method.
	Stage 2: Design and development of the prototype.	Design science.
Phase 2: Post-test	Stage 3: Assess the adoption of the proposed prototype in the target population.	Convergent parallel mixed method.

Table 3.1 consists of two phases that guide the use of adopted methodologies. Phase 1 is the pre-test phase of the quasi-experimental design. Phase 1 consists of two stages namely, Stage 1 and 2. During Stage 1, the researcher applied the convergent parallel mixed method to elicit user requirements and specifications from the target population. After that, the researcher started the design and development of malaria intervention guided by the principles of design science research, that is, at Stage 2 of Phase 1. The proposed prototype was deployed to the target population. Its adoption was using a modified unified theory of acceptance and use of

technology (UTAUT) model. This was done in Phase 2. The following subsection explains the methodology applied in Stage 1 and Stage 3.

3.5 Phase 1: Pretesting Phase

Stage 1: Parallel convergent mixed method

The parallel convergent mixed method was adopted to solicit user requirements and participants' experiences with current and past interventions deployed to disseminate information. The convergent parallel mixed method is a mixed-method approach that combines qualitative and quantitative research techniques concurrently in the same study and interprets the findings of the study together (Creswell, 2008). Therefore, the researcher collected both quantitative and qualitative data at the same time (pre-test phase) and then combined the information to compare and relate to getting an interpretation of the overall results. This was done to gather more user requirements and specifications to ensure inclusive participation from all stakeholders. The quantitative part of the convergent parallel mixed method quantifies and determines the relationship between quantitative variables, and the qualitative part serves the purpose of exploring participants' experiences, opinions and views towards the current information diffusion methods, and determining the most feasible technology for disseminating malaria information in rural communities. Convergent parallel mixed methods and a quasi-experimental research approach complement each other to provide comprehensive user requirements and specifications. Besides using the same methodology during both the pre-test phase and post-test phase, the data collection instruments and techniques applied were different. The following subsection illustrates the research processes done during the pre-test phase.

3.6 Stage 2: Design Science Research Design Methodology

After gathering user requirements and specifications using survey questionnaires in Stage 1, the researcher adopted design science to guide the design and development of the prototype to disseminate malaria information in the rural community. The research sought to address the practical problem using technological means to design and develop an artefact. According to Peffers et al. (2014), design science solves practical problems while increasing scientific knowledge. Also, Hevner et al. (2004) state that design science is a problem-solving paradigm that addresses the real-world situation by creating an artefact. Järvinen (2007) attests that design science supports incremental scientific knowledge that results in artefact development. The study developed a feasible artefact that contributes toward both incremental and new scientific knowledge by fusing existing traditional and digital platforms with the problems faced by rural communities to disseminate malaria information. This sought to address the following study objectives:

- Develop a feasible ICT intervention prototype to disseminate information in rural communities.
- Develop a contextual m-Health framework for improving malaria information dissemination using feasible digital technology in resource-constrained areas.

The design science was applied in a unified way in the study. Also, the development of the prototype was carried out in different phases namely; the requirements definition and elicitation phase; the design and development phase; the evaluation phase and the testing phase, which then informed the development of the m-Health framework. To ensure that the proposed intervention overcomes obstacles experienced by previous interventions deployed in the same application domain, the study iteratively conducts participants through the stages of design science. This was done iteratively to accommodate incremental user requirements from participants. In each stage, the researcher frequently required participants to make contributions incrementally, and changes were incorporated accordingly. For instance, during the testing phase, participants gave their feedback, and their suggestions were incorporated into the new prototype design and development. The iterations between the evaluation, requirements definition, design and development and demonstration continued until the participants were satisfied with the malaria intervention, as depicted in Figure 3.2. The deployment and implementation of the proposed prototype in the healthcare setup were highly inter-correlated due to bureaucracy, legal issues, and the state of the existing and supporting ICT infrastructure.

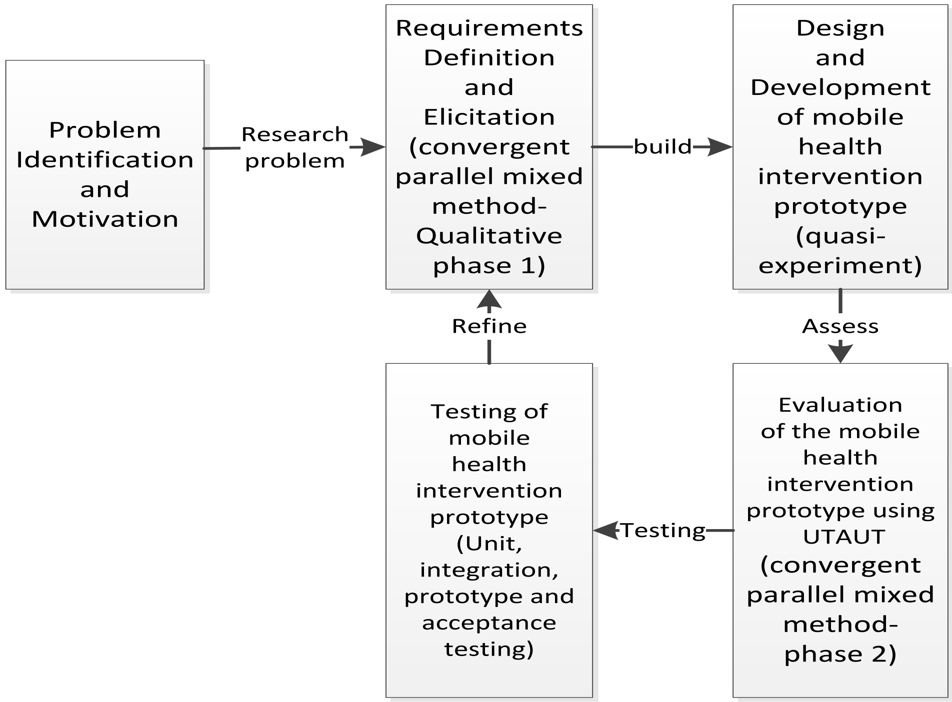

Figure 3.2: Prototype design process

3.6.1 Problem Identification and Motivation

To understand the problems faced by the rural community in eliminating malaria, the researcher first analysed published literature such as journals, conference papers and malaria reports from the Zimbabwean MoHCC and Zimbabwe's sustainable development goals. After that, the researcher synthesised the published literature and developed a baseline survey used during the pretest phase to confirm problems faced by rural communities in disseminating malaria information. It was observed that the adoption of emerging technologies to tackle malaria in resource-constrained communities is still nascent despite the increased mobile penetration rate (Sande et al., 2019). Also, there is a lack of feasible and customisable technologies for modelling, monitoring, mapping, and predicting malaria as well as coordinating malaria research activities remotely (Hannah et al., 2019; Manyangadze et al., 2017). It was also noted that DHIS and weekly rapid disease notification systems are used for surveillance and capturing reported malaria cases and other diseases (Sande et al., 2019); however, emerging digital technologies present untapped opportunities to strengthen malaria control measures, yet their adoption is still low in Zimbabwe (Hannah et al., 2019; Mbunge, Sibiya, et al., 2021).

3.6.2 Requirements definition and elicitation

The requirements elicitation is a very crucial stage in design science as it defines the functional and non-functional requirements of the prototype. The requirements definitions are specified by the stakeholders. According to Sommerville (2008), a stakeholder is anyone or a group of people who are affected by the system directly or indirectly. In this study, stakeholders consist of research participants including community members, healthcare professionals, policymakers, and system administrators. These stakeholders determine the prototype specifications during the requirements discovery phase, which is also known as requirements elicitation and analysis. The requirements discovery is a process of interacting with system stakeholders to elicit their views and opinions as well as user requirements and expectations (Sommerville et al., 2012). To elicit user requirements for the prototype from the stakeholders, the study used survey questionnaires and qualitative questionnaires as baseline surveys. This was done during the pre-test phase of the quasi-experiment. The same data collection instruments used in the pre-test phase were used to elicit user requirements. Such information is critical in prototype design to alleviate challenges encountered by previous digital interventions.

3.6.3 Prototype design and development

The prototype development phase was divided into the client side and the server side. On the client side, stakeholders interact with the system through a responsive user interface based on the dimensions of the computing device. The prototype supports different interfaces such as the USSD module and SMS and web-based application. SMS and USSD modules cater for community members that use feature phones to disseminate information. Feature phones are connected to the server using a global system for mobile communication (GSM) technology to send and receive messages to and from the short messaging system server. The detailed architectural design, case use diagrams and database design of the prototype are explained in Chapter 5. The next subsection illustrates how the prototype was deployed and evaluated.

3.7 Choice of study location

Zimbabwe experiences high malaria transmission and intensity, with seasonal and geographic variations that correspond closely to the country's environmental factors (Manyangadze et al., 2021a). The country is divided into ten administrative provinces. Among these provinces, Manicaland province is malarious. Malaria transmission is perennial in some districts, and seasonal increases occur annually, with most of the transmission occurring during or just after the November to April rainy season (Sande et al., 2017). Manicaland province reported a high malaria morbidity rate of 696 deaths and 947 462 confirmed cases from the year 2005 to 2014 (Kusotera & Nhengu, 2020).

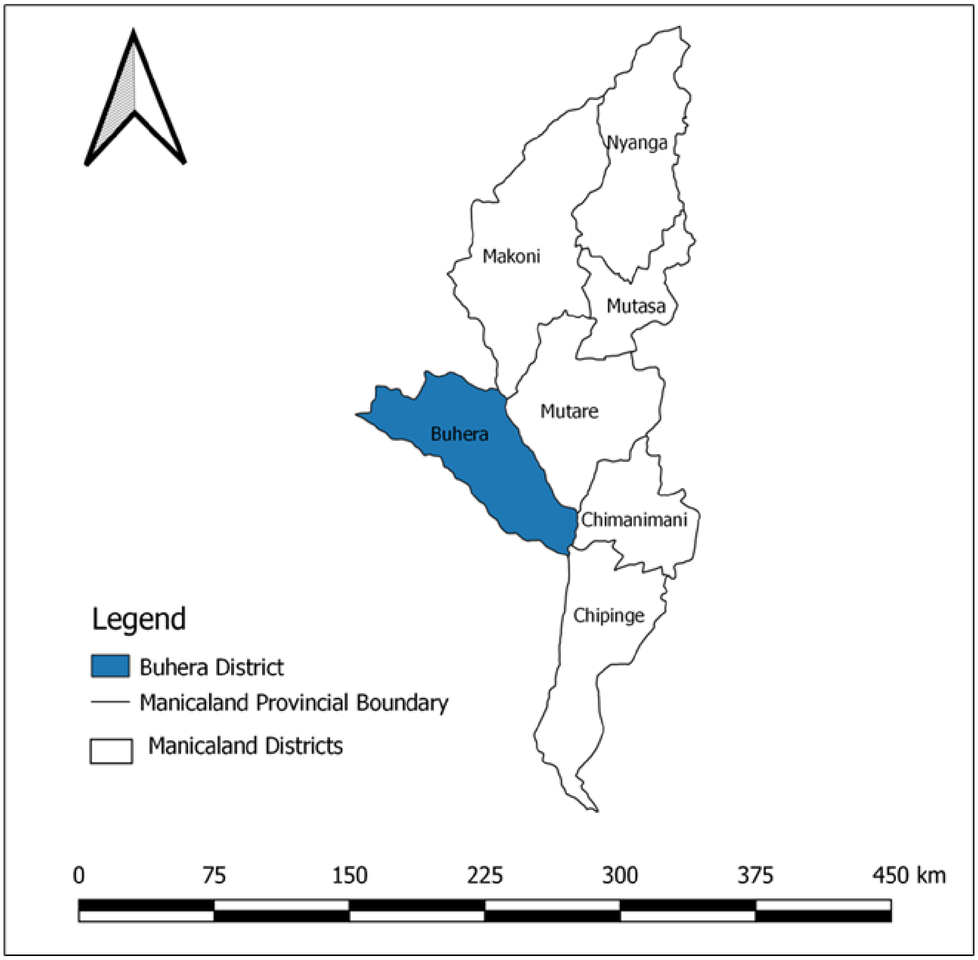

Figure 3.3: Manicaland map showing the study area

Manicaland province is divided into seven administrative districts namely, Buhera, Mutasa, Nyanga, Chimanimani, Nyanga, Mutare and Makoni, as shown in Figure 3.3, with an estimated population of 1 752 698, with 830 697 males and 922 001 females (Zimbabwe National Statistics Agency, 2012). Among seven districts, Buhera district usually records high malaria incidences. Also, a report from Zimbabwe Malaria Operational Plan (2017) shows that malaria cases were gradually increasing in the district with 974 confirmed malaria cases, and 18 people dying from malaria in 2016. Malaria incidences in the district are associated with socioeconomic and environmental factors as evidenced by the study conducted by Mutsigiri et al. (2017). Recently, during COVID-19, the district experienced malaria outbreaks (Kusotera & Nhengu, 2020) exacerbated by the delayed IRS activities, social distancing guidelines, movement restrictions, disruptive movements of IRS commodities and lack of resources.

3.7.1 Study area and population

Buhera district covers an area of 5357 km², with a density of 45.90/km² and an elevation of 919m. Buhera district has an estimated population of 245 878 people residing in four constituencies; Buhera Central, Buhera South, Buhera North, Buhera West, and 33 wards, comprising 14% of the total population in Manicaland province. In Buhera district, 2.8 and 97.2% of the population lives in urban areas and rural areas respectively. 233 993 (95.2%) people reside in the same district and 2438 (1.0%) people reside in other districts in Manicaland, 9059 (3.7%) people reside in other provinces and 388 (0.2%) people reside in other countries (Zimbabwe National Statistics Agency, 2012). According to the Zimbabwe National Statistics Agency's provincial report (2012), the proportion of the male and female population is 46.4 and 53.6% respectively, thus, there are 114 106 males and 131 772 females (Zimbabwe National Statistics Agency, 2012).

The research was carried out in the Buhera district in Manicaland province as shown in Figure 3.4. This is because the Buhera district recorded the highest malaria incidences in Manicaland province (Pellegrino et al., 2022). The study population consists of a complete group of people of interest to whom research findings were generalised. The research population consisted of all people living in the district who needed malaria healthcare services from Buhera health centres. There are 32 healthcare centres in the district; 30 are rural clinics, and 2 are referral rural hospitals.

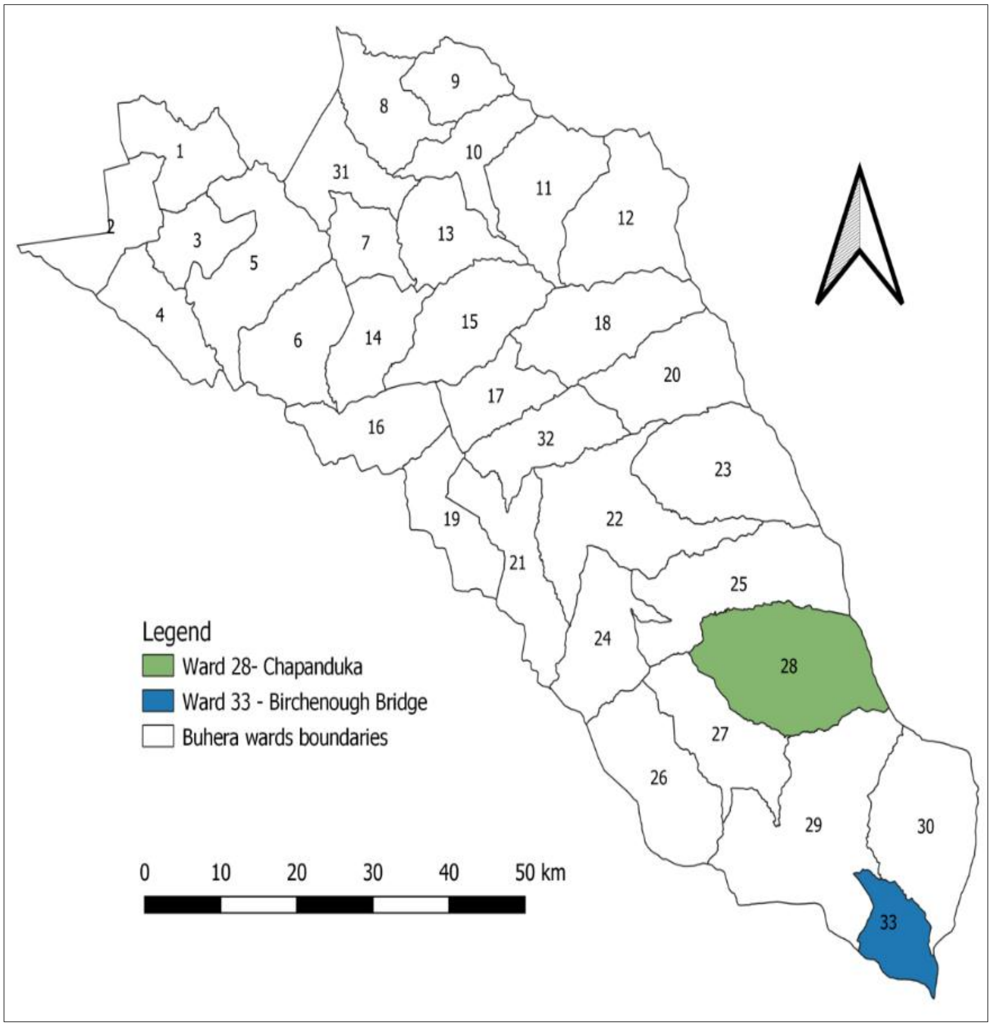

Figure 3.4: Buhera Rural District Map

3.7.2 Target population

The study targeted people living in malarious areas in Buhera rural district. Malaria incidences vary with environmental variables and influence endemicity levels. They tend to cluster into high malaria perennial (perennial hotspots), low malaria perennial, high malaria sporadic (seasonal hotspots), and low malaria sporadic. Hence perennial and seasonal hotspots become sources of continued malaria infection in the district (Mbunge, Sibiya, et al., 2021). Therefore, the study targeted healthcare professionals and rural community members living in perennial malaria hotspots, low malaria perennial and seasonal malaria hotspot areas. There are 32 healthcare centres in the Buhera district; 30 are rural clinics, and 2 are referral rural hospitals clustered in different constituencies based on administrative boundaries demarcated by various wards.

3.7.3 Groups included

Upon identifying the target population, the study clustered wards based on malaria-endemicity level, and further grouped potential participants into two categories namely, healthcare professionals and community members. Healthcare professionals include all health workers stationed in satellite clinics and referral hospitals (Category A). Community members consist of all people living in the district (Category B). This includes adults, teenagers, and learners in secondary schools (12 years and above). For learners in secondary school, ethical clearance and consent were sought from the Ministry of Primary and Secondary Education, as well as from, Provincial Education Officer, District Education Officer, and school headmasters. Therefore, healthcare professionals were classified as Category A participants and Category B as community members.

3.7.4 Exclusion/inclusion criteria

For each category, the researcher defines the inclusion and exclusion criteria as illustrated in the next subsection.

Inclusion criteria for healthcare professionals (Category A)

- All healthcare professionals working in the public healthcare centres that provide primary and secondary healthcare services in Buhera rural district were included.

Exclusion criteria for healthcare professionals (Category A)

- All healthcare professionals working in tertiary healthcare centres were excluded from the study. This exclusion is because tertiary healthcare centres provide advanced medical investigation, diagnosis, and treatment of referral from primary and secondary healthcare that may bias the study outcome.

Inclusion criteria for community members in Buhera district (Category B)

- All people with access to mobile phones were included in the study. Participants who needed help were assisted by the researcher.

- All people residing in Buhera rural district community were included in the study.

Exclusion criteria for people living and residing in Buhera district (Category B)

- All children who were not in secondary schools (less than 12 years) were excluded from the study because of a lack of access to such children.

3.7.5 Sampling process

According to Omair (2014), sampling is a process of selecting research participants that represent the general population. There are two main research sampling techniques namely, probability and non-probability sampling (Elfil & Negida, 2017). With probability sampling, all research participants have equal chances of being randomly selected to participate in the research, whereas, in non-probability sampling, participants do not have equal chances of being included in the sample, which means it does not involve random selection of participants in the research (Berndt, 2020). As shown in Figure 3.4, the district is divided into several administrative wards. In some cases, each ward has a health facility where the community access healthcare services. These health facilities were grouped into several categories such as malaria-free, low malaria sporadic, high malaria sporadic and high malaria perennial as shown in Figure 7.3. These categories are based on the malaria prevalence in each health facility. Therefore, the study applied multi-stage cluster sampling technique to select wards that recorded high malaria incidences, as shown in Figure 3.5. Multi-stage cluster sampling technique is a sampling method that divides the population into groups (or clusters) at each stage using specific characteristics (Taherdoost, 2018). Through multi-stage cluster sampling technique, the study selected, low malaria sporadic, high malaria sporadic and high malaria perennial wards as clusters for conducting the research. These wards report malaria incidences captured in the DHIS. In each selected ward, participants were further grouped into two categories (Category A and Category B) as highlighted in Section 3.7.3.

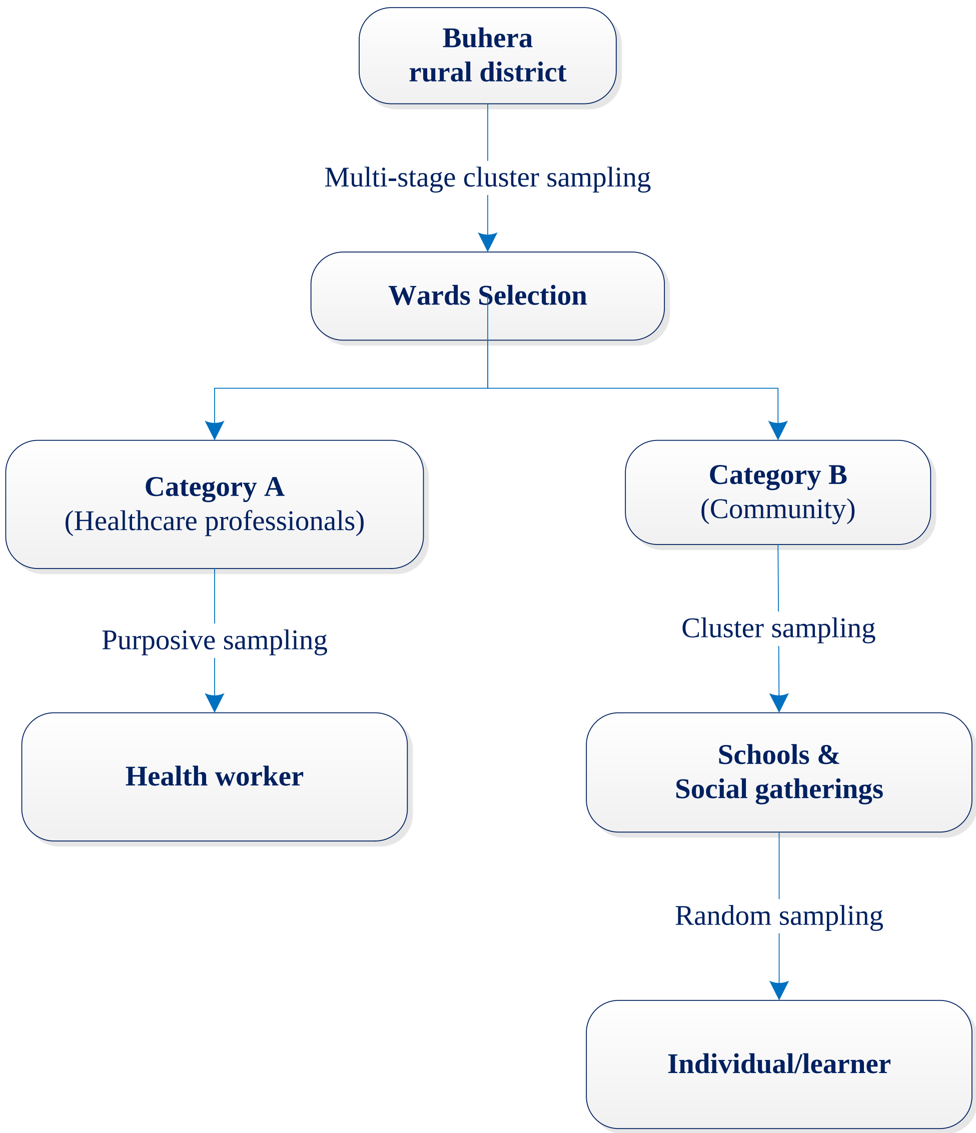

Figure 3. 5: Sampling process and recruitment process

The study further applied purposive sampling to select health workers in Category A. Intentional selection of informants based on their capacity to clarify a certain theme, concept, or phenomenon is known as purposive or judgement or purposeful sampling (Robinson, 2014). Purposeful sampling involves identifying and selecting individuals or groups of individuals that are especially knowledgeable about or experienced with a phenomenon of interest (Benoot et al., 2016; Palinkas et al., 2015). This sampling technique was applied to recruit healthcare professionals who hold extreme knowledge of malaria epidemiology, health promotion and digital awareness strategies being explored. Health workers that have been involved in carrying out malaria prevention and control measures such as indoor residual spraying activities, malaria community outreach programmes, distribution of insecticide-treated nets, reporting and capturing malaria cases, and clustering and mapping malaria hotspot areas in the Buhera district.

As shown in Figure 3.5, the researcher applied cluster sampling to group schools and social gatherings in selected wards for participants in Category B. Cluster sampling was applied because there were some instances where two or more secondary schools are located in one ward and also several social gatherings happening at the same time. Under such circumstances, cluster sampling was used to randomly select a cluster among these clusters to form a sample (Taherdoost, 2018). After that, random sampling was used to select either a learner or a person within a cluster (school or social gathering) to participate in the study.

3.7.6 Sample size

The study calculated the sample size to collect quantitative data. According to Noordzij et al. (2011), a sample is a proportion selected to participate in the research that represents the entire research population. The sample size is the selection of a sample that represents the entire research population. Boddy (2016) defines a sample as a subset of the research population that is large enough to represent the entire research population in the research. The calculation of the sample size followed the guidelines of sampling and sample size calculation provided by Fox et al. (2009), who state that inferential research requires both significant and statistical power to determine the sample size of the research population while avoiding Type I (1) and Type II (2) error. A Type I error (false-positive) occurs if the researcher rejects a null hypothesis that is true in the research population; a Type II error (false-negative) occurs if the researcher fails to reject a null hypothesis that is false in the research population (Banerjee et al., 2009). However, it is inevitable and well-known that Type I and Type II errors cannot be avoided completely but their likelihood can be reduced by increasing the sample size. The larger the sample size, the lesser is the possibility that it will vary substantially from the research population.

A statistical sample size table from Research Advisor (2006) in conjunction with online sample size calculators such as Survey System (Surveysystem 2018) and SurveyMonkey (Surveymonkey 2018) was used to determine the sample size.

The study used a confidence level of 95% (Z-score of 1.96- accurate and confident the researcher can be of the data obtained from the sample), a margin of error of 5%- sampling probability error that measures the uncertainty about the research results (Noordzij et al., 2010) and a sample proportion of 50%. Therefore, using the population size (nearly 245 878 people) confidence level and margin of error, the research has a sample size of 384 research participants during the pre-test phase.

$$\textbf{Sample size} = \frac{z^2 * p(1-p)}{e^2} / \left(1 + \frac{z^2 * p(1-p)}{e^2 N}\right) \qquad \text{Equation 1}$$

Where, ***N*** = population size, ***e*** = Margin of error (percentage in decimal form), ***p*** is the sample proportion and ***z*** = Z-score.

This represents the sample size of the study. A sample size of 384 participants included healthcare professionals and all people living and residing in the district during the pre-test phase. Out of 384 expected participants, the study received 289 feedbacks (36 from health workers and 253 from the community) returned by the participants.

During the post-test phase, data were collected from forty-two (42) healthcare professionals working in rural communities. Due to high staff turnover exacerbated by political and socio-economic push factors (Kanonge & Bussin, 2022) which consequently leads to a high brain drain of health workers (Dzinamarira & Musuka, 2021), especially in rural communities, it was difficult to pre-determine the sample size of health workers. The delivery of quality service within rural healthcare institutions is complicated by the unprecedented emigration of healthcare workers because of poor funding and infrastructure (Makoni, 2020), limited medical resources (Mudzonga, 2021), equipment, and a shortage of healthcare experts (Kanyumba, 2022). However, each health facility in the district was fairly represented in the collection process and data collection stopped when reached the saturation point.

3.7.7 Ethical considerations

The researcher applied for ethical clearance to Zimbabwe's MoHCC, Ministry of Primary and Secondary Education (MoPSE) and Medical Research Council of Zimbabwe (MRCZ) to collect and gather health data in Buhera rural district. Before the researcher applied for ethical clearance in Zimbabwe, the research proposal was submitted to the DUT Ethics committee, after approval by the Faculty Research Ethics Committee with the help of the postgraduate coordinator, supervisor and co-supervisor. After approval, the researcher obtained gatekeeper permission from DUT, which allowed the researcher to conduct the study. Ethical clearance from MoHCC, MRCZ, Ministry of Primary and Secondary Education (MoPSE) was granted to the researcher to carry out the study, under the ethical clearance number MRCZ/A/2507. Ethical clearance from the Ministry of Primary and Secondary Education was further utilised to get permission to collect data from secondary school learners. This was sought from the Provincial Education officer, district education officer and school headmasters.

After getting permission, the researcher began by distributing and explaining consent, assent forms and the letter of information for participation (Appendix 2a and Appendix 2b) to participants. Participants were also informed that any information that was collected from them in the survey would be kept confidential, their anonymity would be preserved, and information would be used for academic purposes. Participants were not forced, or coerced, and were told they should not expect monetary benefits from participating in the research. If participants decided not to participate or withdraw before the survey was completed, there would be neither negative consequences nor penalties related to any future conduct in this research. The researcher sought permission from the participants to distribute questionnaires. The researcher informed participants that data collected from them would be kept safe for five years and securely deleted later as per DUT research policies and guidelines.

3.7.8 Recruitment process of participants

To recruit healthcare professionals in Category A, the researcher visited satellite clinics and hospital centres in the company of healthcare workers from the referral hospitals (research assistants) responsible for monitoring satellite clinics. The research assistant learnt about all healthcare professionals and their respective specialities and then applied purposive sampling to determine a group of healthcare professionals who have malaria knowledge and experience, and had participated in previous malaria outreach events. After that, the researcher explained the purpose of the study and distributed questionnaires. Each participant was given a pen to use when answering the questionnaire.

To recruit participants in Category B, the researcher applied cluster sampling to identify schools and social gatherings, where secondary school learners, adults, and parents or guardians participate in the research. For example, to recruit learners in schools, the researcher applied random sampling. The selected schools were located in malarious wards selected using multi-stage cluster sampling. This also applies to adults and parents or guardians but in this case, the researcher used social gatherings to recruit them. The wards were divided into various clusters based on malaria incidences as explained in Section 3.7.5. The researcher visited schools accompanied by healthcare professionals responsible for conducting malaria outreach events. After having been granted permission by the school heads, the researcher explained the purpose of the study and its potential benefits to the community before distributing the survey questionnaires to learners. The researcher obtained consent for participation from participants. Also, the participants that needed help were assisted accordingly.

3.7.9 Data collection

The study used qualitative questionnaires (Appendix 5a and Appendix 5b) to collect user requirements and specifications from participants in Category A (key informants). Survey questionnaires (Appendix 4a and Appendix 4b) were used to collect quantitative data from participants in Category B. A retrospective data analysis of published reports, unpublished reports and malaria cases from DHIS 2 (for the period 2015-2020) was used to map malaria hotspots and model malaria incidences in the district. The climate hazards group's infrared precipitation with station data (CHIRPS) database and the moderate resolution imaging spectroradiometer (MODIS) satellite data were used to collect environmental data. MODIS is a satellite that records the frequency and distribution of cloud cover. MODIS measures the properties of clouds such as the distribution and size of cloud droplets in both liquid water and ice clouds (Justice et al., 2002). CHIRPS is a quasi-global rainfall dataset that has been used for developing drought early warning systems (Toté et al., 2015) and environmental monitoring among others (Dinku et al., 2018).

3.7.10 Pre-testing data collection tool

The survey questionnaires were piloted before the actual commencement of data collection, to establish internal consistency of the data collection instrument, and to determine its validity, reliability, and feasibility before they were administered to the research sample. Hassan et al. (2006) posit that piloting data collection instruments is paramount to identify potential problems and remove any flaws, or deficiencies stemming from the research instruments. The survey questionnaires were piloted to twenty (20) participants at Murambinda Growth Point, located in Buhera rural district from the first week of November 2019 to 4 January 2020. These participants were not included in the actual sample of the study as alluded to by In (2017).

The pilot process was strictly informed by the guidelines stipulated by Fox et al.(2016), Hassan et al. (2006) and Marshall (2005). That is, a small sample of respondents from the target population was consulted to check whether the instructions and questions are clear and the contents were relevant. The steps followed by the study to collect data are depicted in Figure 3.6. This also relates to content validity. The collected data were analysed using Statistical Package for the Social Sciences (SPSS) version 23. The Cronbach's alpha of the instrument was 0.68, which was below the recommended 0.70 (Trizano-Hermosilla & Alvarado, 2016). The questionnaire was redrafted and re-piloted to ten participants in the same research context and the Cronbach's alpha coefficient of the questionnaire improved to 0.95.

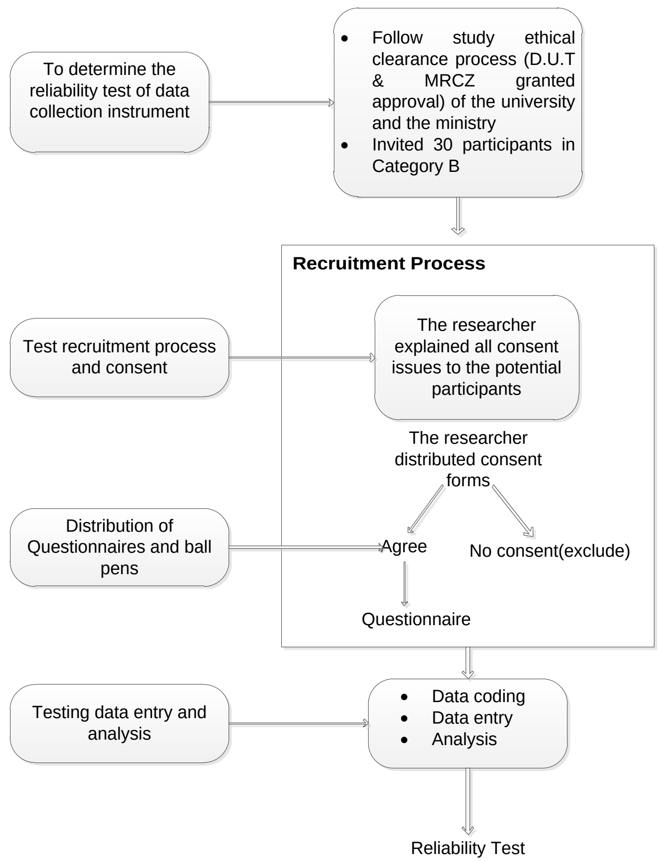

Figure 3.6: Data collection instruments piloting process

3.7.11 Data analysis

Data from the survey and qualitative questionnaires were analysed using the latest statistical tools. The quantitative data collected from survey questionnaires were analysed using SPSS software version 23. The researcher used Chi-Square to measure associations between variables collected with a structured survey questionnaire. The Chi-Square test measured quantitative data. In addition, the researcher applied a correlation bivariate test to determine how demographic data, level of education and mobile phone accessibility factors were causally connected to research participants' malaria knowledge gains such as malaria causes, prevention, symptoms as well as treatment. To analyse qualitative data, the researcher implemented thematic analysis to develop themes from coding to analyse qualitative data. Themes were grouped into categories namely:

- Current malaria information dissemination methods in the rural community.
- Most feasible ICT technology for disseminating malaria information in the rural community.
- Challenges and implications of implementing ICTs in the rural health system.

The coding scheme for analysis enables the researcher to understand the participants' views, perceptions, and attitudes towards the use of ICTs in disseminating malaria information and creating awareness. Thus, the results from the qualitative questionnaires were used to: explore and analyse current strategies and information diffusion methods to help health promotion to manage malaria; explore the views, attitudes, and perceptions of health workers; explore the most feasible ICT technology, and investigate opportunities, challenges, success/failure factors and implications of ICTs health care system in the rural community.

3.8 Phase 2: Stage 3 - Prototype evaluation and testing

The prototype was tested and evaluated by the participants throughout the development phase as per design science principles. However, the overall evaluation of the prototype was done during the post-test phase of the quasi-experiment. The study used online survey questionnaires (different from the survey questionnaire used in Phase 1) to test UTAUT constructs centred on perceptions of healthcare professionals towards the behavioural intention to use the prototype to disseminate malaria information. The online survey questionnaires were utilised because of the COVID-19 restrictions such as social distancing, travelling restrictions, avoiding contaminated objects or surfaces, and the prohibition of huge gatherings. The prototype was made available to healthcare professionals to get their views and to test its functionalities. The results of prototype evaluation and testing are explained in Chapter 6. The researcher iteratively received feedback from participants and the requirements were redefined. The intervention was redesigned and modified to include the suggestions and comments provided by the participants. The prototype was iteratively improved until a refined prototype was obtained. The stages involved in developing the prototype are clearly defined in Chapter 5.

3.9 Tools for modelling malaria cases and predicting malaria outbreak

The study utilised modelling tools such as QGIS 3.10.5 to map malaria risk zones in Buhera rural district. QGIS 3.10.5 is an open-source geographical information system (GIS) used for geospatial analysis. Instead of commercialised GIS software, the study opted to use QGIS 3.10.5 for analysing and editing spatial information in Buhera rural district. Detailed information on the micro-spatial modelling of malaria cases is presented in Chapter 7. After mapping malaria cases into their respective wards to determine hotspot areas, the study utilised Geographically Weighted Regression (GWR) 4.09 package that comes with Geographically Weighted Poisson Regression (GWPR) to model spatial varying relationships and the association between malaria cases and environmental risk factors such as rainfall, day land surface temperature, night land surface temperature and normalised difference vegetation index. Furthermore, after spatial analysis, the study further utilised PyCharm Community Edition Python interpreter to predict malaria outbreaks in malaria perennial wards using previously confirmed malaria cases and environmental risk factors. The dataset description and data pre-processing methods adopted by this study to predict malaria are described in the following sections.

3.10 Dataset description

The dataset used to predict malaria consists of environmental risk factors and confirmed reported malaria cases. Monthly confirmed malaria cases were collected from DHIS, and environmental risk factors were collected from CHIRPS and MODIS databases, as shown in Table 3.2.

Table 3.2:Malaria dataset sources

Variables	**Description**	**Spatial Resolution**	**Temporal Resolution**	**Source**
Rainfall	Rainfall estimates(mm/day) per ward	5km	Monthly	CHIRPS
Day LST_{mean}	Day LST estimates per ward (^{o}K)	1km	Monthly	MODIS/ LP DAAC
Night LST_{mean}	Night LST estimates at ward level (^{o}K)	1km	Monthly	MODIS/ LP DAAC
NDVI	NDVI estimates at ward level	1km	Monthly	MODIS/ LP DAAC
EVI	EVI estimates at the ward level	1km	Monthly	MODIS/ LP DAAC
Malaria cases	Monthly confirmed malaria cases			DHIS

3.11 Data pre-processing for malaria prediction

The dataset contains six attributes. Several dataset splitting ratios such as 75% (training) and 25% (testing), 70% (training) and 30% (testing) as well as 80% (training) and 20% (testing) were explored to determine the best dataset splitting ratio. The model performed better with a dataset split ratio of 70% (training) and 30% (testing) to train and test ML models, as shown in Figure 3.7. The dataset used did not have missing values, therefore no data cleaning techniques were applied to handle missing values. The study used Python programming to implement the selected machine learning models. However, SMOTE was applied to address the class imbalance problem. The next subsection provides a detailed explanation of machine learning models.

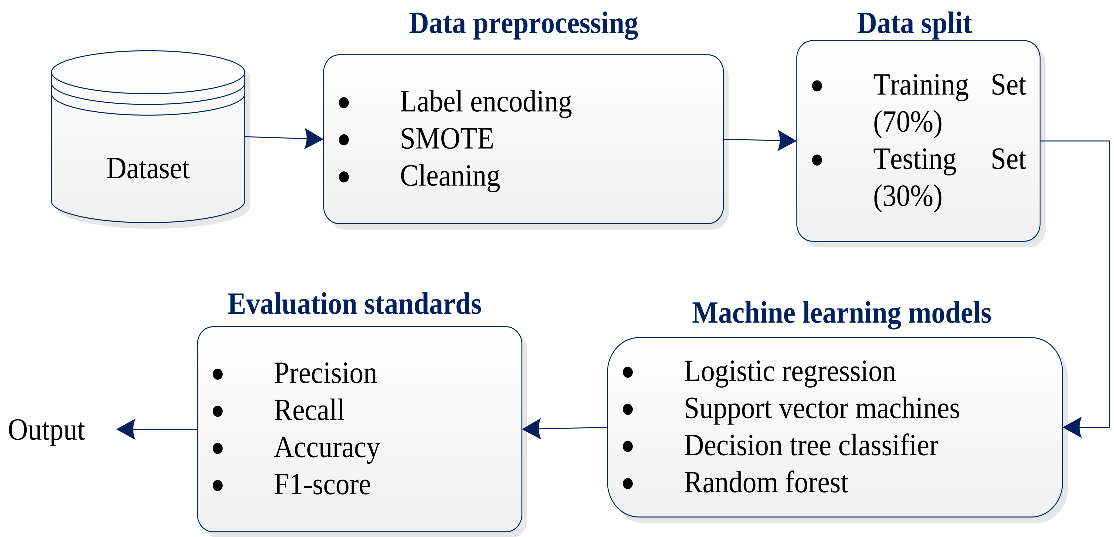

Figure 3.7: Data pre-processing and machine learning models

This study initially tested several machine learning models such as decision tree classifier, multilayered perceptron, AdaBoost, CatBoost, gradient boosting (GB), K-Nearest Neighbours (KNN), Naive Bayes, Extreme Gradient Boosting (XGBoost), logistic regression, support vector machines and random forest that have been used by several researchers to predict malaria. After comparing these models' initial performances, the researcher selected four best performing machine learning models, namely, logistic regression, support vector machine, decision tree and random forest, as shown in Figure 3.7. These models are explained in Section 2.9 and their prediction performance results are shown in Section 4.11.

3.12 Summary of chapter

This chapter explained the research methodology adopted by the study. All the prototype development principles adopted by the study follow a design science approach. The study adopted the convergent parallel mixed method to elicit user requirements, sampling process, and ethical clearance processes involved in conducting the research. After that, the study developed a prototype guided by design science principles. This was done in phases; Phase 1 (stage 1 and stage 2) and Phase 2 (stage 3). Also, the study adopted a quasi-experiment research approach to develop, test, and assess the adoption of the proposed ICT-based prototype in the rural community. This chapter also presents machine learning models adopted to predict malaria in Buhera district. The next chapter presents the results of the data collected in Phase 1.

CHAPTER 4: PRESENTATION OF FINDINGS

4.1 Introduction

The previous chapter outlined the methodology adopted to develop an ICT-based malaria intervention framework in Buhera rural district. Chapter 4 presents the findings of the study for both qualitative and quantitative strands of Phase 1 and Phase 2, highlighting the themes and sub-themes that emerged from the qualitative questionnaire with healthcare professionals, and findings of the survey questionnaire from people residing in Buhera rural district, Manicaland province. The qualitative and quantitative data collection instruments aimed to achieve the following study objectives, which were to:

- Explore and analyse current strategies and information diffusion methods to help health promotion to manage malaria.
- Explore and implement the most feasible ICT technology, which includes investigating mobile technology and alternatives, for malaria health information dissemination and digital awareness, based on the previous investigation to reduce malaria incidences in resource-constrained areas.
- Investigate opportunities, challenges, success/failure factors and implications of ICTs for the healthcare system in Buhera rural community.
- Explore the views, attitudes and perceptions of health workers and communities towards the use of ICTs to communicate and disseminate health information.

Therefore, this chapter presents the findings from both qualitative and quantitative data collection instruments in Phase 1 and Phase 2.

4.2 Sample realisation

The sample included healthcare professionals working in Buhera rural district as well as people living and residing there. All six rural health centres including clinics in Buhera rural district were included in the study for participants in Category A. These six rural health centres were coded as health centres A, B, C, D, E and F to ensure the anonymity of healthcare professionals working in the public healthcare centres. During the qualitative phase, a total of 36 healthcare professionals working in six rural health centres responded to the qualitative questionnaire. The number of healthcare professionals who participated in the study during the qualitative phase was guided by data saturation and the number of health workers per satellite clinic. In the survey questionnaire, a total of 384 survey questionnaires were distributed and 289 questionnaires were returned. Thus, the response rate was 75%. Both qualitative and quantitative data were collected over eight weeks from January 2020 to March 2020.

In the analysis of the documents, the researcher received malaria data (cases and deaths) from the district information system 2 (DHIS2) referencing the year 2015-2020 (April). These reports were sent after the malarial peak season (late May 2020). According to Mutsigiri et al. (2017), malaria incidence peaks between February and May due to higher temperatures and rainfall during this period.

4.3 Qualitative Participants Coding

The results from the qualitative questionnaire were used to answer four study objectives: explore and analyse current strategies and information diffusion methods to help health promotion to manage malaria; explore the views, attitudes, and perceptions of health workers; explore the most feasible ICT technology, and investigate opportunities, challenges, success/failure factors and implications of ICTs for the health care system in Buhera rural district. Data were collected from healthcare professionals working Buheral district. To ensure the anonymity of health workers, codes were used to describe their occupations as shown in Table 4.1 and *n* represents a sample size.

Table 4.1: Qualitative Phase Participants Coding

Health workers Occupation	Code	Number of Participants(n=36)
Primary Care Nurses	PCN #1, PCN #2 PCN #3 PCN #4 PCN #5, PCN #6, PCN #7, PCN #8, PCN #9, PCN #10, PCN #11, PCN #12, PCN #13, PCN #14, PCN #15, PCN #16, PCN # 17, PCN #18, PCN #19 and PCN #20	20
Primary Care Counsellors	PCC#1, PCC#2, PCC#3, PCC#4 and PCC#5	5
Clinic Referral Facilitators	CRF#1, CRF#2 and CRF#3	3
Community Health Workers	CHW#1	1
Community Adolescent Treatment Supporters	CARTS#1, CARTS#2, CARTS#3 and CARTS#4	3
Unspecified Occupations	UO#1, UO#2, UO#3	4

Participants in the qualitative questionnaire included all healthcare professionals such as primary care nurses, primary care counsellors, clinic referral facilitators, community health workers, community adolescent treatment supporters, and medical doctors. Table 4.1 shows that the majority of participants were primary care nurses (n=20), followed by primary care counsellors (n=5), clinic referral facilitators and community adolescent treatment supporters who had equal participants (n=3). However, some health workers (n=4) did not specify their occupations.

4.4 Demographic data for qualitative participants (n=36)

The sample (n) included thirty-six (36) healthcare professionals from six health centres. The number of distributed qualitative questionnaires was guided by the availability of health workers and the data saturation point. The demographic characteristics of participants are depicted in Table 4.2.

Table 4.2: Demographic Characteristics of Participants (n=36)

Category	Characteristics	Percentage (%)
Age	18-20	2.78%
	20-30	11.11%
	31-40	47.22%
	41-50	30.57%
	51-60	2.78%
	61+	5.54%
Gender	Male	38.89%
	Female	61.11%
Occupations	Primary Care Nurses	55.56%
	Primary Care Counsellors	13.89%
	Clinic Referral Facilitator	8.33%
	Community Health Workers	2.78%
	Community Adolescent Treatment Supporters	8.33%
	Unspecified Occupations	11.11%

Table 4.2 shows that the majority of the participants were aged between 31-40 years (47.22%), followed by 41-50 years (30.57%) and 20-30 years (11.11%). A significant number of participants were females (61.11%). Primary care nurses had the highest number of participants (55.56%) as compared to other occupations.

4.5 Major themes and sub-themes

Similar themes and sub-themes that emerged from collected qualitative data were presented concurrently with the research objectives where data contrast with or complement each other.

4.6. Current strategies and information diffusion methods to help health promotion to manage malaria in Buhera rural district

Objective 1: Explore and analyse current strategies and information diffusion methods to help health promotion to manage malaria. The purpose of this objective was to analyse current information diffusion methods that have been used to help health promotion and create awareness in Buhera rural district. Three major themes that emerged from the participants' responses under this objective were print media, digital platforms and community events as shown in Table 4.3.

Table 4.3: Current strategies and information diffusion methods

Themes	Sub-themes
Print media helps health promotion to manage malaria	• Clinic posters and charts to educate people about malaria. • Medical billboards for mass communication
Digital platforms to educate and help health promotion to manage malaria	• Use radio adverts to create malaria awareness. • Television malaria campaigns • Mobile phones disseminate malaria information and create awareness

Community events to create malaria awareness and educate people in rural areas	• Schools' events • Churches • Outreach programmes

Table 4.3 shows the current strategies used to disseminate health information in Buhera district. Participants highlighted that print media, digital platforms, and community events create malaria awareness in rural communities.

4.6.1 Theme 1: Print media to help health promotion to manage malaria

One major theme identified pertaining to the current strategies and information diffusion methods that have been used to help health promotion to manage malaria in Buhera rural district was the use of posters. Participants reported several strategies as information diffusion methods for education, communication and creating malaria awareness. These information diffusion methods emerged as sub-themes and were then collated to form the broad theme of posters. The sub-themes are clinic charts to educate people about malaria and the use of medical billboards for mass communication.

4.6.1.1 Clinic posters and charts to educate people about malaria

The use of clinic charts to disseminate malaria information in the Buhera rural community was further confirmed by the participants as follows:

> *"…. posters and charts help to educate people and create awareness about malaria in the community as they stretch into all hard-to-reach areas. However, they should be written in local/vernacular languages for illiterate [meaning those unfamiliar with non-local languages] people to understand the message."* (PCN #1, PCC #1, PCC #4)

The same sentiments were expressed by the following participants who also recommended the use of medical charts, dramas, and billboards for deaf and blind people. This was expressed in the following responses:

"We normally use posters, charts and billboards but they are not friendly to the blind. In such circumstances, we infuse outreach programmes with dramas so that the message can reach everyone." (PCN#7, CRF #1, CRF #2)

"We use posters and charts very often to spread malaria information but sometimes they tear off during the rainy season and are blown away by wind........ and they are also not ideal as they may get washed away and easily get torn." (PCN #2, PCN#10, PCN#7)

"Posters can reach all places without mobile network signals but need improvements to use prominent languages such as Shona or isiNdebele." (PCN #8, UO #3, UO #4)

"Posters are a good strategy to educate people about malaria but the Ministry should also include cell phones, television and radio for better coverage." (PCN #12)

4.6.1.2 Medical billboards for mass communication

Medical billboard advertising is a particular type of communication involving the use of large, stationary structures placed along roadsides and other transit routes to display health messages to passers-by. Therefore, given health disparities in the Buhera rural district and the reduced access to health of the underprivileged, coupled with high exposure to billboard advertisements, opportunities emerged to deploy the medium in a manner that connects these difficult-to-reach audiences with malaria information. Even though medical billboards are used as an information dissemination method in Buhera rural district, their density is very low in the community as indicated by the participants as follows:

Medical billboard advertising appears to engage the less fortunate, providing a productive pathway for the conveyance of helpful, supportive details, yielding healthier populations, enhanced opportunities, and better communities. This was expressed in the following response from the participant:

"*.......sometimes, the Ministry use billboards placed along the road when doing health campaigns to create awareness but they should be written in the local language of* *people staying in areas around so that they understand the message." (*PCN #10, UO #1, UO #2)

4.6.2 Theme 2: Digital platforms to educate and help health promotion to manage malaria

Several digital platforms emerged as information diffusion methods in Buhera rural district. These platforms include radio, television, and mobile phones.

4.6.2.1 Use of radio adverts to create malaria awareness

Radio stations are widely used as information technology for participatory communication style of information and knowledge transfer, especially on emerging issues. Radio advertisements are extensively used through vernacular radio programmes during campaigns to create awareness of service locations and timings, however, in areas with limited or no radio frequency, the health care professionals rely on peer educators, print media and other technological methods as indicated by the participant as follows:

> *"We use different platforms, it depends on the targeted audience, for example during the male circumcision campaign, the ministry utilised mass media communication platforms such as television and radio adverts supported with billboards along the major roads. These radio adverts were developed in a different language to cater for various ethnic groups in the country. During malaria peak season, we also use radio adverts to create awareness and posters, even though in some areas there is limited radio frequency." (*CHW #1)

4.6.2.2 Television malaria campaign

Television is one of the ICT-based mass communication strategies used for advertisements and sensitisation campaigns in the Buhera rural district. Based on sub-themes that emerged on digital platforms, television helps to bridge the dearth of knowledge about malaria in some areas where television satellites are installed. This was indicated by the participant quoted as follows:

*"......The Ministry of Health and Child Care uses different ways to create malaria awareness such as charts, posters, radio and television; though they are very few people with satellite television sets here in Buhera rural districts as compared to urban areas due to some factors such as poverty level, income level, and signal strengths." (*PCN #16, CHW #1)

4.6.2.3 Mobile phones disseminate malaria information and create awareness

Mobile phone technologies increasingly play a critical formal role in health services, particularly in low-resource settings such as Buhera rural district as half of the population lives in areas with a high risk of malaria transmission. Generally, communication using feature phones is done through text messaging (SMS) and USSD platforms. For instance, Table 4.14 shows that SMS-based platforms have been used to disseminate general health information and create awareness. Due to the improved features of smartphones, there is a growing demand for developing mobile applications to disseminate health information. A few prototypes have been developed as shown in Table 4.14 to improve access to care, but none have been developed for tackling malaria. These prototypes require a consistent internet connection to function effectively. In Buhera, there are three competing mobile network service providers, Econet Wireless, NetOne and Telecel, providing mobile lines and network services to the populace. However, among them, Econet Wireless through EcoHealth in partnership with Medical Aid Firms and Zimbabwe's MoHCC and a team of expert-initiated malaria mobile-friendly video animations focus on the prevention, diagnosis, and treatment of malaria, and developed in English, Shona and Ndebele, supporting the training and awareness-raising work of Zimbabwe's National Malaria Control Programme and the transformation of malaria health education using mobile animation.

In Buhera rural district, mobile technologies including tablets and smartphones are used by healthcare professionals to disseminate, access and upload health information from the satellite health facilities into the District Health Information system (DHIS). This was confirmed by several participants as they shared the same sentiments as follows:

"Posters, radios, televisions, and mobile phones are good mediums of communication because they encompass all types of communication to reach out to all people in society. This is because the community is made up of people who understand things differently." (PCC #3)

"As a support group, we use posters, charts, cell phones and WhatsApp groups to create awareness, communicate and educate youths about many diseases including malaria." (CART #1)

"...To communicate and educate the public, we use posters and charts but they are very few because of the cost of printing. As health workers, we sometimes communicate using mobile phones, more often our work WhatsApp group to share and disseminate health information, meetings and workshops because the message reaches many people in various areas at a lesser cost." (PCN#13, CHW #1)

4.6.3 Theme 3: Community events to create malaria awareness and educate people in rural areas

Participants indicated that community public gatherings and events play a paramount role in disseminating health information in the community. These events include school activities, church gatherings and outreach programmes led by health workers, which emerged as sub-themes.

4.6.3.1 Schools' activities

Schools' activities involve all events in the schools' calendars hosted by the school(s) as directed and approved by the District Education Officer (DEO). These activities include sports activities, arts, and culture events (drama), career guidance events and inter-school visits. It emerged that healthcare professionals utilise schools' activities to create awareness about malaria following Zimbabwe school health policy (ZSHP) guidelines. The ZSHP ensure effective coordination, implementation linkages, learners, teachers, government, stakeholders' participation and ownership, monitoring, and evaluation. The ZSHP emanates from the inseparable relationship between health and education, thus, ensuring quality health services for all learners as confirmed by the participants as they noted that:

"We use posters to spread malaria information and sometimes, we visit schools and communities since other people do not visit clinics and hospitals and other people do not have radios, televisions and telephones at home." (PCN #6)

*"Here, in deep rural areas, we use dramas, choirs and face-to-face communication because charts and posters are very scarce, therefore, drama and outreach activities are very useful but drama takes more time to prepare." (*PCN #17, CRF #1)

4.6.3.2 Churches

Buhera rural district consists of people with different cultures and religious diversity such as faith-based organisations and traditional institutions. The faith-based organisations, particularly churches, play a substantial role within the overall health system of Buhera rural district to create awareness and communicate malaria information as confirmed by the participants' responses:

".....we usually use posters and charts from the Ministry of Health and Child Care and also church gatherings to educate people about malaria and encourage them to visit health facilities but some churches do not allow their congregants to go to health facilities to seek health care." (CRF#3)

"..we use charts and posters.......However, some churches and people in the community believe in traditional medicines and pastors, therefore, we end up going to churches and traditional gatherings to educate people about diseases including malaria."(CHW #1)

4.6.2.3 Outreach programmes

Healthcare professionals, particularly community health workers (CHW) consistently with the community and schools to educate, communicate and create awareness about health-related issues including malaria to improve an essential aspect of health promotion. Health outreach programmes rely on community health workers particularly in resource-limited settings to support care for long-term conditions including malaria, HIV, and maternal issues. These programmes build rapport with community members. The following responses from the participants confirmed the involvement of health workers in community gatherings as a key information diffusion method through outreach programmes:

> *".....community gatherings and outreach programmes make people free to air out their views and get to ask questions and gain knowledge about malaria from nurses and community health workers."* (PCC #2)

> *"We educate people in the community through schools' outreach programmes, public rallies, community events and dramas,"* (PCN #9)

The same sentiments were expressed by the primary care nurse but with some little contradictions as follows:

> "*.....some people cannot read posters and charts, so we also do outreach programmes to educate people about many health issues but some people are shy to ask questions because they are not used to that."* (PCN #4, PCC #4 and PCC #5)

> *".........outreach programmes are very useful but they require clearance from the regulatory authorities which usually takes time." (*CHW #1)

4.7. The most feasible ICT technology for disseminating malaria information and creating awareness

Objective 2: Explore and implement the most feasible ICT technology, which includes investigating mobile technology at healthcare centres and alternatives, for malaria health information dissemination and digital awareness, based on the previous investigation, to reduce malaria incidences in rural communities.

The second research objective tried to determine the current and most feasible ICT technology that healthcare professionals in Buhera rural district have been using. To develop an ICT-based malaria intervention framework, it was imperative to understand and establish what ICT technologies have been adopted by the MoHCC and healthcare professionals to disseminate malaria health information. This would assist to determine the most feasible ICT technology, including investigating mobile technology at healthcare centres and alternatives, for malaria health information dissemination and digital awareness. The emerging major themes and sub-themes derived from the responses to the qualitative questionnaire of participants in Category A are presented in Table 4.4. The major themes included mass media communication/broadcast media, mobile technology, and social media platforms.

Table 4.4: ICT-based information dissemination methods

Themes	Sub-themes
Mass media communication	• Radio • Television • Video films • Electronic billboards
Mobile technology	• Mobile phones/cell phones • Computers, laptops, and tablets • District Information System (DHIS)
Social media platforms	• WhatsApp and Facebook

Table 4.4 shows that mass media communication, mobile technology and social media platforms (WhatsApp and Facebook) are among the digital technologies used to disseminate

health information in Buhera district. These digital platforms are explained in the following subsequent sections.

4.7.1 Theme 4: Mass media communication

It emerged that mass media communication or broadcast media have been disseminating malaria health information to create malaria awareness in Buhera rural district. Findings from responses reveal that mass media communication platforms such as radio, television, and video films play a significant role in creating malaria awareness and influencing individuals to act.

4.7.1.1 Radio

Most participants indicated that the MoHCC increases community awareness about malaria by using radio campaigns and campaigns in different dialects peculiar to a specific region through using various radio stations in the country. Participants in this study indicated that radio motivates people and creates awareness by building on aural/oral traditions and stimulating the imagination. It was confirmed by the following responses from participants:

> *"The ministry uses radio campaigns because radio is a very common and reliable way to spread information as it reaches the whole community faster and follow-ups can be made."* (PCN #2)

> *"………people can listen to radio campaigns through radio shows and radio lessons hosted in several stations. Usually, when there is an outbreak, we use radio stations to enhance campaigns."* (PCN #9 and PCN#18)

> *"Some people listen to the radio during their free time at home; therefore, we use radio to create awareness campaigns." (PCN#12, UO#1, UO#2, PCN #20 and CHW#1)*

4.7.1.2 Television

Television as an alternative broadcast media creates malaria outbreak awareness through news broadcasting, commercial advertisements, shows, movies and documentaries. It emerged that television conveys messages through audio, graphic images and emotional content as confirmed by the following responses from the participants:

"…use of television, laptops, radio and digital billboards playing pictures at centres where a large of people can reach; can probably help to increase malaria awareness campaigns." (PCN#3, UO#3)

"Television, radio, and cell phones can be used to communicate with village health workers for them to mobilise people." (PCN#10)

*"…. some people in Murambinda have access to television so, using television to educate and communicate malaria information might be helpful." (*CART#3)

4.7.1.3 Video films

Integrating video films in the community viewing centres and outreach programmes can be used in the vanguard of creating malaria awareness. In the context of raising malaria awareness, the following participants highlighted that:

"Incorporating and showing videos about diseases in our outreach programmes help people to understand the importance of disease prevention and adherence to prescribed medication." (PCN #5)

"……people understand better when seeing movies and videos about the effects of malaria. So, we sometimes educate primary and secondary school learners using videos about malaria from the Ministry of Health and Child Care but it depends on the disease." (PCC#3, PCN#16, PCN#5)

4.7.1.4 Digital Billboards

Health workers indicated that digital billboards have been strategically positioned on various major roads to engage audiences including motorists and passers-by. The participants further indicated that electric billboards have been used to enhance health campaigns, especially in urban areas' major roads.

"In urban areas, the ministry uses electronic billboards on major roads to raise awareness. For example, during HIV/AIDS and male circumcision campaigns digital billboards and big posters were used to create more awareness and destigmatisation." *(*PCN#7)

"…use of television, laptops, radio and digital billboards playing pictures at centres where a large of people can reach; can probably help to increase malaria awareness campaigns." (PCN#3)

4.7.2 Theme 5: Mobile technology

It emerged that mobile health technology facilitates data transmission and enhances communication between health care professionals in impassable areas in Buhera rural district, and in some instances communicates with patients remotely. Sub-themes that emerged from mobile technology included the use of mobile phones or cell phones, computers, laptops and tablets.

4.7.2.1 Mobile phones/cell phones

Mobile phones are the leading form of communication in the Buhera rural district, therefore, it emerged that the participants harnessing the potential of mobile and wireless technology could improve health and health care delivery. This shows that mobile phones are most frequently used to communicate and receive health information through SMS alerts (notifications). The following responses were highlighted by the participants:

*"Disseminating malaria health information via mobile phones (especially SMS) is very useful especially during peak malaria season to educate people about the importance of using mosquito nets and removal of bushes in their homes." (*CHW#1)

"People in the area have got cell phones and they can easily share health information because of its mobility." (PCN#1)

"Mobile phones can be a very effective way but only to people who have access to them. So, mobile phones have to be used together with other methods such as posters, dramas, radio and television to create awareness." (PCN#5, CART#2, PCN#8, PCN#18, PCN#19, PCN#20, UO#1)

"Mobile phones can move and spread health information better because most clients have cell phones in the community." (PCN#9, CRF#2)

"We use cell phones because many households have at least one person with a cell phone. Again, a significant number of people are using WhatsApp; therefore, information can be shared quickly. Television and radio can be used together with cell phones to cater for the young generation." (CRF#2, PCN#16)

4.7.2.2 Computers, laptops and tablets

"Laptops and cell phones should use messages written in our language so that people understand. This will help everyone to understand even though some older people may not be able to open and read cell phone SMS." (PCN#4)

"*…use of television, laptops, radio and digital billboards playing pictures at centres where a large of people can reach; can probably help to increase malaria awareness campaigns."* (PCN#3, UO#1)

4.7.2.3 District Health Information System (DHIS)

Healthcare professionals indicated that they use health information systems called District Health Information Systems to capture, transfer, visualise data and surveillance of malaria cases.

*"Here in Buhera rural district, we enter new malaria cases and other diseases in our district information system which is linked to the provincial health system and the national health information system for surveillance and reporting purposes. At the end of the month, we generate reports from the DHIS for statistical and reporting purposes. However, we experience some challenges such as power cuts, and network problems that sometimes lead to delayed capturing and update of our records." (*CHW#1)

"At our level, we send reports and extract data from the DHIS. We can also access DHIS on our laptops and tablets as long the device is connected to the internet." (UO#2)

4.7.3 Theme 6: Social media platforms

WhatsApp and Facebook

There is an indication that people in Buhera rural district share and disseminate health information and other related issues on social media platforms such as WhatsApp and Facebook. This is supported by the following quotes revealed from the qualitative questionnaire:

"*…. ICTs are used to spread malaria information are radio, television and cell phones. Some residents have WhatsApp groups, and Facebook groups in Murambinda to fast share information about current issues. For example, there is a COVID-19 WhatsApp group used to update people in Murambinda about coronavirus*." (CRF#3, PCC#3)

"Some people share WhatsApp messages to spread information about diseases by using text, audio and videos but some send false information on WhatsApp." (CART#1, PCN #19, PCN#18)

4.8. Challenges and implications of implementing ICTs in the health system

Objective 4: Investigate opportunities, challenges, success/failure factors and implications of the ICT intervention system in health policy formulation in Zimbabwe.

To better understand the challenges and implications of integrating ICTs in health policy formulation in Zimbabwe, especially in the rural health system, the study solicited implications and challenges faced by participants when delivering health services and data transmission through ICTs in Buhera rural district. The challenges were further grouped into internal and external challenges. Internal challenges are setbacks faced by the MoHCC when implementing, integrating, and providing health services through ICTs (e-health). External challenges require extra support and guidelines from external stakeholders outside the Ministry of Health and Child Care. The emerging themes from data collected from participants were classified as internal and external challenges while sub-themes that emerged were classified respectively as shown in Table 4.5

Table 4.5: Challenges and implications of implementing ICTs in the health system

Themes	Sub-themes
Internal challenges	• Network problems • Inconsistent power supply • Unavailability and inaccessibility of ICT infrastructure • Lack of technical support • Lack of training • Digital illiteracy • Language Barriers
External challenges	• Absence of active e-health policy • Lack of funding • Absence of data protection policy • Bureaucracy • HIS integration and standards

Table 4.5 shows that the adoption of ICTs into the health system is affected by internal and external challenges. Internal challenges include network problems, inconsistent power supply,

unavailability and inaccessibility of ICT infrastructure, lack of technical support, lack of training, digital illiteracy, and language barriers. External challenges include the absence of an active e-health policy, insufficient funding, absence of data protection policy, bureaucracy, HIS integration and standards, corruption, lack of political will and lack of feasible digital technologies. These challenges are explained in detail in the following subsections.

4.8.1 Theme 7: Internal challenges

Internal challenges highlighted by the participants included network problems, inconsistent power supply, unavailability and inaccessibility of ICT infrastructure, technical support, digital literacy, lack of training, lack of funds and language barrier.

Network problems

Whilst there has been significant progress in rolling out ICT communication infrastructure including 2G, 3G technology, satellite communication and high-speed broadband coverage (Gwaka et al., 2018), there are some rural and remote areas where network coverage is still patchy. It emerged that some rural areas experience network problems as confirmed by the following quotes:

> *"There is poor internet access in some communities."* (PCN#3, PCN#4, PCN#6, CART#2)

> *"Here, we face the network signal problem. Sometimes our cell phones messages take time to deliver and we walk a distance searching for network signals."* (PCN#11)

> *"In this area, we have poor network coverage......but now we know the spot where we get network signals."* (PCN#8, PCN#9, CART#3)

> *"........mobile network can be a challenge as the messages may take time to be delivered or reach people."* (PCC#1)

"We experience connectivity problems...... we are asking for WIFI, computers and zero-rated mobile phones for clinics in rural areas because there is poor internet access in some areas." (PCN#2, PCN#10)

"We use cell phones to communicate with our workmates in the referral hospital but experience limited network signal. Sometimes WhatsApp messages are delivered late whether I have data bundles or airtime." (UO#4, PCN#14)

"......radio signals and mobile network signals are major problems in this area because people listen to the radio and use mobile phones for communication." (CRF#2)

"Poor network access in some areas in Buhera." (PCN#16, PCN#18)

Inconsistent power supply

The national power supply does not cover the whole country which leaves a proportional number of people needing to use alternative power sources (Maphosa, 2018). It emerged that even those who are connected to the national power grid experience erratic power supply as attested by the following participants:

".......there are erratic power cuts in Zimbabwe, and it takes longer to replace a damaged transformer." (PCN#2)

"Lack of power (ZESA) supply in rural areas, so cell phones might not be in use all the time unless we use car batteries and solar energy to recharge our phones. Here at clinics, we have solar panels to recharge our cell phones and to run refrigerators but very few people in the community have access to solar energy." (PCN#3)

"........poor electricity supply in our area, we are now using solar to recharge cell phones and lighting." (PCN#9, PCN#6)

"........we want to use ICTs but there is a shortage of power." (PCC#1)

".........no power supply which will lead to missing important information, especially when broadcasted on radio or televised." (PCC#3)

"*........ there are few areas that receive electricity regularly in Buhera rural district."* (PCC#4, CRF#2)

"Poor or limited access to electricity due to power cuts which cause radio and television to shut down resulting in people missing important health information spread on such platforms." (CART#3)

"......lack and poor access to electricity to power devices......." (PCN#7, PCN#19 and PCN#20)

Unavailability and inaccessibility of ICT infrastructure

The unavailability of ICT infrastructure involves the perceived shortage and unavailability of ICT tools such as computing devices, software as well as internet access. Participants highlighted that there is limited internet access, and a shortage of computing devices such as computers, mobile phones, and computers. This was confirmed by the following quotes from the participants:

"..........lack of WIFI internet access at the clinics." (PCN#9)

".... shortage of funds to buy cell phones and internet data." (*PCN#1)*

"......... asking for WIFI, computers and zero-rated mobile phones for clinics in rural areas because there is poor internet access in some areas." (PCN#2)

*"Some age groups do not have phones; especially school learners are not allowed to use cell phones in some schools but they can use cell phones at home." (*PCN#3)

"Some people do not have mobile phones and computers." (PCN#8)

"Not everyone living in the community has a cell phone or radio to receive health information......." (PCN#4)

"We sometimes share office computers and laptops when working at the clinics but when we are conducting outreach programmes, we struggle a lot because we do not have work tablets and cell phones and internet data bundles." (PCC#2)

*"..........lack of ICTs such as radio, television and cell phones in some areas." (*PCC#3)

".... some people are poor, they focus on buying food for living they cannot afford to buy computers, laptops and cell phone........." (PCC#4)

".... radio does not receive radio signals in some areas making it difficult for some people to receive health information..." (CART#3)

".... lack of ICT gadgets to use..." (CHW#1, PCN#17, PCN#18)

"...insufficient internet data bundles and airtime for us to communicate with nurses, doctors, patients and people in the community...." (PCN#19)

Lack of technical support and Skills

There is an indication of inadequate ICT skills to roll out, support and maintain e-health programmes. The lack of ICT skills and technical support has been identified by participants as one of the challenges of implementing ICTs in the health system. Excerpts from participants include:

*"If a server or computer is down, it takes time for them to repair or get it fixed. We experience more system downtime including the DHIS." (*UO#1)

*"People including nurses, doctors, counsellors and community health workers should be trained through workshops and outreach programmes on how to use ICTs." (*PCN#1)

*"......advanced ICT methods may need skilled manpower to operate them. As medical professionals, we lack those ICT skills to operate computers, laptops and e-health software. We need training." (*PCN#5)

Lack of training

Participants appreciated the importance of ICTs in health service delivery but all highlighted that training is required to upgrade their skills. Excerpts from participants included:

*".........as medical professionals, we lack those ICT skills to operate computers, laptops and e-health software. We need training." (*PCN#5)

"People including nurses, doctors, counsellors and community health workers should be trained through workshops and outreach programmes on how to use ICTs." (PCN#1)

Digital literacy

Digital literacy is the ability to use technologies including computers, smartphones, laptops and other computing devices; using skills in typing and entering information via a keyboard and the ability to use a mouse. Healthcare professionals' digital literacy levels have an impact on the adoption of ICTs health services as they indicated that:

*"......lack of knowledge on how to use and operate computers, laptops and mobile phones." (*PCN#7)

*"Knowledge deficit might cause a lot of people, old people, to fail to understand the message and also they do not know to use their cell phones. They ask relatives to read messages on their behalf and interpret on their behalf." (*PCN#6)

*".......people do not know how to operate computers, laptops and smartphones." (*PCN#4)

“.....lack of knowledge on how to operate ICTs....” (UO#2, PCN#17)

Language Barriers

There is an indication that rural communities experience communication barriers when receiving health information through posters, billboards and SMSs written in a foreign language. Excerpts from participants indicated that:

*“.....adopted systems are written in a foreign language which might be difficult for people in rural areas to understand the message.”(*PCN#4)

“.....help to educate people and create awareness about malaria in the community as they reach all hard-to-reach areas. However, they should be written in local languages for illiterate people to understand the message.” (PCN #1, PCC #1, PCN#3)

“.......... but need improvements to use languages, English and Shona or isiNdebele.” (PCN #8, UO #3, UO #4)

“.....although posters may cause wrong interpretation of information due to illiteracy.”(PCN#4)

4.8.2 Theme 8: External challenges

The study identified external challenges to the implementation of ICTs in the health system as the absence of an active e-health policy, lack of funding, absence of data protection policy and bureaucracy.

Absence of active e-health policies

Zimbabwe’s health delivery system, once amongst the best in Sub-Saharan Africa, has suffered severely during and post hyperinflation. Despite the economic crisis, several e-health applications are underway in Zimbabwe’s health system which led to Zimbabwe’s e-health strategy from 2012-2017. Participants indicated that:

".... there is no active electronic health policy for the meantime. The previous one expired because it had a timeframe. So, we do not know the extent to which we should incorporate ICTs into our health system. Yes, people use cell phones especially WhatsApp to send and receive health information but that medium is neither included in the policy nor verified by the ministry." (UO#1)

Lack of funding

Participants indicated that there is a huge shortage of funds to cater for operational costs; workshops; malaria prevention campaigns and measures; and acquisition of equipment.

".... shortage of funds to equipment and hosting workshops for training on new diseases and ICTs." (PCN#1)

*".... lack of resources such as money to buy airtime and ICT devices." (*PCN#3)

"......shortage of funding to facilitate early treatment of patients and ICT for malaria monitoring, case surveillance, monitoring tool in Buhera rural area ...... inadequate malaria prevention resources such as human resources and finances to fund malaria prevention programmes." (PCN#5)

"........it is very expensive to send and receive health information using our cell phones and data; the regulations do not allow us to use WhatsApp...." (PCN#15)

"....we do not have sufficient posters and charts to distribute to all clinics and busy areas like shopping centres where we have a large audience."(PCN#11, PCN#6)

Absence of data protection policy

Zimbabwe rolled out its Cybercrime and Cybersecurity Bill in 2017 as a measure to combat any potential cyber threats but it is not yet gazetted into law. While there is no designated national legislation dealing with data protection for private persons in Zimbabwe yet, there are existing laws that have a bearing on the right to privacy and protection of personal information for specified types of data, or about specific activities. It was confirmed in the following participants' excerpts:

> *"The use of ICTs in clinics and hospitals is a good idea but should not violate doctor-patient privacy. They are many mobile health software programmes that have been used by people but they are verified to ensure privacy and security of health data.........health policy does not incorporate the use of mobile applications that are not verified by the ministry." (*PCN#6)

> *"...... misuse of information intentionally or just ignorance...."* (CHW#1)

> *".........for a medium like WhatsApp, some people may send unverified health information ......we do not have a Cybersecurity Act, however, there is an ongoing Cybersecurity Bill in the Parliament."* (UO#3)

Bureaucracy

One participant indicated that the clearance process is very long as people are moved from office to office when seeking permission to conduct outreach programmes and mobilise people for health promotion. The participant states that:

> *".......sometimes it takes time to get clearance or approval to get access and contact outreach programmes in school to educate the community about malaria and other health issues."* (CHW#1)

4.9 Other challenges faced by Buhera rural district in preventing Malaria

It emerged that participants encounter non-ICT-related challenges in preventing malaria in the rural community. The challenges include religious beliefs, ignorance, misuse of mosquito nets, inadequate IRS coverage and shortage of fuel and transport.

4.9.1 Theme 9: Religious practices and beliefs

Zimbabwe is a country with diversity in religious practices and beliefs. However, it emerged that some faith-based organisations including churches discourage congregants from seeking medical help as part of their church doctrines as indicated below by the participants as follows:

> *"......culture and churches are also a barrier as other people who belong to the apostolic sects refuse to use either conventional medication or visit clinics because of their beliefs."* (PCC#1, PCN#7)

> *".......some people do not seek medical help because of their beliefs."* (CART#2, CART#3)

> *".... churches especially apostolic sects do not allow their congregants to visit clinics and hospitals when they get ill."* (CRF#3, PCN#20)

4.9.2 Theme 10: Ignorance

Even though health professionals educate people in Buhera rural community using the available means, it emerged some villagers are ignorant. Excerpts from participants confirming that are as follows:

> *"...people here do not come to the clinic early for treatment when they experience mild symptoms....and show a lack of malaria drug compliance..."* (PCN#3)

> *"......some people keep the bushy environment at their houses which attracts mosquitoes......"* (CHW#1)

> *"......and some keep stagnant waters closer to their homes as water sources even after being informed and educated."* (CRF#3)

> *"......people refuse malaria testing....."* (PCN#12)

4.9.3 Theme 11: Insufficient use and misuse of mosquito nets

The mosquito net is one of the malaria prevention methods in Buhera rural community, but it has emerged that they are insufficient and often misused in the community. Participants indicated that:

> *".......lack of resources such as the provision of mosquito nets and some people are staying in waterlogged areas, which are breeding grounds for mosquitos." (*PCN#9, PCN#20)

> *"Some people do not have mosquito nets and oil at all because we sometimes receive a few of them."* (PCN#11, UO#4)

> *"......lack of mosquito nets..."* (PCN#6)

> *"Sometimes, we give them mosquito nets but they use them for fishing......and net less coverage."* (PCC#3, PCC#3)

> *"We need help; we have a big shortage of mosquito nets and poor sanitation especially toilets because people use bush toilets."* (CHW#1)

4.9.4 Theme 12: Inadequate IRS coverage

Intermittent residual spraying (IRS) is part of the malaria vector control methods in the Buhera rural district. IRS programmes reduce adult mosquito vector density and longevity and, therefore, reduce malaria transmission but they are beset by quality and coverage concerns. Participants indicated that:

> *".......another challenge is that some people refused to let the IRS team spray their houses to prevent malaria because of the side effects of the chemicals used for IRS."* (PCN#10)

".......due to the economic crisis, IRS coverage is done in high malaria-infested places but IRS should be done and cover all places in Buhera rural district." (PCN#11)

There was an indication that the chemicals used for mosquito nets and IRS had side effects as some participants noted that:

".... the chemical used for mosquito nets and IRS is not good for some people because they are allergic (react); that's why they refuse to use these methods to prevent malaria." (UO#3)

4.9.5 Theme 13: Shortage of fuel and transport

Due to the prevailing economic situation in Zimbabwe, the fuel crisis is a major problem threatening the movement of patients, healthcare professionals and medical equipment, especially in rural areas. Excerpts from participants indicated that there is a shortage of fuel and transport as stated below:

"......we also face a problem of lack of transport and fuel to move from one health facility to another. The problem is worse when we have to carry a patient to Murambinda referral hospital." (PCN#3)

"......no transport for outreach programmes and ferry medical equipment...." (PCN#9, PCN#6)

"......transport problem to move items and staff personnel to and from one clinic to another." (PCC#4)

4.10 Quantitative Results

The sample size for the survey questionnaire was 384, but the researcher received 289 questionnaires from the participants. Therefore, a response rate of 75.2 per cent was achieved. The response rate was affected by the outbreak of COVID-19 and imposed travelling restrictions. The questionnaire was coded in SPSS and the respective data was fed into the appropriate columns. After the data was cleaned, the sample size came down to 257, with a

66.9% response rate, as a result of missing variables and incomplete questionnaires from other participants. According to Scheffer (2002), one way of dealing with missing data is to delete cases that contain missing data if the percentage of missing data is not too big and if the absence is independent of the observed and missing responses (missing completely at random). In this scenario deletion of missing cases is recommended rather than adopting imputation methods (Maria et al., 2016; Kang, 2013). Hence 31 participants were excluded from the study for the aforementioned reasons.

(i) Demographic data

Of the sampled participants, 51% of males and 49% of females participated in the study as shown in Figure 4.1. This ratio of 49:51 is not far-fetched from what the 2015 census revealed. In 2015, the male-to-female ratio in Zimbabwe was 90.66 males per 100 females. Male to female ratio in Zimbabwe fell gradually from 99.31 males per 100 females in 1970 to 90.66 males per 100 females in 2015. According to the Zimbabwe National Statistics Agency's provincial report (2012), the proportion of the male and female population was 46.4% and 53.6% respectively in the Buhera rural district. This demonstrates that the sample size is a direct representation of the overall Zimbabwe population, hence the results of the study can be generalised to the whole population.

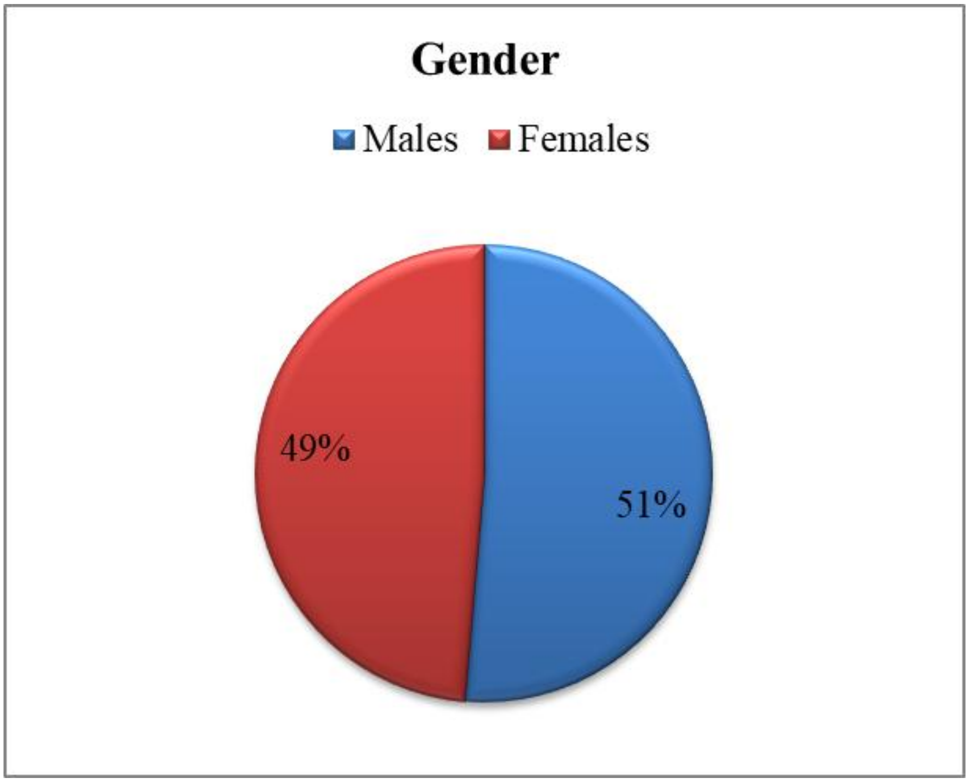

Figure 4.1: Demographic data

(ii) Name of the Community

Buhera rural district is composed of 33 wards, and 29 of them are in resource-constrained areas. From the four constituencies in Buhera, the researcher distributed questionnaires in Buhera, concentrating more on Buhera South and Buhera Central because they are more infected with malaria. From the 13 communities where the participants were sampled, a point to note is that all communities were represented by at least 1 individual. Also, 93% of the participants came from 3 communities, mainly Murambinda, Birchenough and Chapanduka as shown in Figure 4.2. These 3 communities are more majorly affected by malaria as compared to the other 10.

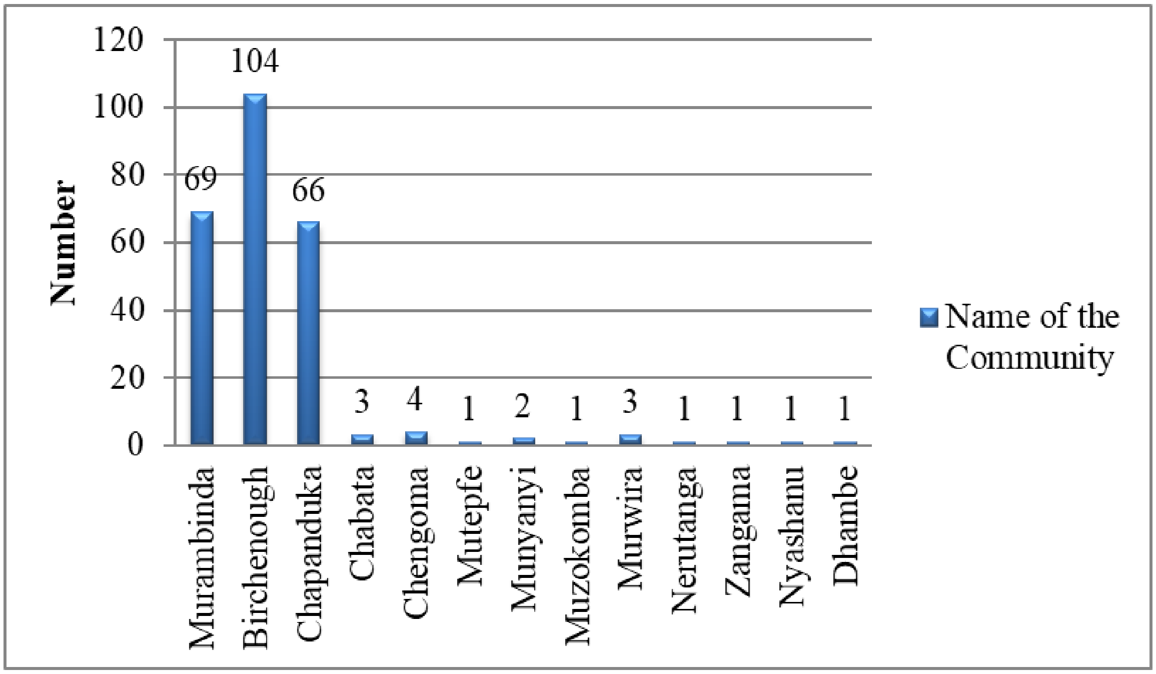

Figure 4.2: Communities of the Participants

(iii) Marital Status

According to Zimbabwe National Statistics Agency's provincial report (2012) and Zimbabwe Malaria Operational Plan (2019), the most malaria-vulnerable age groups are children under (<5) five years and learners that are above five years (>5) but less than fifteen (<15) years as shown in Figure 4.4. Generally, these learners are in primary and secondary education. Therefore, Figure 4.3 shows that 94% of the participants are single, this reflects that the study received more participants than are in schools. This is because children are among malaria vulnerable groups (Gunda et al., 2017; Gavi et al., 2021) hence the need to assess their malaria knowledge and preventive measures.

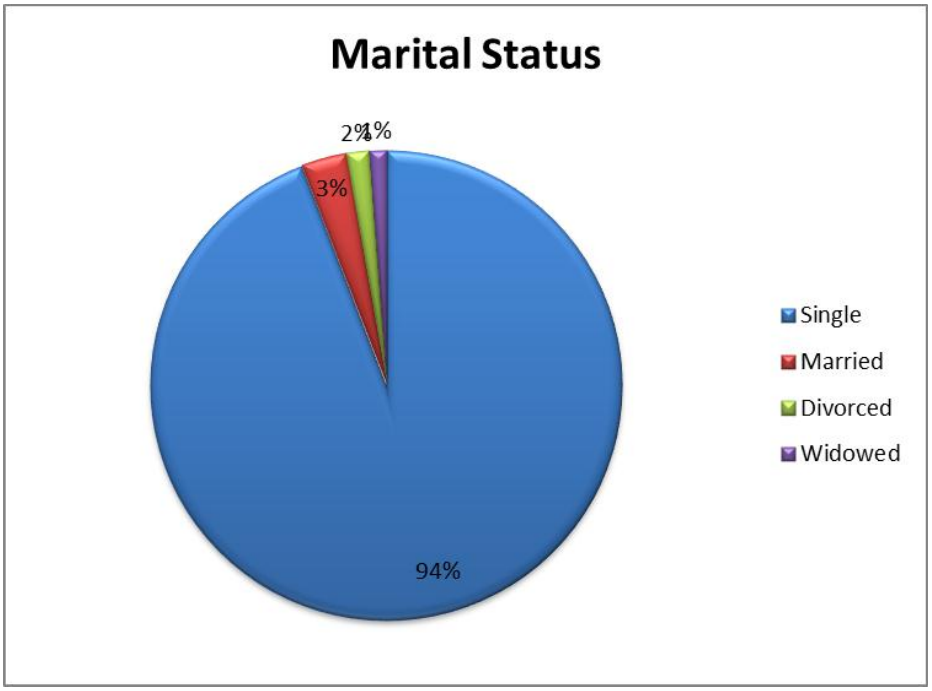

Figure 4.3: Marital Status

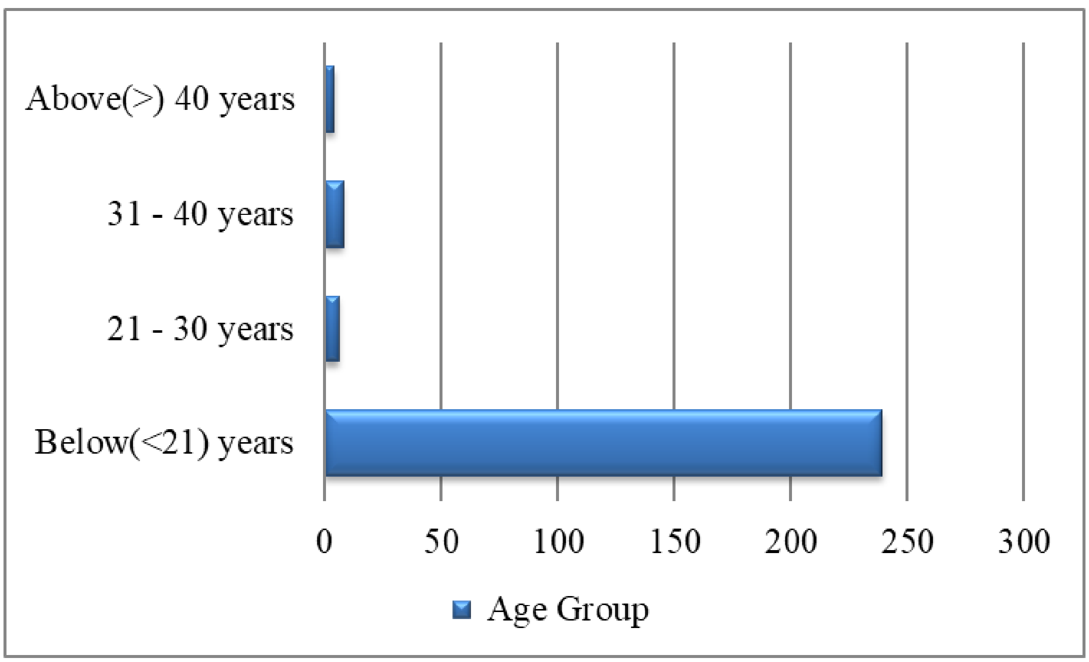

Figure 4.4: Age group

(iv) Level of education

Participants were asked to indicate their highest level of education attained or completed. From the enumerated sample, 77% of the participants are primary school certificate holders or completed primary education, 20% completed secondary education whilst the minority of 3% attended University or college as shown in Figure 4.5.

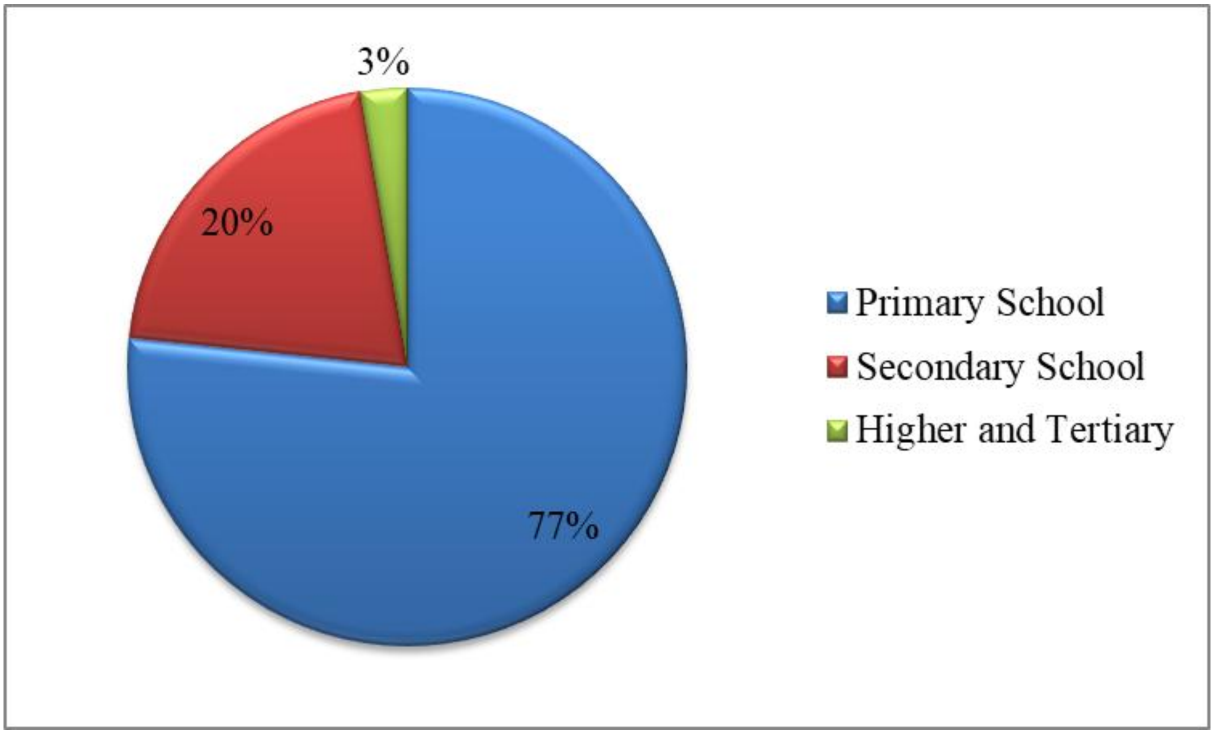

Figure 4.5: Level of Education

(v) Malaria prevention methods

In Buhera rural district, malaria is prevented using mosquito nets, IRS and antimalarial drugs. Participants were asked to respond whether they used the malaria prevention methods mentioned or not. Figure 4.6 shows that 54% (n=138) of the participants do not have mosquito nets; 81% (n=207) of participants' houses were not sprayed with intermittent residual spraying in 2019 while 86% (n=221) never used antimalarial drugs in 2019.

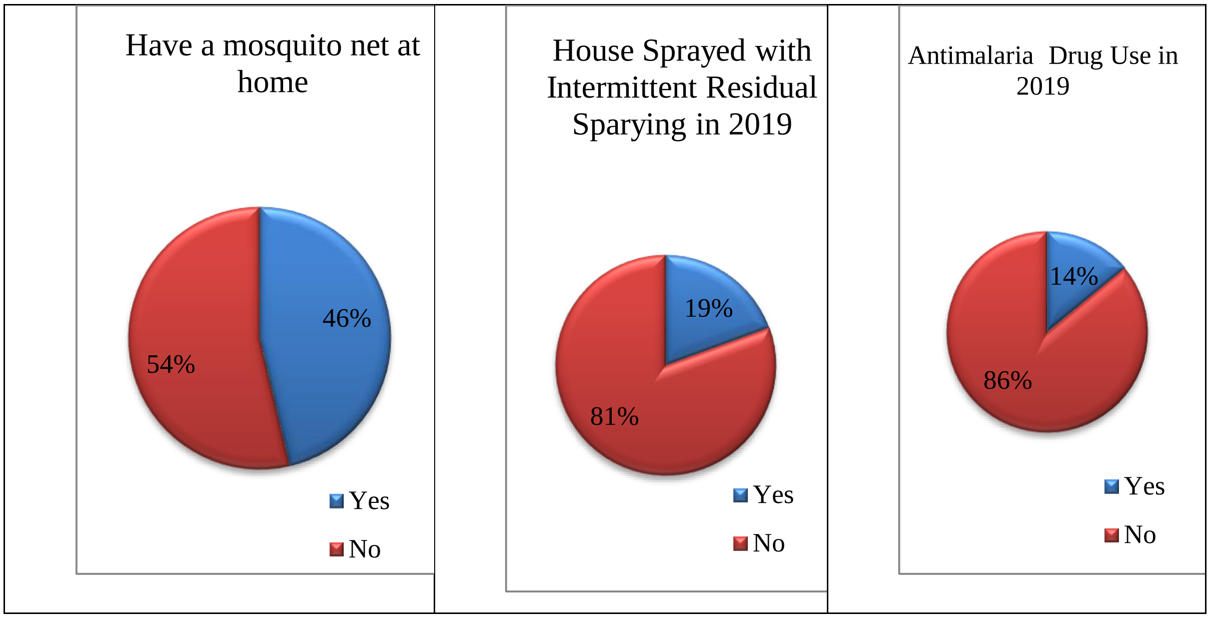

Figure 4.6: Malaria prevention methods

(vi) Malaria Knowledge testing

Participants were asked to select their choice from a list of symptoms that are related to malaria symptoms. Those that stated that they didn't know and those that got the answer wrong were grouped into one category based on whether the response was correct or not as depicted in Figure 4.7 since the responses meant the same thing. Table 4.6 shows the distribution of responses (right answer, wrong answers and don't know) from the enumerated sample.

Table 4.6: Malaria Symptoms Proportion

Symptoms	**Right Answer**	**Sample Proportion**	**Wrong Answer**	**Sample Proportion**	**Don't Know**	**Sample Proportion**
Shivering	52	*20.2%*	159	*61.9%*	46	*17.9%*
High Temperature	190	*73.9%*	40	*15.6%*	27	*10.5%*
Vomiting	132	*51.4%*	77	*30%*	48	*18.6%*
Headache	181	*70.4%*	36	*14%*	40	*15.6%*
Loss of appetite	38	*14.8%*	177	*68.9%*	42	*16.3%*

Body weakness	12	*4.7%*	220	*85.6%*	25	*9.7%*

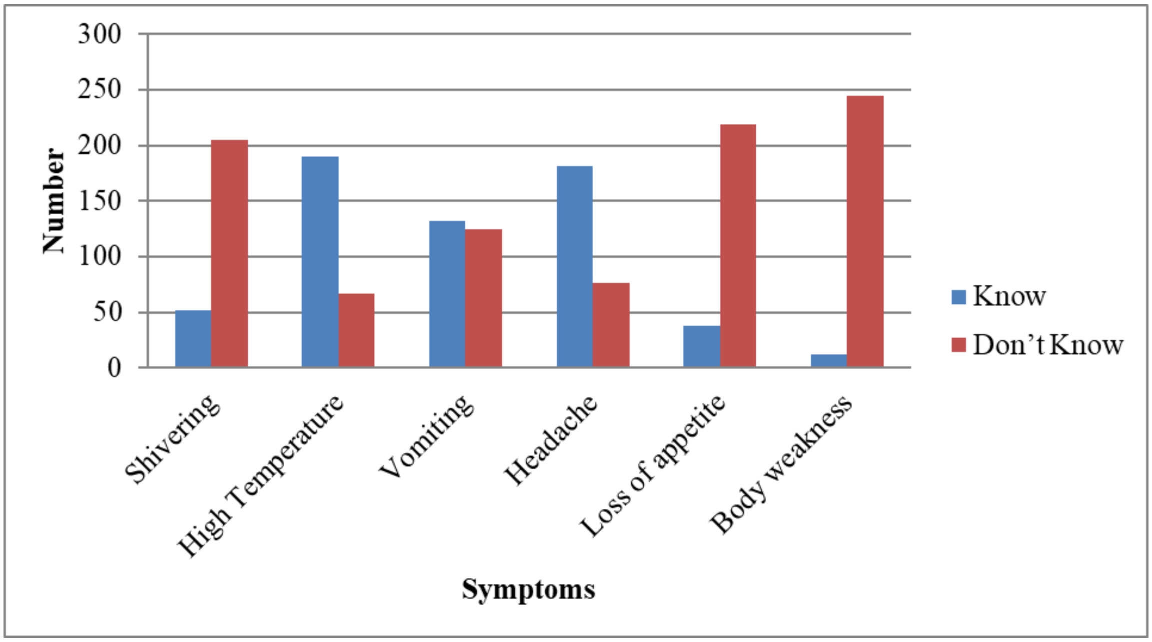

Figure 4.7: Malaria symptoms

(vii) Ways of preventing Mosquito breeding

Participants were asked about ways of preventing mosquito breeding and their responses were grouped based on whether the response is correct or not as depicted in Figure 4.8. Table 4.7 shows the distribution of responses (right answers, wrong answers and don't know) from the enumerated sample.

Table 4.7: Ways of preventing mosquito breeding proportion

Ways of Preventing malaria breeding	**Right Answer**	**Sample Proportion**	**Wrong Answer**	**Sample Proportion**	**Don't Know**	**Sample Proportion**
Avoid keeping stagnant water	194	*75.5%*	44	*17.1%*	19	*7.4%*

Clearing of bushes around the house	148	*57.6%*	71	*27.6%*	38	*14.8%*
Use of treated mosquito nets	224	*87.1%*	21	*8.2%*	12	*4.7%*
Indoor Residual Spraying	231	*90%*	16	*6.1%*	10	*3.9%*

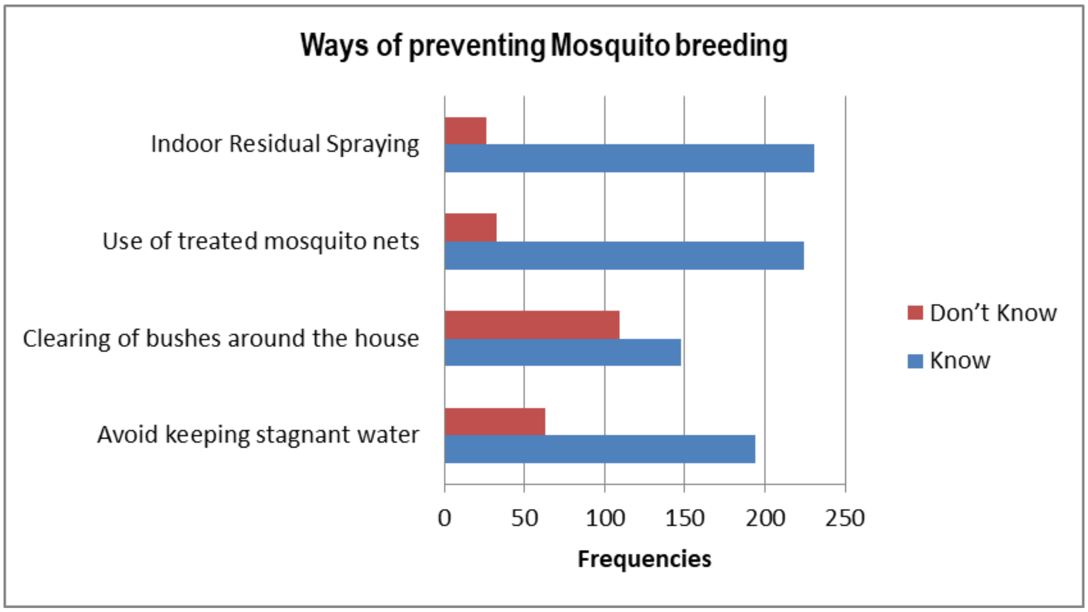

Figure 4.8: Ways of Preventing Mosquito Breeding known by respondents

(viii) Possible methods to disseminate malaria information in the Buhera district

Participants were asked to indicate the extent (strongly agree, agree, disagree, strongly disagree) to which they agree to use ICTs such as television, radio, Community Networks-Murambinda Works, mobile phones, WhatsApp, Facebook, email, or computers to disseminate malaria information. The frequencies are presented in Table 4.8 and Figure 4.9.

Table 4.8: ICTs information dissemination platforms proportion

	Television	Radio	Community Networks - Murambinda Works	Mobile Phone	WhatsApp	Facebook	Email	Computers
Strongly Agree	51.0%	59.5%	35.0%	54.5%	47.9%	35.0%	26.5%	32.7%
Agree	30.7%	23.7%	30.7%	25.7%	32.3%	31.5%	31.1%	29.6%
Disagree	10.5%	8.6%	20.2%	14.4%	9.7%	18.3%	24.9%	19.8%
Strongly Disagree	7.8%	8.2%	14.0%	5.4%	10.1%	15.2%	17.5%	17.9%

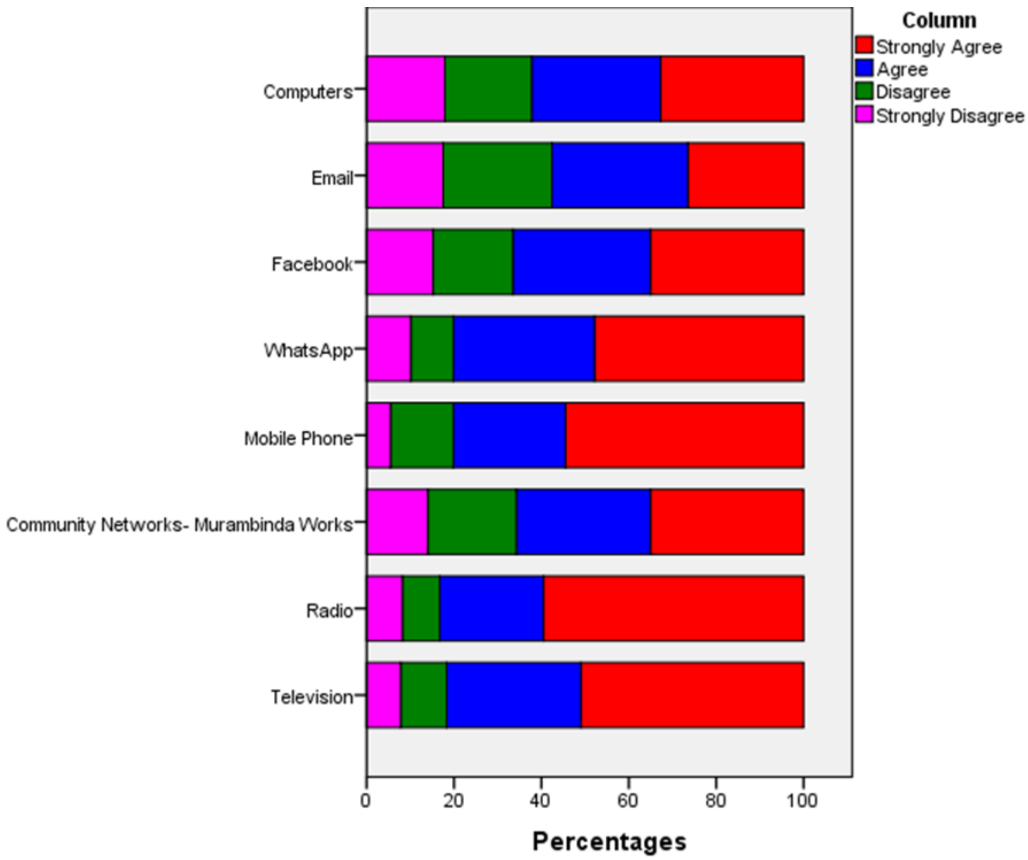

Figure 4.9: ICTs information dissemination platforms

(ix) Send or receive health information using ICTs

Participants were asked to indicate whether they send and/or receive health information using platforms such as television, radio, Community Networks - Murambinda Works, mobile phones, WhatsApp, Facebook, email, or computers in the Buhera district. Their responses were categorised in the Likert scale with the following categories; never, rarely, occasionally, frequently and always as shown in Table 4.9 and Figure 4.10.

Table 4.9: ICTs to send or receive health information proportions

	Television	Radio	Billboards	Mobile Phone	WhatsApp	Facebook	Email
Never	31.9%	21.8%	60.3%	17.9%	28.8%	52.9%	61.5%
Rarely	17.5%	14.8%	12.8%	18.3%	17.9%	15.2%	13.6%
Occasionally	19.1%	19.8%	8.9%	14.8%	17.9%	14.0%	10.5%
Frequently	15.2%	21.0%	9.7%	17.9%	15.6%	9.3%	4.7%
Always	16.3%	22.6%	8.2%	31.1%	19.8%	8.6%	9.7%

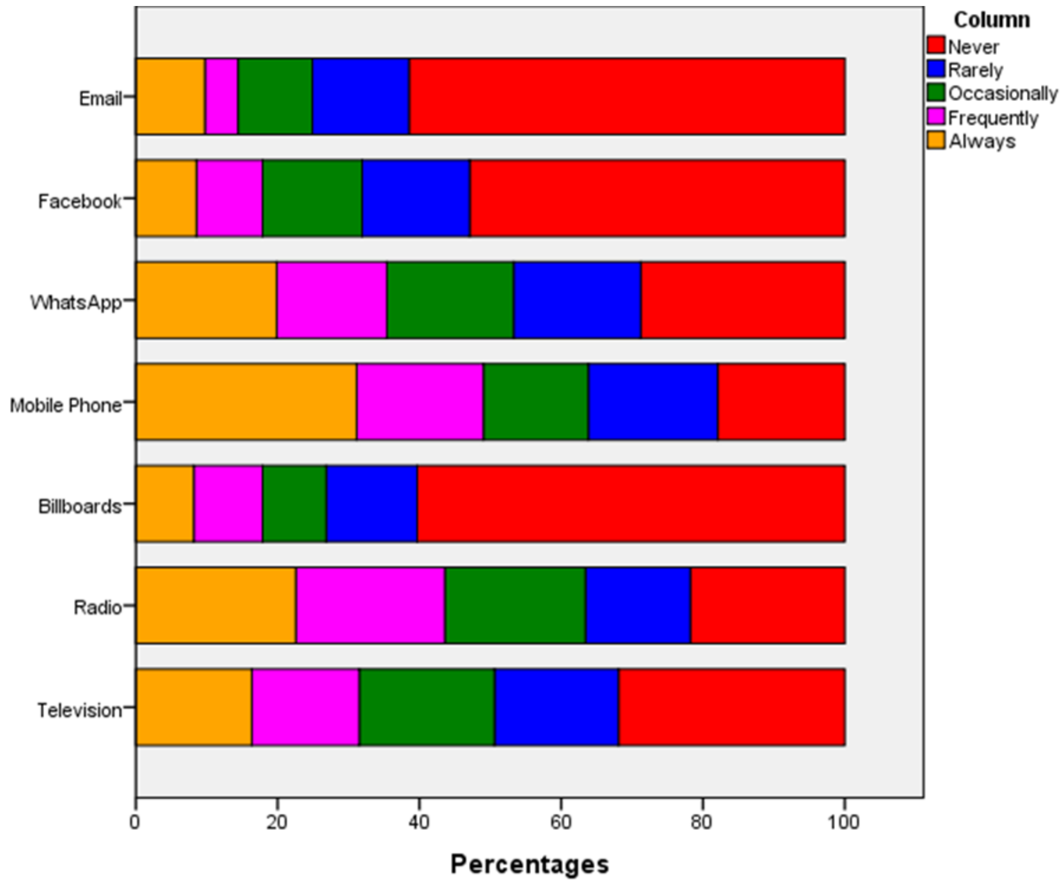

Figure 4.10: ICTs to send or receive health information

(x) Access to ICT platforms

Participants were asked how often they access television, radio, Community Networks-Murambinda Works, mobile phones, WhatsApp, Facebook, email, and computers. Their responses were grouped using a Likert scale with the following categories; never, rarely, occasionally, frequently and always as shown in Table 4.10 and Figure 4.11.

Table 4.10: Access to ICT platforms proportion

	Television	Radio	Billboards	Mobile Phone	WhatsApp	Facebook	Email	Computers	Murambinda Works
Never	17.9%	17.5%	65.8%	12.1%	23.3%	48.6%	58.8%	43.2%	49.0%
Rarely	16.3%	17.1%	12.5%	13.2%	17.5%	16.0%	17.5%	18.3%	14.0%
Occasionally	24.5%	18.7%	11.3%	15.6%	16.3%	13.6%	12.5%	16.0%	14.4%
Frequently	19.1%	17.9%	4.3%	17.5%	14.4%	10.5%	6.6%	8.9%	10.5%
Always	22.2%	28.8%	6.2%	41.6%	28.4%	11.3%	4.7%	13.6%	12.1%

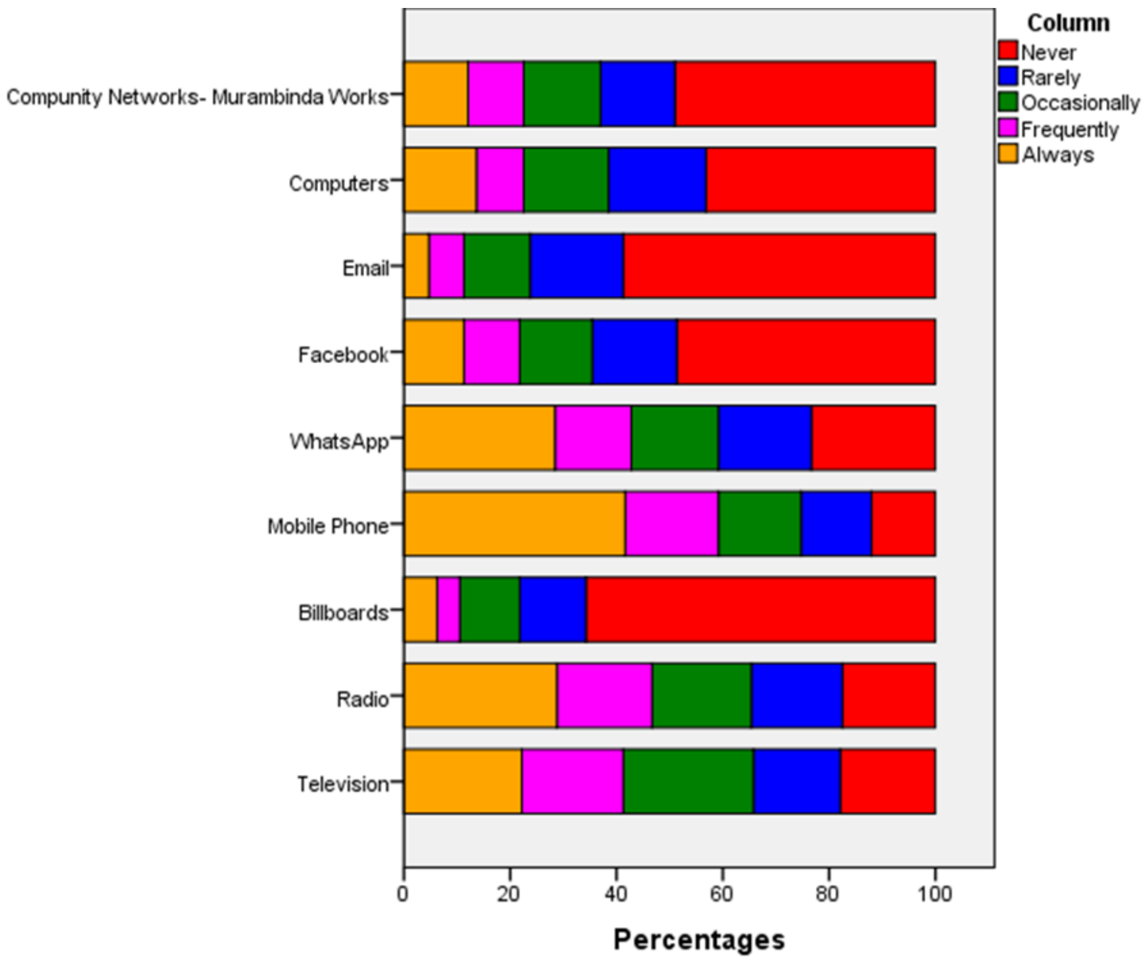

Figure 4.11: ICT platforms accessibility

(xi) ICTs for communication

Respondents from the enumerated sample were asked to indicate how often they use mentioned ICTs for communication and their responses are shown in Table 4.11 and Figure 4.12. During high malaria peak season, the national television, and radio stations create programmes and advertisements to create malaria awareness. Additionally, community health workers visit schools to create more malaria awareness. In busy roads in rural areas billboards are usually mounted in strategic areas to intensify awareness. Learners in rural areas usually walk to (and from) schools on daily basis from their parental homes, hence the need to use television, radio, and billboards to intensify awareness.

Table 4.11: ICTs for communication proportion

	Television	Radio	Billboards	Mobile Phone	WhatsApp	Facebook	Email
Never	35.4%	27.6%	79.0%	11.3%	25.3%	50.6%	62.0%
Rarely	18.3%	17.5%	7.8%	11.7%	11.7%	10.1%	13.3%
Occasionally	14.4%	14.8%	4.3%	16.3%	15.6%	15.2%	8.6%
Frequently	10.5%	17.9%	3.1%	17.9%	14.4%	8.2%	8.2%
Always	21.4%	22.2%	5.8%	42.8%	33.1%	16.0%	7.8%

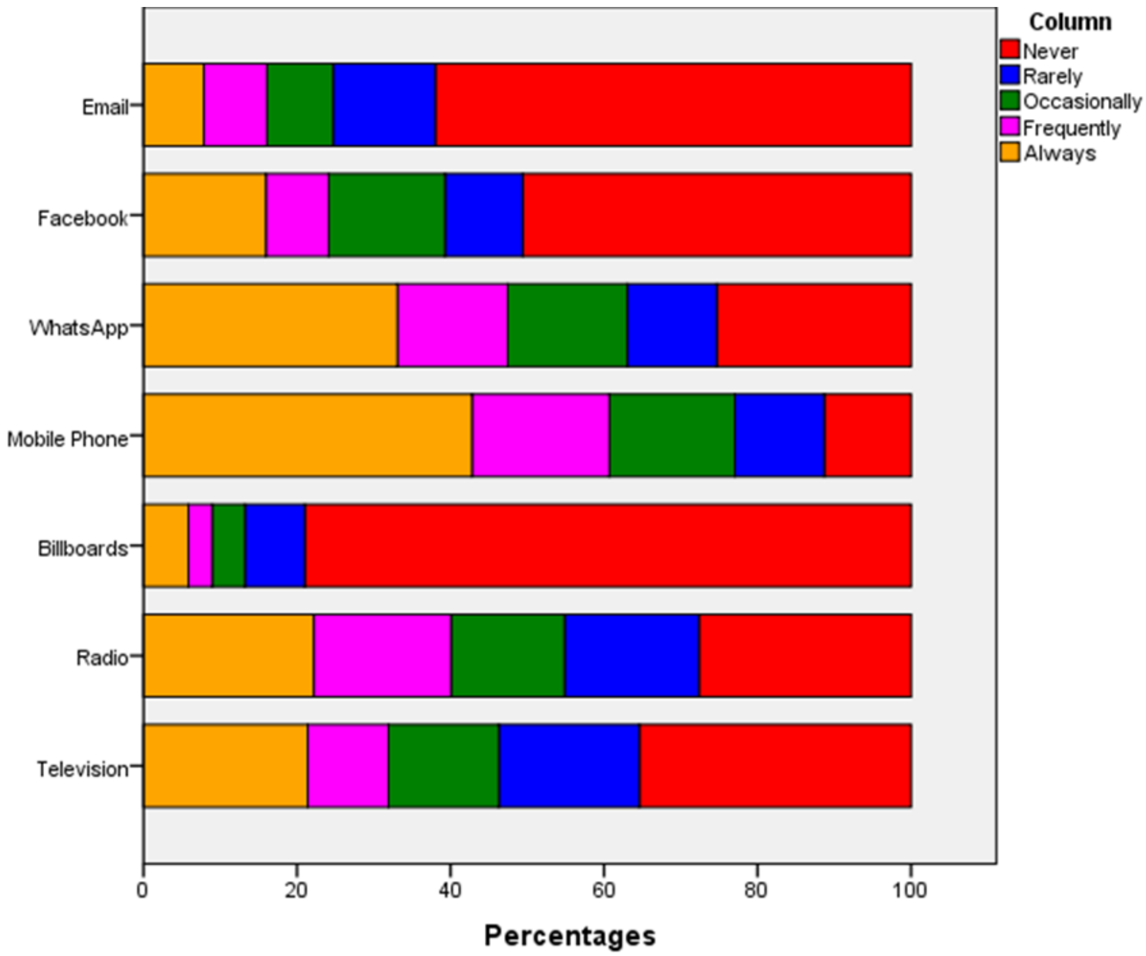

Figure 4.12: ICTs for communication

Mobile Networks usage

Figure 4.13 shows the distribution and usage of mobile networks for messaging and voice calling from the enumerated sample. From Figure 6.13, 56% (n=145) of the respondents have access to Econet Wireless line, 9% (n=23) for NetOne mobile, 22% (n=57) have Econet and NetOne lines, 5% (n=12) have access to Econet, Netone and Telecel lines, 3% (n=7) have Telecel line, 3% (n=9) do not have a mobile line.

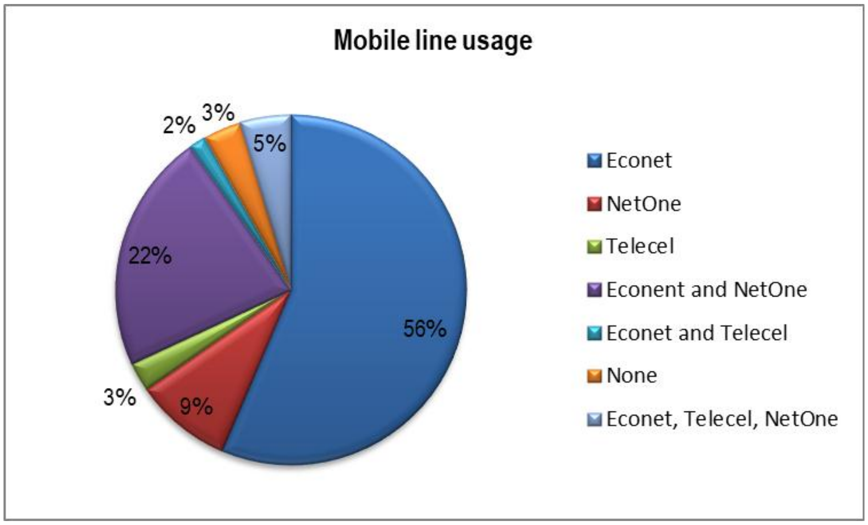

Figure 4.13: Mobile line usage

Internet Access

Respondents were asked to indicate whether they have internet access or not. Figure 4.14 shows that 44% (n=112) have internet access as compared to 56% (n=145) of the participants who do not have internet access.

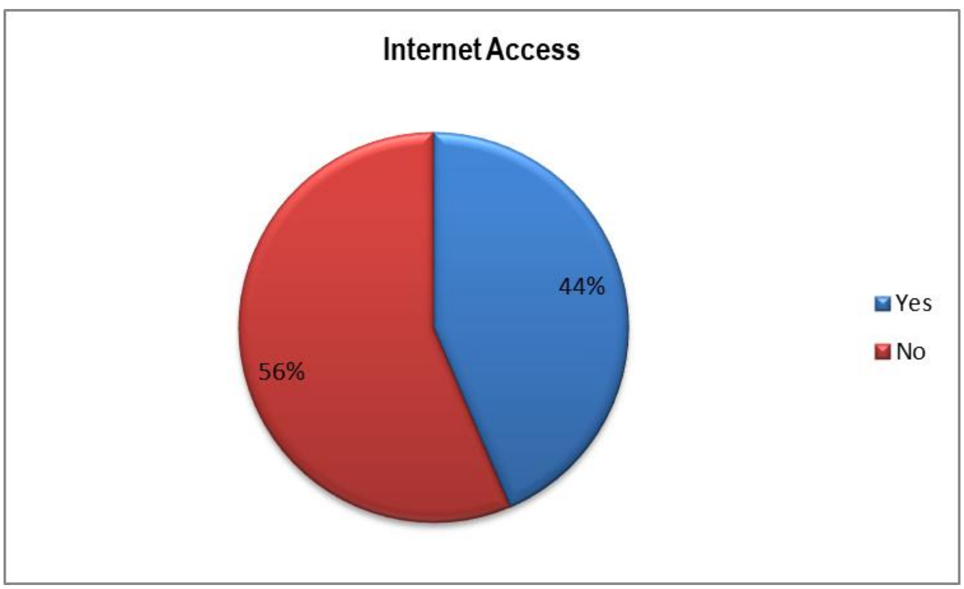

Figure 4.14: Internet access

Challenges that can hinder the use of ICTs to disseminate health information in the Buhera district

The study analysed several published literature including reports, policies, conference papers and journal articles to determine the challenges that can hinder the use of ICTs in Zimbabwe's health system (Bali, 2018; Bhochhibhoya et al., 2021; Chidawanyika et al., 2014; Chidhau et al., 2021a; Chitungo, Mhango, Mbunge, et al., 2021; Dehnavieh et al., 2019; Dimaguila, 2015a; Nhapi, 2019; Zhou et al., 2015). Later on, participants were asked to indicate whether the following challenges namely; network problems, poor access to electricity, high cost of ICT devices, unavailability of ICT devices, poor access to ICT devices, digital literacy, lack of health information written in the vernacular language, cultural issues, religious issues, use of technical language, poor health data security, lack of patients' data privacy, poor ICT policy in the health sector, and incompatibility of mobile health applications, might hinder the utilisation of ICTs to disseminate malaria information, as shown in Table 4.12 and Figure 4.15.

Table 4.12: Challenges of adopting ICTs in Buhera rural health systems

	Strongly Agree	Agree	Disagree	Strongly Disagree
Network problems	50.0%	35.9%	7.5%	6.6%
Poor access to electricity	50.8%	35.9%	7.0%	6.3%
High cost of ICT devices	60.4%	26.3%	9.0%	4.3%
Unavailability of ICT devices	46.2%	27.7%	19.0%	7.1%
Poor access to ICT devices	40.4%	34.5%	16.9%	8.2%
Digital literacy	28.7%	26.4%	26.4%	18.5%
Lack of health information written in vernacular language	26.6%	21.1%	31.2%	21.1%
Cultural Issues	17.6%	12.1%	36.3%	34.0%
Religious issues	14.8%	11.3%	34.4%	39.5%
Use of technical language	22.7%	21.9%	30.1%	25.4%

Poor Health Data Security	23.4%	32.8%	25.8%	18.0%
Lack of Patients Data Privacy	27.0%	23.8%	30.9%	18.4%
Poor ICT policy in the health sector	33.2%	26.6%	21.1%	19.1%
Incompatibility of Mobile Health Applications	35.2%	23.4%	23.4%	18.0%

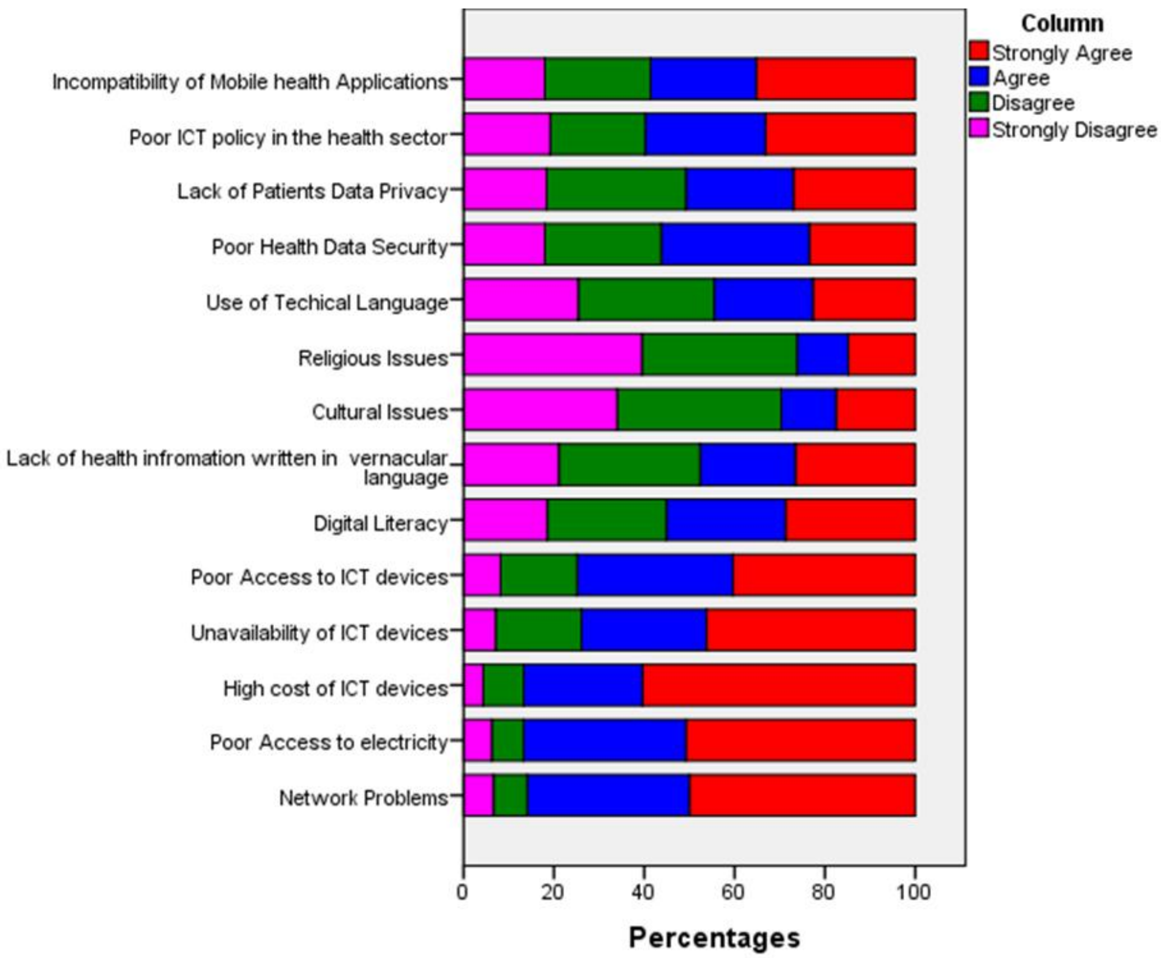

Figure 4.15: Challenges of adopting ICTs in Buhera rural health systems

The study revealed that network problems (coverage and intermittent signals), the high cost of ICT devices, and poor access to electricity and ICT devices significantly affect the adoption of ICTs in Buhera rural health systems. For instance, people who rely on television and radio to disseminate malaria information might be affected by poor access to electricity more rather than those who use mobile phones. Even though mobile phones require electricity to recharge, solar energy can be used as an alternative for battery charging. The study also revealed that cultural and religious practices have less effect in preventing the adoption of ICTs to disseminate health information in the rural community. However, digital literacy, lack of ICT policy, incompatible mobile health applications, and lack of health data security and privacy also influence the adoption of ICTs in Buhera rural community.

4.11 Malaria prediction models performance results

This section presents the results of malaria prediction models. Since the study sought to predict malaria outbreaks, which is a classification problem, the study used machine learning classification performance metrics to assess the performance of prediction models, as shown in Table 4.13.

Table 4.13: Summary of performance evaluation metrics of malaria prediction models

Malaria prediction model	**Accuracy**	**Precision**	**Recall**	**F1-score**
Logistic regression	0.83	0.82	1.00	0.90
Support vector machines	0.77	0.78	1.00	0.88
Decision tree	0.66	0.79	0.79	0.79
Random forest classifier	0.83	0.87	0.93	0.90

This study shows that machine learning models are increasingly becoming indispensable tools for predicting malaria and assisting in decision-making at the ward level. The results of the four machine learning models namely, logistic regression, support vector machine, decision tree and random forest classifier to predict malaria are shown in Table 4.13. Logistic regression and random forest classifier both achieved 83% prediction accuracy. These are the best models and they both achieved the highest number of correctly predicted values. However, the random forest classifier achieved 87% precision outperforming other machine learning classifiers. The study revealed that the decision tree had the worst performance with a prediction accuracy of 66%, a precision of 79%, a recall of 79% and an F1-score of 79% as compared to other machine learning classifiers. These metrics are equally important in determining the performance of machine learning models because they are calculated from the confusion matrix based on the true positive, false positive, true negative and false negative (Uddin et al., 2019). However, machine learning-based malaria prediction models can aid decision-makers in effectively allocating resources such as human, financial, and physical (vehicles and amount of ITNs,), intervention policy and optimise the distribution and deployment of indoor residual spraying teams and spray equipment by giving more priority to high sporadic wards such as Birchenough Bridge and Chapanduka. Predicting malaria at the ward level can also assist policymakers to expedite the development of early warning systems to monitor the spread of malaria and subsequently strengthen malaria prevention and control measures.

4.12 Common digital tools for disseminating health information

In addition, the literature review was also used to understand digital tools that have been used to disseminate health information and factors that contributed to the failure of past interventions that were previously adopted to disseminate information in rural communities. The findings of the literature analyses are shown in Table 4.14

Table 4. 14: Digital tools for disseminating health information in Zimbabwe

Reference	mHealth App	Participants	Technology	Purpose	Limitations/challenges
(Marufu & Maboe, 2017a)	Mobile phones	48 medical doctors (Cross-sectional study)	Mobile technology	Patient identification and treatment activities	• Lack of knowledge and unawareness in using mHealth to support chronically ill patients. • Lacked documentation on the mHealth projects previously. • The use of mobile phones by medical doctors is relatively unknown. • Low acceptance of mHealth by end users and healthcare providers

(N. Kumar et al., 2015)	Mobile Women and Child Health (WaCH)/ODK diagnostic	Five clinics and hospitals	Bidirectional SMS messaging platform	Communication between pregnant women and a clinic nurse	• Community engagement was difficult. • Lack of digital devices
(Makacha & Makanga, 2021)	Mapping Outcomes for Mothers (MOM) and RoadMApp	Not specified	Mobile application	Enhancing maternal health outcomes in areas with limited resources	Geo-enabled mHealth solutions' acceptance, clinical applicability, and accessibility have not yet influenced health policy.
(Dabengwa et al., 2022b)	RoadMApp	84 participants	Mobile application	Improve birth preparedness and complications readiness	Savings are not always available for institutional childbirth, transport problems and donor dependency
(Gadkaree et al., 2019a)	SMS notification platform	57 patients	SMS	Patient enrollment for cleft lip-palate surgery	• Survey data were collected only from patients who underwent surgery. • lack of infrastructure or transportation
(Dambi et al., 2022)	*Inuka* and WhatsApp	176 participants	Mobile Application and chat application	Digital Mental Health Intervention for increasing health care coverage	Loss of follow-up in the *Inuka* intervention arm and nonattendance of participants.
(Nyati-Jokomo et al., 2020b)	RoadMApp	193 participants	Mobile Application	Improve maternal health delivery in a low-resource setting	Lack of electricity, poor road network, poor phone network, and the high cost of transport
(Nyapwere et al., 2021a)	RoadMApp	49 health facilities	Mobile application	Lessens the detrimental consequences of pregnant women travelling a long distance to health facilities	Several rural areas lack basic infrastructure for cell phones, electricity, and transportation.
(Maphosa, 2022a)	Drug Information App	206 participants	Mobile application	Delivering drug information to rural communities	Limited public awareness about mobile health apps.
(Tran et al., 2022)	REDCap	26,904 males	Web-based application	Improve data quality among roving nurses in routine male circumcision.	Rolling out of the application was interrupted by COVID-19. Data inconsistency was reported.
(Dimaguila, 2015b)	SMS for Life	Not specified	SMS platform	Improve access to information	The outage of battery power for mobile phones
(Maphosa et al., 2020)	WhatsApp	200 students	Social media platform	Lecture delivery during the COVID-19 lockdown	Short battery life, small screens, data bundles constraints and limited input capability were noted

(Maphosa, 2022b)	mHealth app	30 health workers	Mobile Application	Promoting access to COVID-19 Information	The small sample was used for usability testing. rural communities with no Wi-Fi access affect the rolling out of the application. Network challenges due to intermittent power and load shedding
(Furusa & Coleman, 2018)	e-Health	20 medical doctors	e-health application	Improving access to healthcare services	Lack of e-health policies that support the integration of mobile health apps.
(Chidhau et al., 2021b)	SMS, mobile apps,	Not specified	Digital Health Interventions	Curbing COVID-19	Corruption, lack of funding, shortage of qualified workforce and medical expertise, and weak healthcare infrastructure
(Dhakwa et al., 2021a)	SMS reminders	8,800 adolescent girls and young women	SMS platform	Improving Access to Adolescents' Sexual and Reproductive Health Services	Limited instant feedback from the participants,
(Feldacker et al., 2020)	Two-way texting	362 male adults	SMS platform	Follow-up for voluntary medical male circumcision	Financial challenges, phone theft, damage, and change of phone numbers.
(Marongwe et al., 2022b)	Two-way texting	17417 men	SMS-based telehealth	Male circumcision follow-up	Rural network coverage, inaccessible roads, provider hesitancy, and the slow pace of MC guideline changes.
(Le Bel et al., 2014)	FrontlineSMS	60 participants	SMS platform	Early warning network for human-wildlife conflicts mitigation	IT problems are linked to the use of commercial 3G USB modems.
(Maphosa, 2020)	MyLSU app	220 participants	Mobile application	Enhance student engagement and promote a smart town	The sample size used to evaluate the app was relatively small, which affects the generalizability of the results
(Bello et al., 2021)	Web mapping application	Not specified	ArcMap and ArcGIS Web mapping application	Support active COVID-19 case search	Internet unavailability ins some areas, cost of data bundles, and outage of battery power for the tablets in the field.

Table 4.14 shows that several digital tools such as short message services (SMS), mobile applications, and web-based applications have been used to disseminate health information. The tools provide different health services including sending reminders, making appointments, improving access to care, and monitoring treatment adherence and activities among others. From the literature review, the study established that:

- None of the ICT-based malaria interventions was specifically developed and deployed to disseminate malaria information in the district other than radio, social media and television.
- SMS technology, mobile application development platforms and social media platforms were used to develop digital health interventions in Zimbabwe.
- Poor internet access and network coverage, intermittent network signal, inconsistent power supply, insufficient funding, lack of active mobile health or e-health policy, language barrier, lack of knowledge and digital skills, weak health systems, the outbreak of diseases, religion and culture, disparities in access to care, lack of computing devices, corruption and theft of mobile phones are some of the challenges that deter the adoption of mobile health technologies in Zimbabwe.
- The involvement and engagement of potential users in the development of the interventions influence their adoption.

4.13 Summary of the Chapter

This chapter focuses on the presentation of qualitative data from the qualitative questionnaire, and quantitative data from the survey questionnaires. In addition, this chapter also presents the performance of machine learning models to predict malaria in Buhera rural communities using confirmed malaria cases and environmental risk factors. Thus, machine learning can assist in predicting malaria with high precision using a dataset that would ordinarily present challenges with manual computations. This can also assist policymakers to expedite the development of early warning systems to monitor the spread of malaria and subsequently strengthen malaria prevention and control measures. In addition, malaria prediction models help to plan, organise, expeditiously allocate resources and operationalise malaria control and vector management giving priority to the predicted high malarial zones. However, despite the important application of machine learning models in predicting malaria in endemic areas, the adoption and implementation of ML to alleviate malaria are still nascent in many sub-Saharan African nations. The next chapter provides detailed steps followed in the development of the prototype.

CHAPTER 5: PROTOTYPE DESIGN AND DEVELOPMENT

5.1 Introduction

The previous chapter outlined the results of the pre-test phase. This chapter focuses on the conceptual and architectural design of the ICT-based malaria intervention prototype called the malaria mobile app to disseminate health information. The design of the system follows the design science research approach principles.

5.2 The research in accordance with Design Science Research (DSR)

The following sections provide detailed DSR steps followed when designing and developing the prototype.

5.2.1 Requirements gathering

Requirements gathering is a systematic way of collecting user requirements and specifications from the end-users involved in the system development (Sommerville, 2005). This study used a survey qualitative (see Appendix 5a and Appendix 5b) and a quantitative questionnaire (see Appendix 4a and Appendix 4b) to collect user requirements from the research participants in Category A and Category B, respectively. The qualitative questionnaire helped to get an overall understanding of what stakeholders have been doing and to predict how they interact with the proposed malaria digital intervention and to elicit the challenges encountered and associated with current platforms used to create malaria awareness in resource-constrained rural communities. The research used the survey questionnaire (Appendix 4a and Appendix 4b) used to collect quantitative data from participants in Category B to determine the most feasible digital technology. These two requirements' elicitation techniques complement each other in the data-gathering process and development of the prototype.

To model users' possible interactions and prototype functionalities, the study applied the use case diagrams as per software engineering principles (Sommerville, 2008) for functional requirements modelling. Use case diagrams are graphical illustrations used to capture the requirements and interactions with the user of the system to be built (Shaari et al., 2007). Use case diagrams were first used by Jacobson's object-oriented requirements discovery to identify actors involved in an interaction and name the type of interaction (Elallaoui et al., 2018). Additional information is provided to describe the interactions between actors and the system. Descriptions of interactions might be in the form of textual information. Therefore, the use case provides a high-level description of possible interactions that depict prototype requirements.

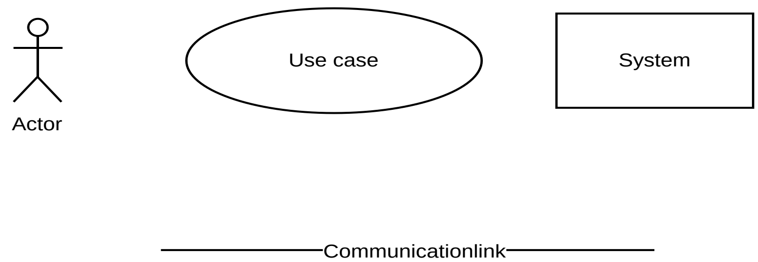

Figure 5.1: Use Case Diagram Key

As shown in Fig 5.1, an actor in the process represents system stakeholders namely, health workers and people living in Buhera rural district, with their respective interactions and use cases, as shown in Figure 5.2. Each class of interaction is represented as a named ellipse and lines link the actors with the interaction. Use cases identify the interactions between the system and its users (Sommerville & Sawyer, 1997).

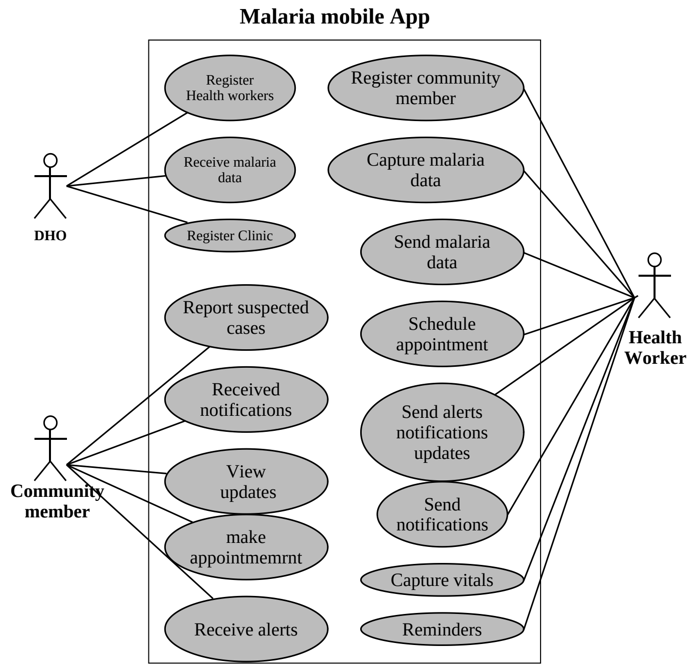

Figure 5.2: Malaria mobile app use case diagram

Figure 5.2 shows stakeholders denoted by actors and their respective associations. Stakeholders of the proposed prototype involve health workers, district health officers and community members. The schematic interactions of health workers, district health officers (DHO) and community members with the proposed prototype are shown in Figure 5.3 below.

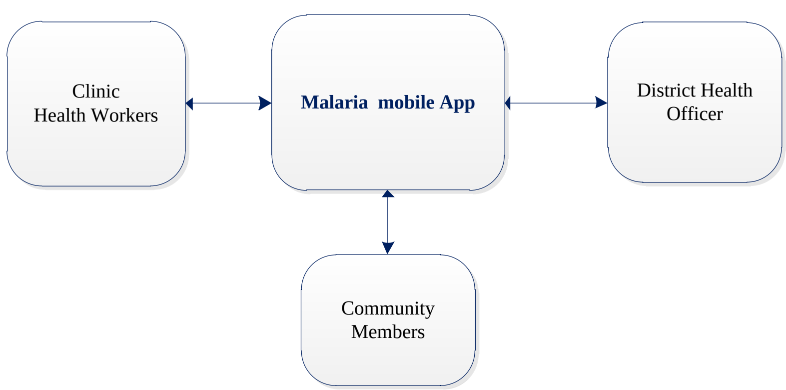

Figure 5.3: Malaria mobile application schematic presentation

Health workers

This involves all health workers that can interact with the malaria mobile application to provide malaria health services to the community. This includes nurses and community health workers working in satellite health centres that report directly to the referral hospital. To improve malaria data quality while avoiding malaria data inconsistencies highlighted by Hannah et al.(2019) and Eyesan & Okuboyejo (2013), the proposed prototype allows health workers to capture and report malaria data in real-time. Such data can be assessed by the district health officer pending consolidation and validation. When capturing malaria data, the health worker captures the patient's name (see Figure 5.5), surname, area, mobile number, date of birth, and national identification number. The mobile number is used to send malaria alerts, and notifications, and do follow-ups. To access these services shown in Figure 5.4, health workers login into the system using their username and password. Upon validation, the health workers can perform several activities as shown in Figure 5.3.

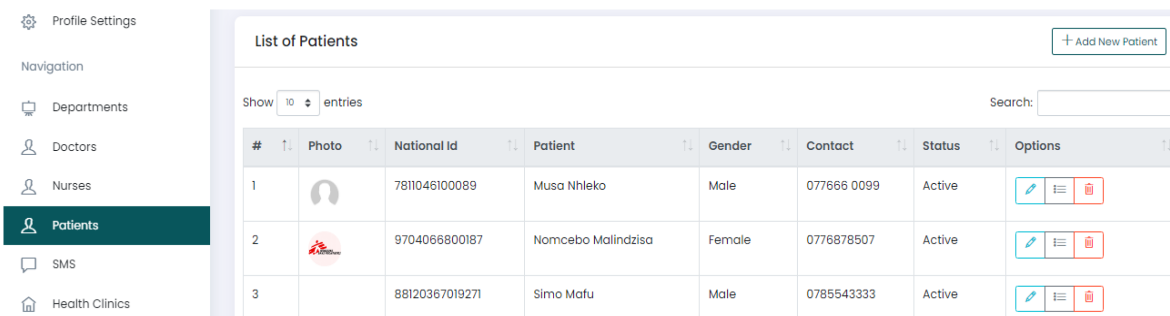

Figure 5.4: Health workers' panel

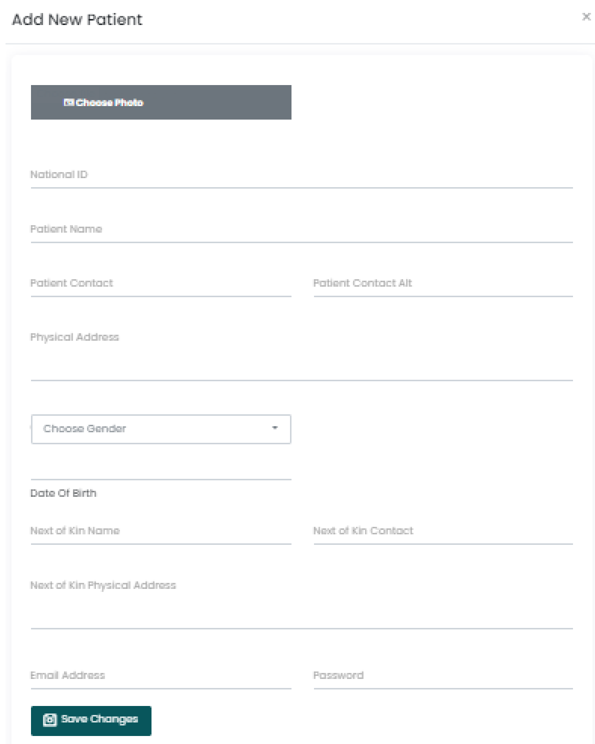

Figure 5.5: Add new patients.

District Health Officer

The responsibilities of the district health information officer are to receive malaria data such as incidences and deaths from satellite health centres (clinics) in real-time. Before capturing such data into DHIS2, the DHO should validate it with malaria incidences captured in T5 forms to improve data quality to avoid data inconsistency when accessed at the provincial level. The DHO can send updates to health workers stationed in satellite health centres. The DHO can also view reports of malaria incidences per health satellite clinics. In addition, DHO can act as the system administrator meaning he/she also register health centres, and health workers and de-activate their roles in the system, as shown in Figure 5.6 and 5.7.

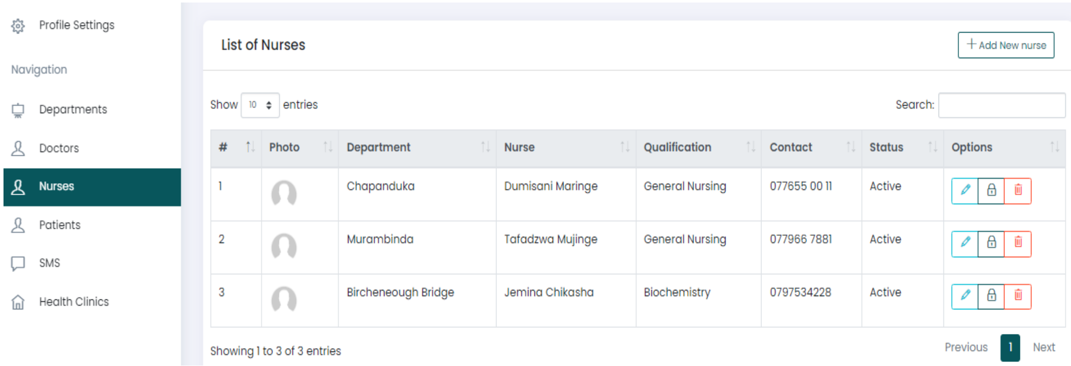

Figure 5.6: District Health Officer panel

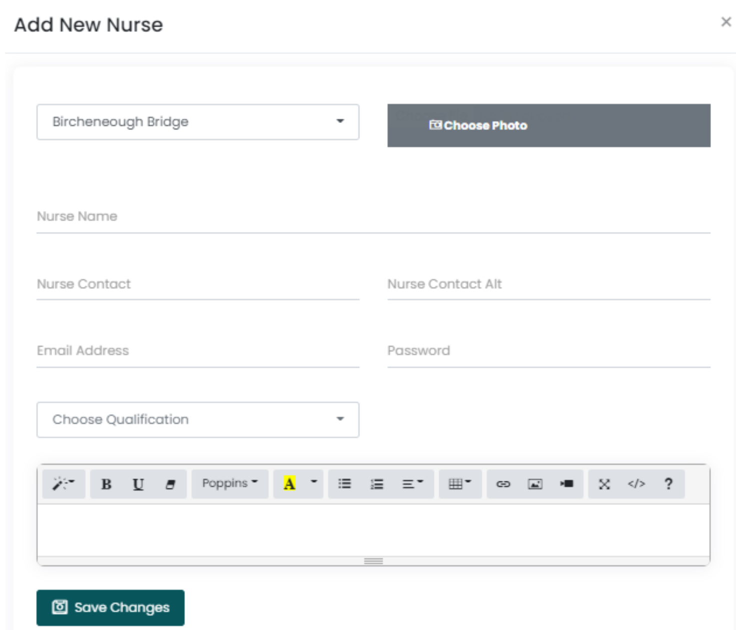

Figure 5.7: Add a new nurse.

Community

This involves people living around the health centres that might need malaria healthcare services. Such people can make appointments, report malaria, and receive malaria updates, notifications and alerts. These services can be accessed using SMS services and a web-based application connected to Twilio REST API. Twilio application programme interface (API) allows users to query meta-data to and from a mobile phone using voice calls, text messages, and recordings (Eyesan & Okuboyejo, 2013). Twilio can convert text to speech and play audio files, record calls, and store them. Therefore, community members receive malaria alerts and updates using text messages (SMS) sent by health workers stationed at a certain clinic, as shown in Figure 5.8.

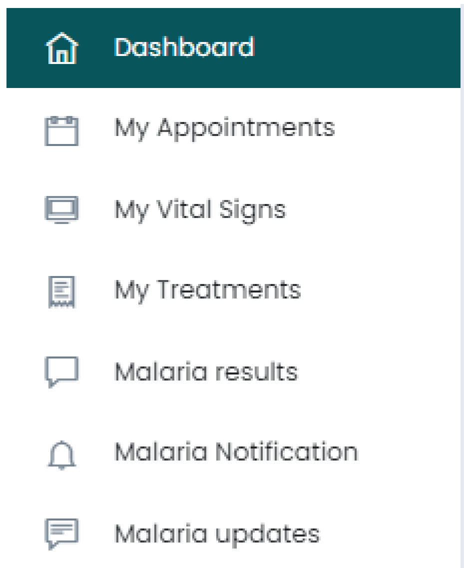

Figure 5.8: Community's Panel

SMS services have been greatly used to improve access to care especially for the underserved populations in rural areas because the cost of providing services is relatively affordable (Sowon et al., 2022).

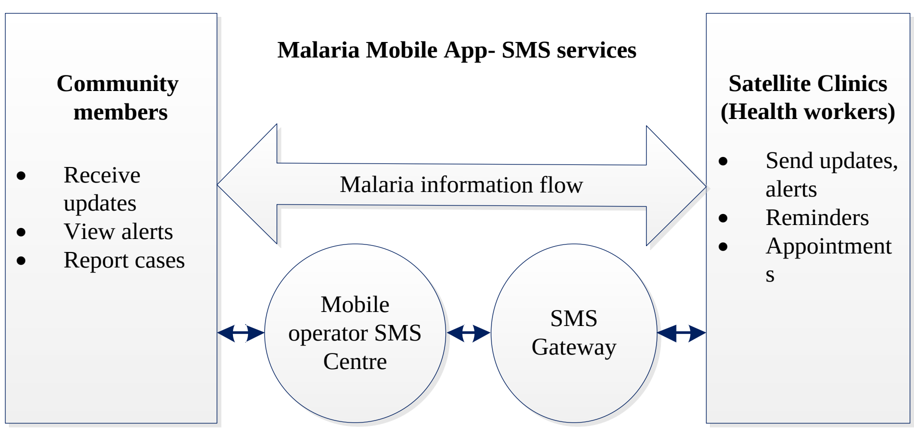

Figure 5.9: Schematic structure of SMS services

Thus, health workers working at a clinic (at the ward level) can create, update, and manage clients' malaria data and messages for future reference. Malaria messages such as alerts, reminders and notifications are sent to the registered community members.

Messages are sent to the community members in form of a Hypertext Transfer Protocol (HTTP) query from the malaria mobile application to the SMS gateway, see Figure 5.9. This study used a subscription-based online SMS gateway platform called Twilio which converts HTTP messages into short message service centre format of the local mobile operators (such as Econet, Telecel or NetOne). The short message service centre then forwards the text message to the community member's mobile phone number. The community members with smartphones can similarly log in and acknowledge the messages (see Figure 5.10) and access other services such as updating profile data among others.

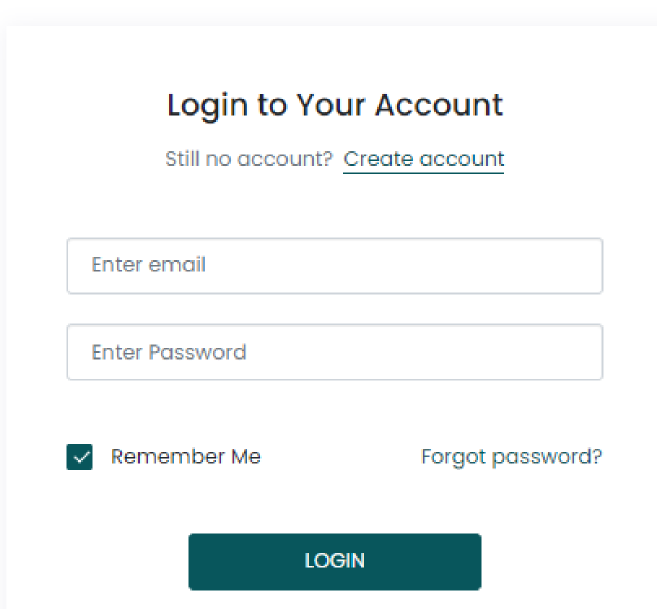

Figure 5. 10: User authentication panel

However, sending messages using feature phones (from community members) to health workers using Twilio SMS gateways was not explored (to avoid misuse of SMS) but rather zero-rating clinic's mobile number to receive SMS for reporting malaria should be considered in the future. Also, due to high SMS gateway cost implications, local mobile network operators’ SMS gateway was not explored, hence the utilisation of Twilio SMS gateway.

5.2.2 Malaria mobile application architectural design

The architectural design of the proposed malaria mobile application is shown in Figure 5.11. The artefact supports bilateral communication between the community and health workers. The artefact is divided into two sections: the client side and the server side. On the client side, stakeholders interact with the system through a responsive user interface based on the dimensions of the computing device. The prototype supports a web-based application integrated with Twilio REST API. The SMS module caters for community members that use feature phones to disseminate information. Feature phones are connected to the server using a global system for mobile communication (GSM) technology to access SMS services. Smartphones can send and receive information using SMSs or a web-based platform. If stakeholders use the mobile web-based application, then data is sent and received via the internet to the data controller or short messaging system gateway that further propagates messages to the database located on the server side. The database contains satellite health facilities in Buhera rural districts, mobile numbers and malaria data.

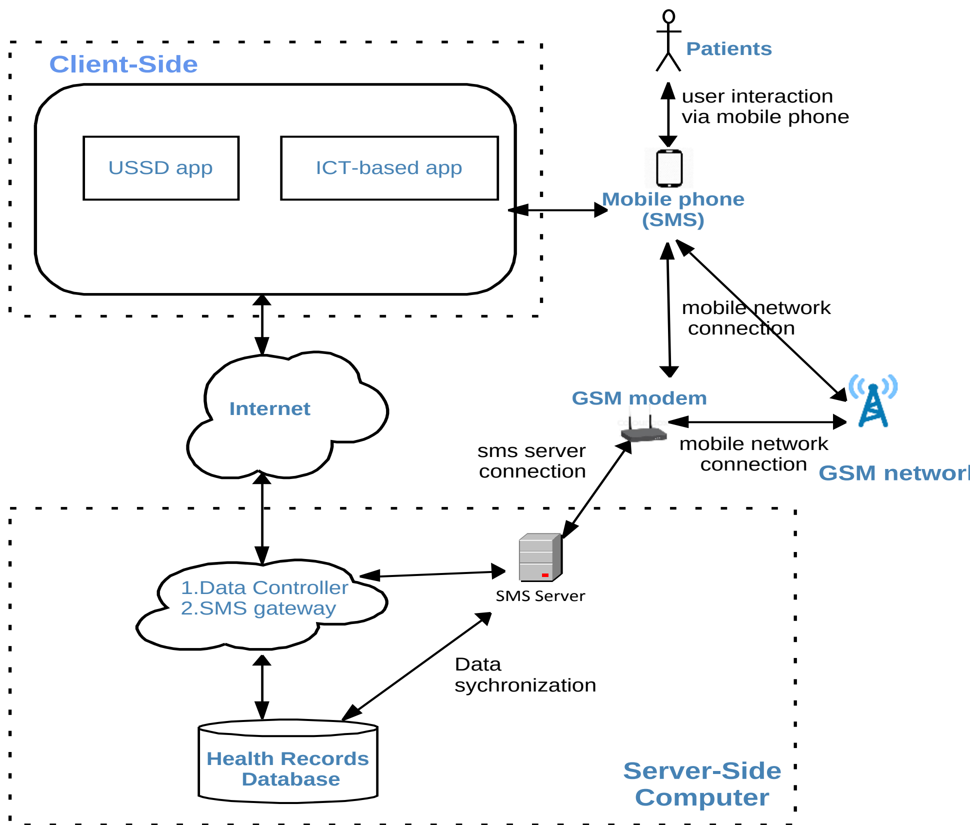

Figure 5. 11: Prototype design

The development phase of the proposed prototype follows the principles of evolutionary prototyping. The evolutionary prototype supports the use of requirements gathered during the requirements elicitation phase to develop a prototype where the initial prototype is improved iteratively based on the user's feedback until an acceptable version is obtained. Based on the principles of evolutionary prototyping, the prototype was initially divided into modules that were further subdivided into units to speed up the development of the initial prototype. To get feedback from end-users during regular testing, the study adopted an iterative development approach (Ngabo et al., 2012). Therefore, feedback from participants was incrementally incorporated into the prototype as per design science principles. The initial prototype was tested by key informants in satellite centres to improve prototype functionalities. Initial comments from the participants were subsequently added to the improved prototype, with additional functionality and improvements until the final prototype emerges throughout the system development life cycle. This was an iterative process performed until the final version was completed.

5.2.3 Prototype database design

The database was designed after several consultations with some key informants in the Buhera rural district. Key informants were consulted to understand how health-related data is captured and the sequential flow of the prototype. Based on policies, security, privacy and other ethical issues, dummy data was captured to protect the identities of participants during the developing stage. Individuals' data captured by the prototype was provided based on voluntary participation in designing, developing, and testing the prototype. The database stores data such as reported malaria suspected cases, health facility information, health workers' details and messages. Health workers consist of caregivers, doctors and nurses who provide care and have direct access to patients' health information, as shown in Figure 5.12. Health facilities involved centres of care, where community members get access to care. The database contains individuals' data such as contact details, area, and closest health centre. The prototype used dummy client data as advised by the key informants due to security and privacy issues beyond the researcher's control. However, data from health centres in every ward were captured to help health professionals further analyse malaria data based on the facility's geographical location. This can also assist to track reported malaria incidences. Also, the database stores malaria message communication between health workers and community members for further analysis. In addition, the database also stores information about health professionals such as name, speciality, contact details, roles, health facility and access level. The role and access level were used to define the privileges of healthcare professionals.

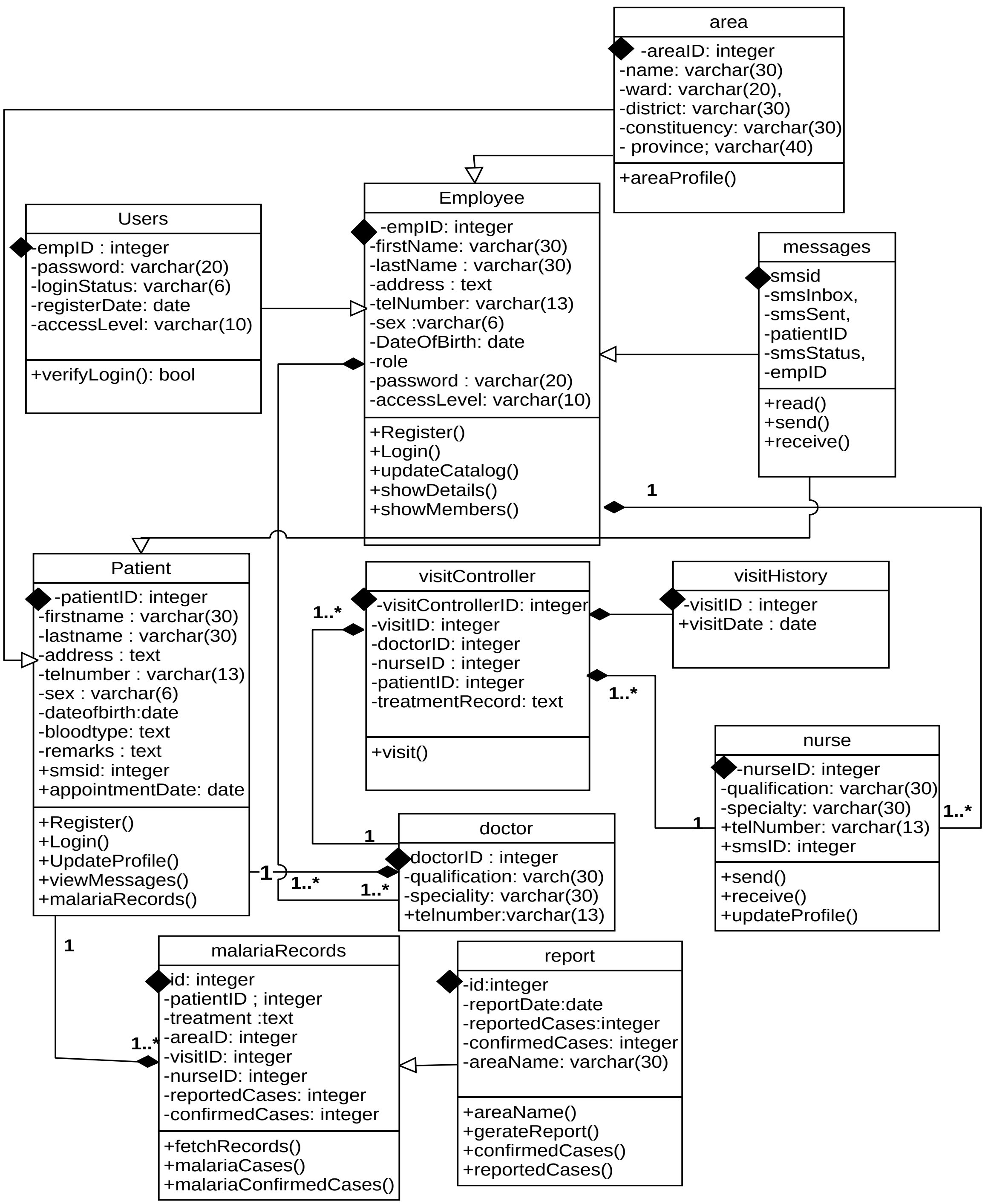

Figure 5.12: Prototype Database Design

After the successful development, the final prototype was deployed to the target population for evaluation. After the final version, prototype execution results were analysed by the researcher to check whether they conformed to the user requirements. This was done by consulting participants during the evaluation stage. The next subsection illustrates how the prototype was deployed and evaluated.

5.2.4 ICT intervention prototype development phase

The development phase of an ICT intervention prototype follows artefact development guidelines and principles of evolutionary prototyping. An evolutionary prototype supports the use of requirements gathered during the requirements elicitation phase to develop a prototype (Carter et al., 2001). The research implements a bottom-up approach whereby a system is divided into modules (DHO, community member and health worker) that are further subdivided into units. In Figure 5.13, each unit of the prototype was developed separately and later integrated into modules. Feedback from participants was incrementally incorporated into the prototype during the development phase. In support of this, (Berg et al., 2018) state that evolutionary prototyping allows initial feedback from the participants to be subsequently added into the system unit, each with additional functionality and improvements until the final prototype emerges throughout the system development life cycle. After completion of each unit, execution results were analysed by the researcher to check whether they conform to the requirements.

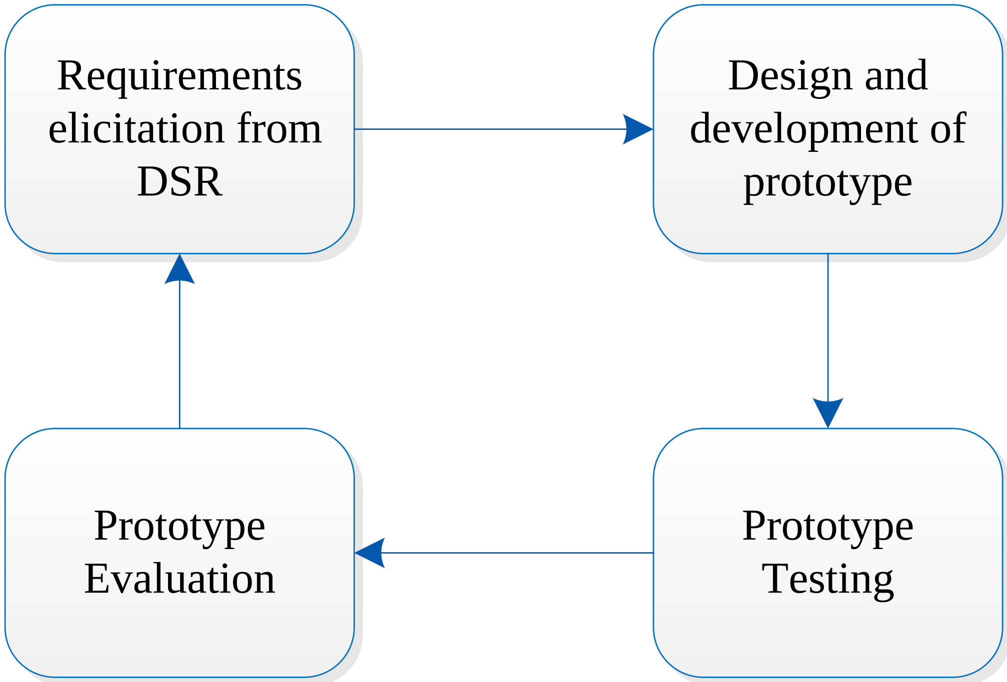

Figure 5. 13: Prototyping method

5.3 Chapter Summary

The proposed prototype adopted two technologies underlying mobile health applications, the web-based application integrated with Twilio API to provide SMS services to community members with feature phones. These technologies complement each other in coming up with a feasible digital platform to create malaria awareness in resource-constrained rural communities. The next chapter focuses on the modified UTAUT model used to evaluate and assess the adoption of the prototype.

CHAPTER 6: PROTOTYPE EVALUATION AND ADOPTION

6.1 Introduction

The previous chapter outlined the conceptual design and prototype development processes adopted by the study. The purpose of this chapter is to explicitly explain the evaluation framework guiding the exploration of views, attitudes and perceptions of healthcare professionals towards the use of the prototype to disseminate malaria information in the rural community. The prototype was tested and evaluated by the participants throughout the development phase as per design science principles. However, the overall evaluation of the prototype was done during the post-test phase of the quasi-experiment guided by a modified UTAUT model in Phase 2. To test the prototype, the study used online survey questionnaires (different from the survey questionnaire used in Phase 1) to explore the adoption of the prototype by healthcare professionals to disseminate malaria information. The modified unified theory of acceptance and use of technology (UTAUT) constructs were used to evaluate and assess the adoption of the proposed ICT-based malaria intervention by healthcare professionals to disseminate malaria information in the rural community.

6.2 Theoretical background of technology acceptance

Technology acceptance and adoption behaviour is paramount in electronic health services since the advent of Information and Communication Technologies (ICTs) in healthcare. Many theories and models have been developed to understand the technological behaviour of healthcare professionals, as it plays a critical role in technology acceptance and adoption in facilitating health services delivery through technology. However, some scholars including Debon et al. (2019), Dwivedi et al. (2020) and Lee et al. (2017) argue that mobile health applications experience a low adoption rate due to factors such as low usage rates, resistance, and abandonment, which in some extreme circumstances lead to rejection and a search for alternative methods. Thus, the successful utilisation of mobile health technologies highly depends on the level of user acceptance and adoption (S. Kim et al., 2015). Therefore, to understand the substantial effects of a low adoption rate, the views, attitudes, and opinions of end-users including healthcare professionals, patients and other important stakeholders should be thoroughly considered, as well as factors influencing the adoption and utilisation of mobile health technologies in vulnerable rural communities. Some notable technology acceptance and adoption theories and models have been developed to understand the behaviour of patients, healthcare professionals and other players across health domains. Such theories and models include the Theory of Reasoned Action (TRA) (Harst et al., 2019), the Diffusion of Innovation (DOI) (Kesse-Tachi et al., 2019), the Unified Theory of Acceptance and Use of Technology, the Theory of Planned Behaviour (TPB), and the Technology Acceptance Model (TAM) (Rahimi et al., 2018). The dilemma of selecting the appropriate theoretical framework to assess technology acceptance and use of technology still exists especially in healthcare (Dwivedi et al., 2020). However, Sitar-Tăut (2021a) highlighted that the Unified Theory of Acceptance and Use of Technology is a solid framework that has been successfully applied in various health systems to access technology acceptance, adoption and utilisation. Therefore, this study adopted the UTAUT model to develop constructs of the modified UTAUT and modelling predictors for adoption, acceptance, and utilisation of low-cost malaria digital intervention in vulnerable rural communities.

6.3 The unified theory of acceptance and use of technology Theoretical Background

The unified theory of acceptance and use of technology is an extension of the Technology Acceptance Model (TAM), a widely recognised model which explains the intention to use technology (De Veer et al., 2015). TAM is based on concepts from social psychology as it defines and tests the intentions of individual end-users to use new technology (Shiferaw & Mehari, 2019). TAM was developed from the Theory of Reasoned Action, focusing on the attitudinal explanation of the intention to use a specific technology. UTAUT is an assessment tool for technology acceptance as well as the intention to use and actual use of technology (Venkatesh et al., 2003). Generally, UTAUT relies on four exogenous variables – performance expectancy (PE), effort expectancy (EE), facilitating conditions (FC) and social influence (SI). These influence health workers' behavioural intention (BI) to use technology. However, due to COVID-19, new challenges have emerged such as delayed indoor residual spraying activities, long-lasting treated nets (LLINs), utilisation of artemisinin-based combination therapy (ACT), procurement of medical equipment and social distancing. Such challenges affect malaria control programmes which led to malaria outbreaks in some areas. To alleviate the catastrophic impact of these challenges, mobile phone-based interventions have been utilised to strengthen awareness campaigns while maintaining social distancing regulations. Some researchers believe that technology adoption in such circumstances and attitude towards the available technological infrastructure can influence health workers' BI to use malaria mobile phone-based applications. Therefore, the following subsection explains hypotheses developed through the modified UTAUT model for the potential adoption of mobile phone-based malaria applications in vulnerable rural communities.

A. Performance expectancy (PE)

According to Ladan et al. (2018), PE is defined as "*the degree to which an individual believes that using technology will help to improve job performance*". PE is based on different concepts such as perceived usefulness, motivation, and other outcome expectations. Several studies such as Alam et al. (2020) and Sitar-Tăut (2021b) highlighted that PE is an important predictor of system users' BI to use the technology because it impacts attitude toward using technology. Therefore, in this study, it is hypothesised that,

H1: *PE positively impacts health workers' attitudes* to using *malaria mobile phone-based applications.*

H2*: PE positively influences health workers' BI to use malaria mobile phone*-*based applications*.

B. Social influence (SI)

Social influence is defined as "the degree to which an individual perceives that important others believe he or she should use the new system". It is grounded on social factors and subjective norms. Shiferaw & Mehari (2019) and Ladan et al. (2018) suggested that social influence has a strong impact on users' intention to use technology. Therefore, this study considers social influence's positive influence on the behavioural intention to use the ICT-based malaria intervention system. It is hypothesised that,

H3: *SI positively impacts health workers' attitude to use malaria mobile phone*-based *applications*

H4*: SI has a positive impact on health workers' BI to use malaria mobile phone*-based *applications.*

C. Facilitating Condition (FC)

Facilitating condition refers to "the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system." FC is a determinant factor of behavioural intention to use technology (Tosuntaş et al., 2015). Therefore, it is hypothesised that,

H5*: FC* *positively impacts health workers' attitudes to using malaria mobile phone*-based *applications.*

H6*: FC has a positive impact on health workers' BI to use malaria mobile phone*-based *applications.*

D. Effort expectancy (EE)

According to Venkatesh et al. (2003), EE is defined as "*the degree of ease associated with the use of the system*". Previous studies found that EE is considered to be a very significant determinant because it aids users in the process of assessing the extent to which efforts are demanded in the usage of a particular technology. It is hypothesised that,

H7*: EE positively influences health workers' BI to use malaria mobile phone*-based *applications*.

H8: *EE positively impacts health workers' attitudes to using malaria mobile phone*-based *applications.*

Attitude (AT) of health workers' BI to use malaria mobile phone-based applications

The adoption of digital health interventions is primarily influenced by the attitude of end-users to effectively utilise the digital interventions. Several digital interventions deployed to improve health services delivery are generally faced with different impediments that affect their efficacy. Such challenges are centred on perceived need (Sitar-Tăut, 2021b), risks and benefits, level of education, data security and privacy, digital divide, internet connectivity, infrastructure, ease of use, digital literacy and public trust which ultimately influence the attitude of system users to effectively utilise deployed digital interventions (Akinnuwesi et al., 2022). In addition, the perception is that integrating digital technologies into daily work routines increases workload among healthcare professionals, and as a result of this increased workload, these professionals would expect higher remuneration. Also, given the limited knowledge, access to technology and digital illiteracy among people and healthcare professionals staying and working in resource-constrained rural communities (Chitungo, Mhango, Dzobo, et al., 2021), their attitude towards the adoption of digital health interventions is highly likely to be challenged. Because of such challenges, the diffusion of digital health interventions is substantially low in many developing countries (Shiferaw & Mehari, 2019). Therefore, the attitude seems to be a significant predictor in studying behavioural intention to utilise digital health interventions. In support, several studies such as Akinnuwesi et al. (2022), Rajak & Shaw (2021) and Shiferaw & Mehari (2019) alluded to the importance of accessing systems users and healthcare professionals' attitudes, especially when deploying digital health interventions. Therefore, Figure 6.1 shows the proposed modified UTAUT research model. Attitude, as a psychological construct, becomes imperative in this study and it is hypothesised that:

H9: *Attitude influences health workers' BI to use malaria mobile phone-based applications*.

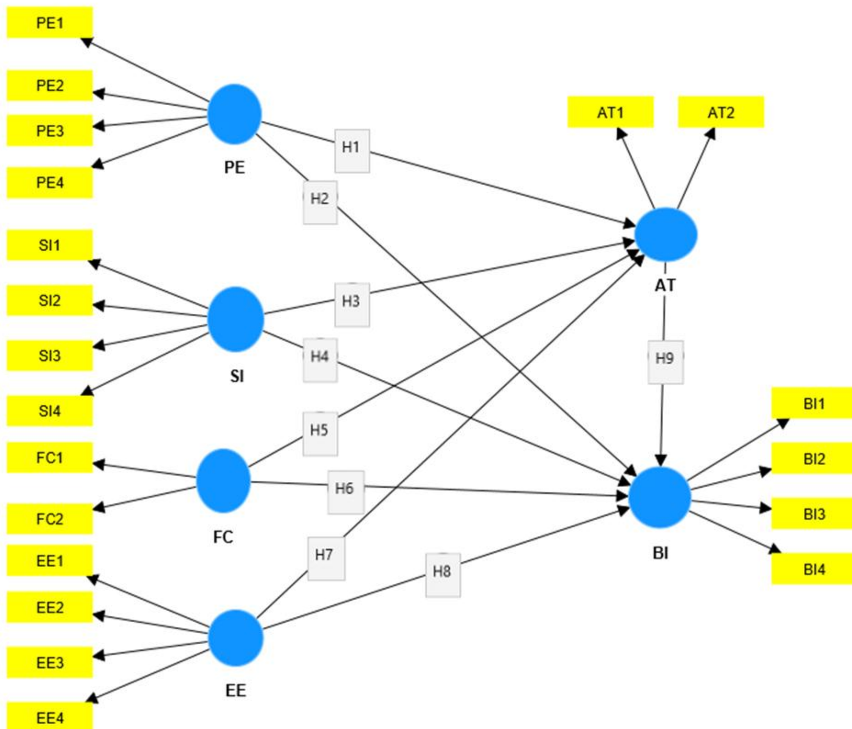

Figure 6.1: Modified UTAUT research model

6.4 Prototype evaluation recruitment process

With the help of key informants in Buhera rural health system, the researcher visited satellite clinics to recruit health workers using purposive sampling, guided and helped by the key informants (health workers) to select other health workers to participate in the study. Health workers who agreed to participate were trained on how to use the prototype. The inclusion and exclusion criteria and the sample size are explained in the following subsection.

Inclusion criteria

- Health workers should have a mobile phone or access to mobile phones to use the proposed malaria intervention.
- Health workers should be working in Buhera rural community.

Exclusion criteria

- Health workers without mobile phones were excluded from the evaluation of the proposed intervention.
- Health workers who were not in health centres were excluded from the evaluation of the prototype.

6.5 Sampling and participants

Due to high staff turnover and the brain drain of health workers (Dzinamarira & Musuka, 2021; Mudzonga, 2021), there are few health workers in rural communities. However, usually, each satellite clinic had at least two health workers providing care to the community (Mangundu et al., 2020). These health workers rotate since they are usually engaged in different projects and training at the referral hospitals. This study was conducted in Buhera rural district. No study had been previously conducted in the study area to model predictors for the adoption of mobile-based malaria digital interventions in Buhera rural district. Therefore, the questionnaires were administered to health workers in rural satellite centres that are vulnerable to malaria. Due to COVID-19 restrictions such as social distancing, and travelling restrictions, the study randomly sampled health workers and administered questionnaires. The UTAUT data were collected using a 5-point Likert scale (1 = strongly disagree up to 5 = strongly agree) survey questionnaire with 20 modified UTAUT items in total. All modified UTAUT constructs were measured by the items listed in Table 6.1. These constructs and items were modified and guided by the UTAUT model.

Table 6.1: Modified UTAUT constructs

Construct	Description of items	Supporting literature source
Performance Expectancy	PE1: I find the ICT-based malaria intervention prototype useful in reporting malaria PE2: Using an ICT-based malaria intervention prototype enables me to get malaria information more quickly	(Akinnuwesi et al., 2022; Dwivedi et al., 2020; S. Kim et al., 2015; Rajak & Shaw, 2021)

	PE3: Using ICT-based malaria intervention prototype to improve communication with health workers. PE4: If I use an ICT-based malaria intervention prototype, I will increase my chances of getting constant malaria updates.	
Effort Expectancy	EE1: My interaction with the ICT-based malaria intervention prototype is clear and understandable. EE2: I am skilful at using the ICT-based malaria intervention prototype. EE3: Communicating malaria information through an ICT-based malaria intervention prototype is easy for me. EE4: I find it easy to get an ICT-based malaria intervention prototype to do what I want it to do.	(Abbad, 2021; Hoque & Sorwar, 2017a; J. Kim & Lee, 2020)
Social Influence	SI1: I think the community should use an ICT-based malaria intervention prototype to report malaria. SI2: Other health workers influence my behaviour to use an ICT-based malaria intervention prototype. SI3: Other health workers help me to use of ICT-based malaria intervention prototype. SI4: In general, I support the use of an ICT-based malaria intervention prototype to report and get malaria updates.	(Shachak et al., 2019; T Alrawashdeh, 2012)
Facilitating Conditions	FC1: I have the resources necessary to use the ICT-based malaria intervention prototype. FC2: I have the knowledge necessary to use an ICT-based malaria intervention prototype.	(Panicker et al., 2016)
Attitude	AT1: I have a positive attitude towards the use of an ICT-based malaria intervention prototype. AT2: I have positive intentions to use an ICT-based malaria intervention prototype.	(Shiferaw & Mehari, 2019; Sitar-Taut & Mican, 2021)
Behavioural Intentions	BI1: I intend to use an ICT-based malaria intervention prototype in the future. BI2: I would use an ICT-based malaria intervention prototype in the future. BI3: I plan to use an ICT-based malaria intervention prototype in the future.	(Rahimi et al., 2018; Sitar-Tăut, 2021b)

	BI4: I would recommend an ICT-based malaria intervention prototype to my colleagues	

6.6 Results analysis

A total of forty-two (42) responses were received from health workers working in rural communities. The demographic characteristics presented in Table 6.2 show that 52.4% of the participants were males and 42% were females. Most health workers (47.6%) are of the age group between 31-40, and 31% are between 18-30 years of age, as shown in Table 6.2. In addition, most health workers (92.8%) have 4+ years of experience in using mobile phones to send and receive health information. They are relatively young so may be more familiar with mobiles than older health workers.

Table 6.2: Demographic characteristics of the respondents (n=42)

Variable		Frequency	Percentage
Gender	Male	22	52.4%
	Female	18	42.9%
	Other	2	4.8%
Age group	18-30	13	31%
	31-40	20	47.6%
	40+	9	21.4%
Experience with mobile phones	Less than one year (<1 year)	1	2.4%
	1-3 years	2	4.8%
	4+ years	39	92.8%

6.6.1 Measurement model assessment

The measurement model displays the relationships between the constructs and the indicator variables (Hair et al., 2017). The study utilised SmartPLS 4.0.6.8 software to evaluate the hypothesis as it incorporates Partial least squares structural equation modelling (PLS-SEM). PLS-SEM estimates the parameters of a set of equations in a structural equation model by combining principal component analysis with regression-based path analysis (Ali et al., 2018). The PLS-SEM has been widely used in various studies such as marketing (Hair & Sarstedt, 2021), health information systems acceptance, tourism (Ali et al., 2018), recommender systems, and educational technologies acceptance (Sarstedt & Cheah, 2019) in conducting explanatory, confirmatory, descriptive, exploratory and predictive research (Henseler, 2018). PLS-SEM performs better and can effectively manage small samples (Schamberger et al., 2020) as it supports the development of both confirmatory analysis and exploratory models without normalisation (Henseler et al., 2015). Therefore, the measurement model was assessed by examining the internal reliability, convergent validity, and discriminant validity using PLS-SEM (Fornell & Larcker, 1981). The internal reliability was evaluated by examining Cronbach's alpha and composite reliability (CR) values for all constructs. Convergent validity was assessed by measuring the average variance extracted (AVE). Construct reliability indicates how well a construct is measured by its items, and can be assessed based on Cronbach's alpha and CR (Shmueli et al., 2019). Therefore, the analysis was carried out in three phases: (i) determining convergent validity, construct validity and reliability, (ii) determining indicator collinearity and model fitness and (iii) the structural model assessment.

(i) Determining convergent validity, construct validity and reliability

All constructs and their respective indicators considered in this empirical study were tested for validity and reliability using Cronbach's alpha (α), average variance extracted (AVE), composite reliability (CR), outer loadings and Heterotrait-monotrait (HTMT) ratio. The reliability of constructs was measured in ways, namely composite reliability, and Cronbach's alpha. According to Hair et al.(2020), the rule of thumb for both reliability criteria is they need to be above 0.70. However, because indicators are not equally reliable, composite reliability, which is weighted, is more accurate than Cronbach alpha (unweighted), and therefore composite reliability should be assessed and reported (Hair et al., 2019). As shown in Table 6.3, all Cronbach alpha and composite reliability of latent reflective variables are all above the recommended (0.70), which means there is internal consistency. The least outer loadings of indicators is 0.618, being above the recommended 0.5 (Henseler et al., 2011). In addition, the average variance extracted (AVE) was used to measure convergent validity (Henseler et al., 2015). Convergent validity refers to the degree to which the formative specified construct correlates with an alternative measure of the same concept (Chin, 2010). It is sometimes referred to as redundancy analysis. Therefore, the average variance extracted is calculated by averaging the indicator reliabilities of a construct. This metric measures the average variance shared between the construct and its individual indicators. The value of the average variance extracted is greater than or equal to 0.5 (Hair et al., 2020). All AVE values of latent reflective variables are above the conservative upper boundary of (0.50), which means there is convergent validity in this model.

Table 6.3: Convergent validity, construct validity and reliability of variables

Latent reflective variables	Reflective indicators	Outer loadings	α	AVE	CR
Performance Expectancy	PE1 PE2 PE3 PE4	0.865 0.728 0.743 0.857	0.811	0.641	0.876
Effort Expectancy	EE1 EE2 EE3 EE4	0.731 0.725 0.809 0.803	0.767	0.590	0.851
Social Influence	SI1 SI2 SI3 SI4	0.835 0.647 0.617 0.821	0.736	0.543	0.824
Facilitating Conditions	FC1 FC2	0.920 0.881	0.769	0.811	0.896
Attitude	AT1 AT2	0.929 0.936	0.851	0.870	0.930
Behavioural Intentions	BI1 BI2 BI3 BI4	0.873 0.881 0.812 0.839	0.873	0.725	0.913

Note α: Cronbach Alpha>0.7; AVE: Average Variance Extracted>0.5; CR: Composite reliability>0.7.

(ii) Determining Collinearity

Collinearity refers to the non-independence of predictor variables (Dormann et al., 2013). It is sometimes referred to as multicollinearity. Collinearity assessment was performed by computing each item's variance inflation factor (VIF) by running a multiple regression of each indicator in the measurement model of the formatively measured construct on all the other items of the same construct (Mason & Perreault, 2018). All VIF scores for construct combinations and indicators are shown in Table 6.4 and Table 6.5, respectively. The highest VIF value for predictor constructs is 2.916 and 2584 for indicators, both still below the conservative upper boundary of 3 (Becker et al., 2015). Therefore, no collinearity was discovered between indicators as well as between predictor constructs.

Table 6. 4: Collinearity statistics (VIF) evaluation between the predictor constructs

	AT	BI
AT		2.128
BI		
EE		2.916
FC	1.272	2.066
PE	1.554	2.088
SI	1.284	1.368

Table 6.5: Collinearity statistics (VIF) evaluation between indicators

Indicators / Item variables	VIF values
AT1	2.210
AT2	2.210
BI1	2.346
BI2	2.584
BI3	1.888
BI4	2.148
EE1	1.580
EE2	1.535
EE3	1.741
EE4	1.643

FC1	1.640
FC2	1.640
PE1	2.300
PE2	1.347
PE3	1.544
PE4	2.431
SI1	1.485
SI2	1.483
SI3	1.306
SI4	1.994

Discriminant validity

This study applied discriminant validity as one of the key building blocks of model evaluation as alluded by (Henseler et al., 2015). Discriminant validity specifies the degree to which each construct measures different variables of the study (Shiferaw & Mehari, 2019). Discriminant validity ensures that a construct measure is empirically unique (Fornell & Larcker, 1981) and represents phenomena of interest that other measures in a structural equation model do not capture (Sarstedt et al., 2021).To determine discriminant validity, the study used the Heterotrait-monotrait ratio (HTMT) of correlations, as shown in Table 6. The HTMT criterion is defined as the mean value of the indicator correlations across constructs relative to the (geometric) mean of the average correlations of indicators measuring the same construct (Hair et al., 2017; Sarstedt et al., 2021). Therefore, if the HTMT value is below 0.90, discriminant validity has been established between two reflective constructs, otherwise, there is a lack of discriminant validity (Joe F. Hair et al., 2020). The highest HTMT value is 0.870, as shown in Table 6.6, which is still below the recommended boundary of 0.90, therefore there is discriminant validity.

Table 6.6: Discriminant validity for the reflective variables

	AT	BI	EE	FC	PE	SI
AT						
BI	0.726					
EE	0.797	0.870				
FC	0.791	0.720	0.817			
PE	0.428	0.496	0.848	0.602		
SI	0.293	0.537	0.544	0.271	0.630	

Goodness-of-fit

PLS-SEM does not have an established goodness-of-fit measure, however, some researchers utilised other standard measures such as the standardised root mean square residual (SRMR) (Dijkstra & Henseler, 2015), the root mean square residual covariance RMS_{theta}), and the exact fit test to determine goodness-of-fit (Sarstedt et al., 2021). This study sought to predict and explain a key target construct, which is to determine the behavioural intention of health workers to use mobile phone-based malaria interventions using several UTAUT constructs. Therefore, the study utilised the standardised root mean square residual (SRMR) as an approximate measure of fit as alluded by Dijkstra & Henseler (2015) and Sarstedt et al.(2021). The SRMR values for the saturated model and estimated model are both 0.107. These values are slightly above the close fit of 0.08 recommended by Henseler et al.(2015). The PLS-SEM does not have an absolute goodness-of-fit value. DiStefano et al.(2017) and Shi et al.(2018) indicated that a 0.08 SRMR close fit value appears to be too liberal a criterion for identifying misspecification in the factor structure. Regarding the predictive capacity of the modified UTAUT research model, the study assessed the scores of endogenous variables; AT and BI using the R^2 and Q^2predict. The AT's R^2 and Q^2predict scores are 0.544 and 0.407, respectively and for BI, the R^2 and Q^2predict scores are 0.604 and 0.433, showing the model's substantial predictive accuracy and power as indicated by Hair et al.(2019).

Additionally, the study further assessed and confirmed the predictive capacity of the modified UTAUT model by using the PLSpredict procedure with 10-fold cross-validation and 10-equally sized subsets (Shmueli et al., 2016). PLSpredict is a procedure that generates case-level predictions on an item or a construct level to reap the benefits of predictive model assessment in PLS-SEM (Chin et al., 2020; Ramírez-Correa et al., 2019). Each indicator of the endogenous variables (AT and BI) of the modified UTAUT model recorded a lower prediction error than the prediction Linear Model (LM) as shown in Table 6.7, considering the root mean square error (RMSE). The RMSE is the square root of the average of the squared differences between the predictions and the actual observations(Shmueli et al., 2016), which makes it particularly useful when large errors are undesirable (Akter et al., 2022). According to Shmueli et al.(2016), if PLS-SEM < LM for all indicators, that is, if all indicators in the PLS-SEM analysis have lower RMSE (or mean absolute error) values compared to the naïve LM benchmark, the model has high predictive power. As shown in Table 6.7, all PLS-SEM's RMSE values are lower than LM's RMSE means that the modified UTAUT model has high predictive power.

Table 6.7: Summary of PLSpredict assessment and results of manifest variables

	PLS-SEM		**LM**	**Condition**
Indicators	**Q^2predict**	**RMSE**	**RMSE**	**$RMSE_{PLS-SEM} < RMSE_{LM}$**
AT1	0.345	0.616	0.703	Yes
AT2	0.344	0.551	0.703	Yes
BI1	0.396	0.618	0.700	Yes
BI2	0.289	0.692	0.984	Yes
BI3	0.211	0.845	0.881	Yes
BI4	0.207	0.707	0.815	Yes

6.6.2 The structural model assessment

As mentioned above, SmartPLS was utilised to assess the structural path and the R-square of endogenous variables to evaluate the explanatory power of the structural model. To test hypothesised relationships, the study used a bootstrapping procedure with 5000 samples with percentile bootstrap confidence intervals, and one-tailed testing at the 0.05 significance level (which corresponds to a two-sided 90% confidence interval). At this stage, the study tests hypothesised relationships by analysing t-statistics and path coefficient (β) at a significance level of 0.05 ($p<0.05$) as shown in Table 6.8. Bootstrapping is a nonparametric procedure for testing the statistical significance of PLS-SEM results such as path coefficients, outer weights, Cronbach's alpha and HTMT. Therefore, for intuitiveness, the results of the structural model for the UTAUT model and a modified UTAUT research model are shown in Figure 6.2 and Figure 6.3 respectively. The hypothesised relationships were tested on both models except for the 'attitude' hypotheses, and the results are shown in Table 6.8.

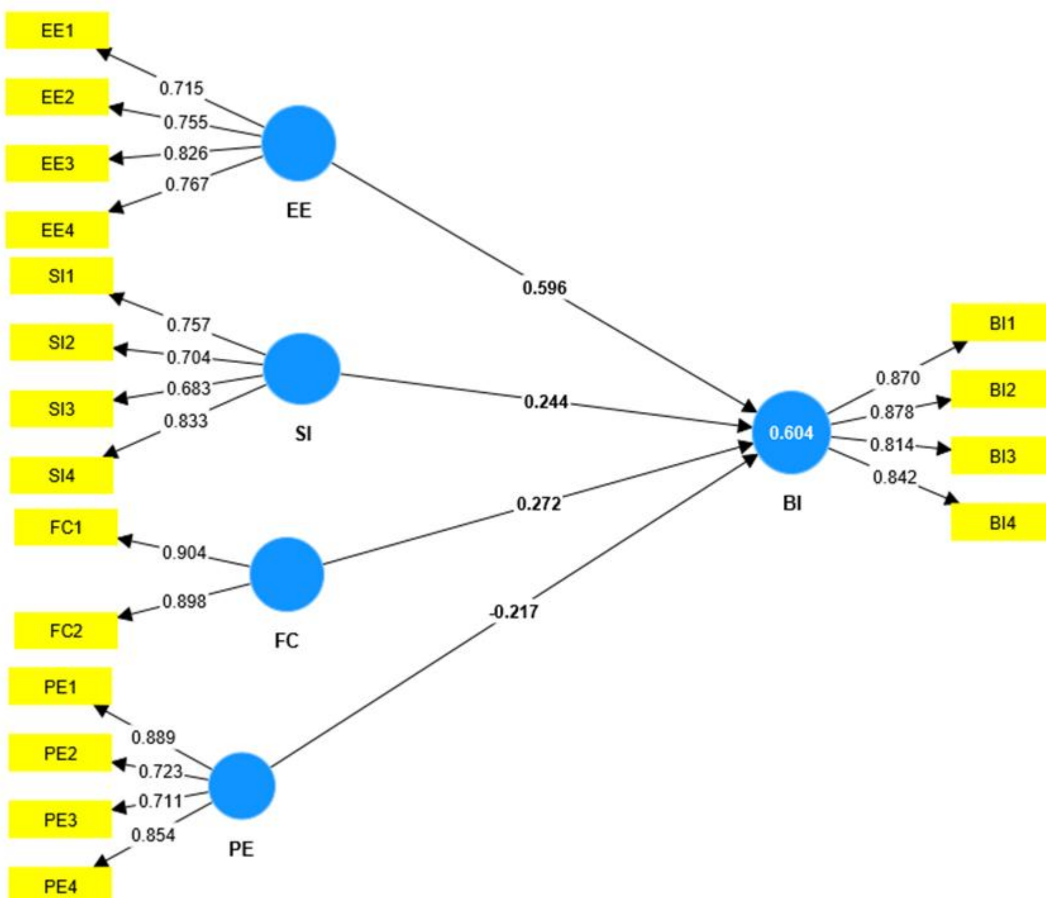

Figure 6.2: General UTAUT model

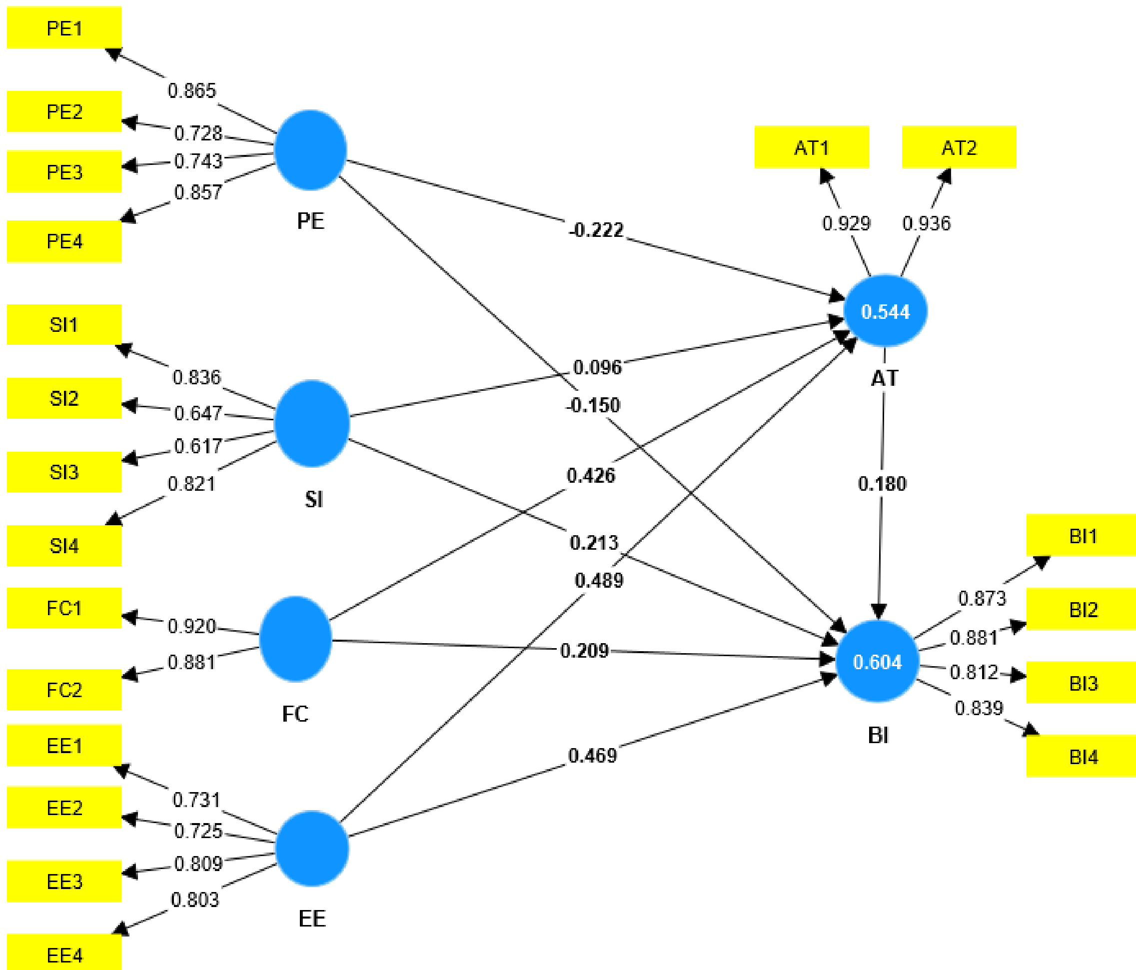

Figure 6.3:Results of the Modified UTAUT research model

Furthermore, the PLS-SEM results of the hypothesised relationships are shown in Table 6.8. The results show that the relationships between SI and BI (β = 0.032, $p<0.05$), FC and AT (β = 0.002, $p<0.05$), FC and BI (β = 0.023, $p<0.05$), EE and BI (β = 0.012, $p<0.05$), EE and AT (β = 0.005, $p<0.05$) were significant. Thus, H4, H5, H6, H7 and H8 were supported. However, the hypothesised relationships between PE and AT (β = 0.097, $p<0.05$), PE and BI (β = 0.107, $p<0.05$), SI and AT (β = 0.251, $p<0.05$), AT and BI (β = 0.177, $p<0.05$), were insignificant and not supported in this study.

Table 6.8: Summary results of hypothesized relationships

Hypothesized path		Path coefficient(β)	T statistics (t)	Hypothesis effect
H1	PE -> AT^{NEW}	0.097	1.298	Not supported
H2	PE -> BI^{UTAUT}	0.107	1.242	Not Supported
H3	SI -> AT^{NEW}	0.251	0.673	Not supported
H4	SI -> BI^{UTAUT}	0.032***	1.846	Supported
H5	FC->AT^{NEW}	0.002***	2.938	Supported
H6	FC -> BI^{UTAUT}	0.023***	1.989	Supported
H7	EE -> BI^{NEW}	0.012***	2.261	Supported
H8	EE->AT^{NEW}	0.005***	2.546	Supported
H9	AT -> BI^{NEW}	0.177	0.928	H8- Not supported

Note: ***significant at $p<0.05$(one-tailed), ^{UTAUT} UTAUT hypothesis, ^{NEW} modified UTAUT research model

6.7 Conclusion

This study developed a novel technology integrative model verified and validated in the rural research context to explore feasible technology acceptance predictors by health workers using the UTAUT model. The model incorporated additional endogenous predictor variables and other UTAUT technology acceptance constructs to explore the adoption of mobile phone-based malaria intervention in rural communities. The study revealed that social influence, facilitating conditions, and effort expectancy have a positive reverberation toward the adoption of mobile phone-based intervention in rural communities. Such digital malaria intervention can be effectively utilised to create malaria awareness, reporting, and surveillance as well as sharing and receiving malaria data to and from satellite health centres. Among these predictors, the study found that facilitating conditions and effort expectancy influence health workers' attitudes towards using mobile phone-based malaria interventions. This study can greatly assist in the decision-making process especially in technology adoption in rural health systems. Understanding important indicators and constructs such as facilitating conditions, social influence constructs and effort expectancy can facilitate the adoption and use of mobile phones to improve healthcare services and subsequently reduce malaria in rural communities by integrating mobile phone-based malaria interventions. Specifically, the results of this study suggest that improving digital literacy, network connectivity, resource availability and accessibility, digital infrastructure and digital devices such as mobile phones, tablets, laptops and computers can increase the possibility of high technology adoption in rural communities. However, further studies are required to explore factors influencing health workers' actual technology usage reflecting on technology acceptance, especially in the post-implementation stage of mobile phone-based malaria interventions.

6.8 Chapter Summary

This chapter provides information on how the proposed prototype was evaluated and assessed. The adoption of malaria mobile phone-based interventions in vulnerable rural communities is still low. Therefore, a modified model relying on the Unified Theory of Acceptance and Use of Technology has been developed to investigate the relationships between constructs and prototype adoption predictors. The hypotheses were tested using structural equation modelling. The next chapter focuses on analysing secondary malaria data from the district health information system 2 (DHIS2) and mapping malaria hotspots and environmental risk factors. Malaria cases from each health facility (at the ward level) were collected to address the following objectives:

- Mapping malaria hotspots and modelling micro-spatial patterns of malaria cases and environmental risk factors in malaria-endemic areas.

- Predicting malaria incidences using malaria cases and environmental risk factors in malaria-endemic areas.

CHAPTER 7: MAPPING MALARIA HOTSPOTS AND ENVIRONMENTAL RISK FACTORS

7.1 Introduction

The previous chapter presented prototype evaluation and adoption results. The adoption of the prototype was guided by the modified UTAUT model. The hypotheses were tested using structural equation modelling. This chapter discusses the genesis of the DHIS and the mapping of confirmed malaria cases extracted from the DHIS. In addition, this chapter also addresses micro-spatial modelling of malaria cases associated with environmental factors in high malaria perennial hotspots - Chapanduka and Birchenough Bridge wards.

7.2 Overview of the District Health Information Systems 2 (DHIS 2)

The genesis of the District Health Information System (DHIS) in Zimbabwe dates back to 2010 when the country moved forward to introduce a modern national health information and surveillance system by adopting (DHIS-1). This was followed by piloting DHIS-2 in 2013 after successful improvements to integrate parallel and vertical information systems. In 2014, DHIS-2 was rolled out country-wide to the national offices of the MOHCC, its provincial offices, as well as to sixty-three districts, and eight city health information offices. It was a transition from using paper-based systems to using a health information and surveillance system. District Health Information Software 2 (DHIS-2) is a free and open-source health management data platform used by multiple organisations to collect health data, perform surveillance, report and track national health indicators and monitor diseases. Therefore, the reported malaria cases from DHIS-2 were extracted from 2015 to 2020 (April). In 2015, DHIS-2 was fully functional and operational. By 2019 reports for the year were completed in DHIS-2. In Buhera, the DHIS is managed at Murambinda rural hospital, which is a referral hospital in the district. Health workers, including primary care nurses and village health workers in different satellite health centres, collect malaria data using paper-based tally sheets and report on a weekly, monthly and quarterly basis. Malaria data are summarised on the paper-based T5 monthly return form which is sent to the Health Information Officer (HIO) at Murambinda rural hospital. The HIO captures malaria data from the T5 monthly return form into DHIS for further processing. Once malaria data is entered into DHIS, it becomes accessible at the provincial and national levels. Malaria data captured on paper-based T5 forms are kept safe at the district level for future reference and as a backup of DHIS.

7.3 Malaria Deaths – special reference to the 2015-2020 period

Malaria case fatality trends in Buhera District, with special reference to the 2015-2020 (April) period, are depicted in Figure 7.1. For reporting malaria deaths and cases, DHIS-2 uses a rapid disease notification system (RDNS) (Gavi et al., 2021). Since the advent of DHIS-2 in the district, more deaths were recorded in 2015, while in 2018 the district recorded the least deaths. However, as of April 2020, the graphs show a sharp increase in malaria deaths (see Figure 7.1) and malaria cases (see Figure 7.2). The sudden increase in malaria deaths might be linked to the outbreak of COVID-19 (Manyangadze et al., 2021), paused community engagement activities, temporary ban movement of people except for essential services providers and delayed IRS activities among others (Gavi et al., 2021).

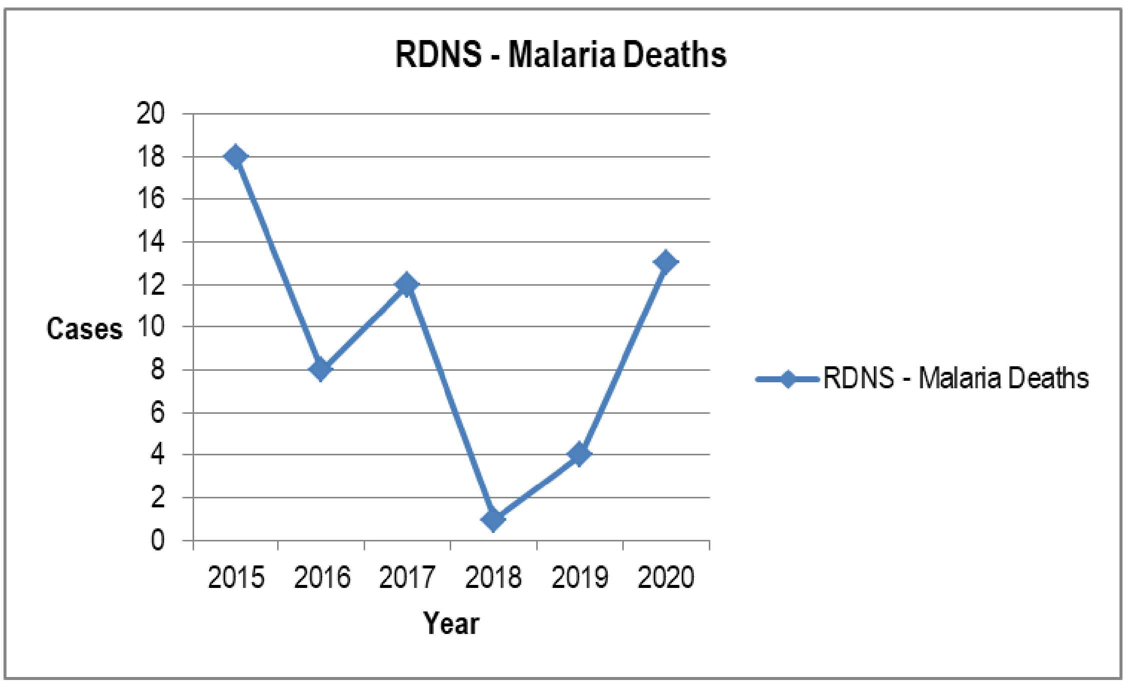

Figure 7.1: Malaria fatality trends 2015-2020 (April)

7.4 Malaria confirmed cases – special reference to the 2015- 2020 (April) period

Malaria incidence (confirmed and suspected cases) trends in Buhera District, special reference to the 2015-2020 (April) periods are depicted in Figure 7.2. The district recorded the highest malaria cases in 2017 as compared to other subsequent years because of intensified testing using RDT in all health facilities, the resistance of malaria parasites to chloroquine (Mutsigiri et al., 2017), excessive rains increased malaria transmission by providing more mosquitoes breeding sites, leading to an increased malaria vector population (Sande et al., 2017). Additionally, poor coverages of the IRS as spray teams fail to access some areas due to bad terrain and excessive rains also contributed towards increased malaria incidences (Mutsigiri et al., 2017).

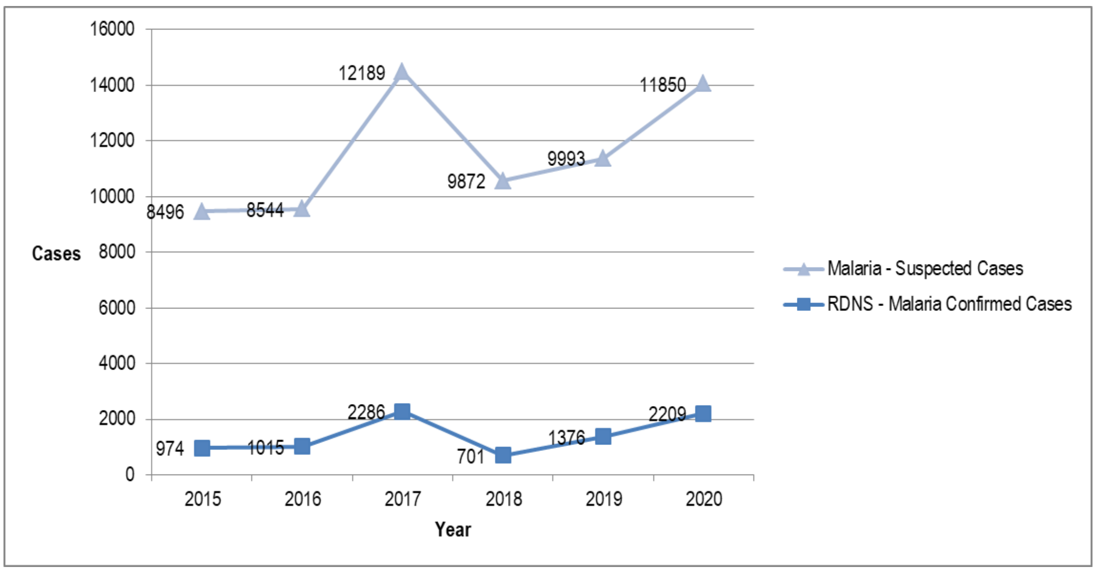

Figure 7.2: Malaria Confirmed and Suspected Cases-2015-2020 (April)

7.4 Mapping Malaria hotspots and distribution in Buhera district

To map malaria hotspots in Buhera district, the researcher utilised reported malaria cases per each health facility located in thirty-three (33) wards in Buhera district. Malaria cases for each year are recorded as per health facility. Therefore, after recording confirmed malaria cases the researcher mapped malaria hotspots using QGIS 3.10.5 software. QGIS is a free and open-source GIS software that allows users to analyse (Graser & Olaya, 2015), edit spatial information, and compose and export graphical maps (Palasio et al., 2021). Therefore, in this study, QGIS 3.10.5 software was used to map cumulative confirmed malaria cases from each health facility into their respective wards in the Buhera district. Health facilities were grouped into several categories such as malaria-free, low malaria sporadic, high malaria sporadic and high malaria perennial as shown in Figure 7.3. These categories are based on the malaria prevalence rate in each health facility.

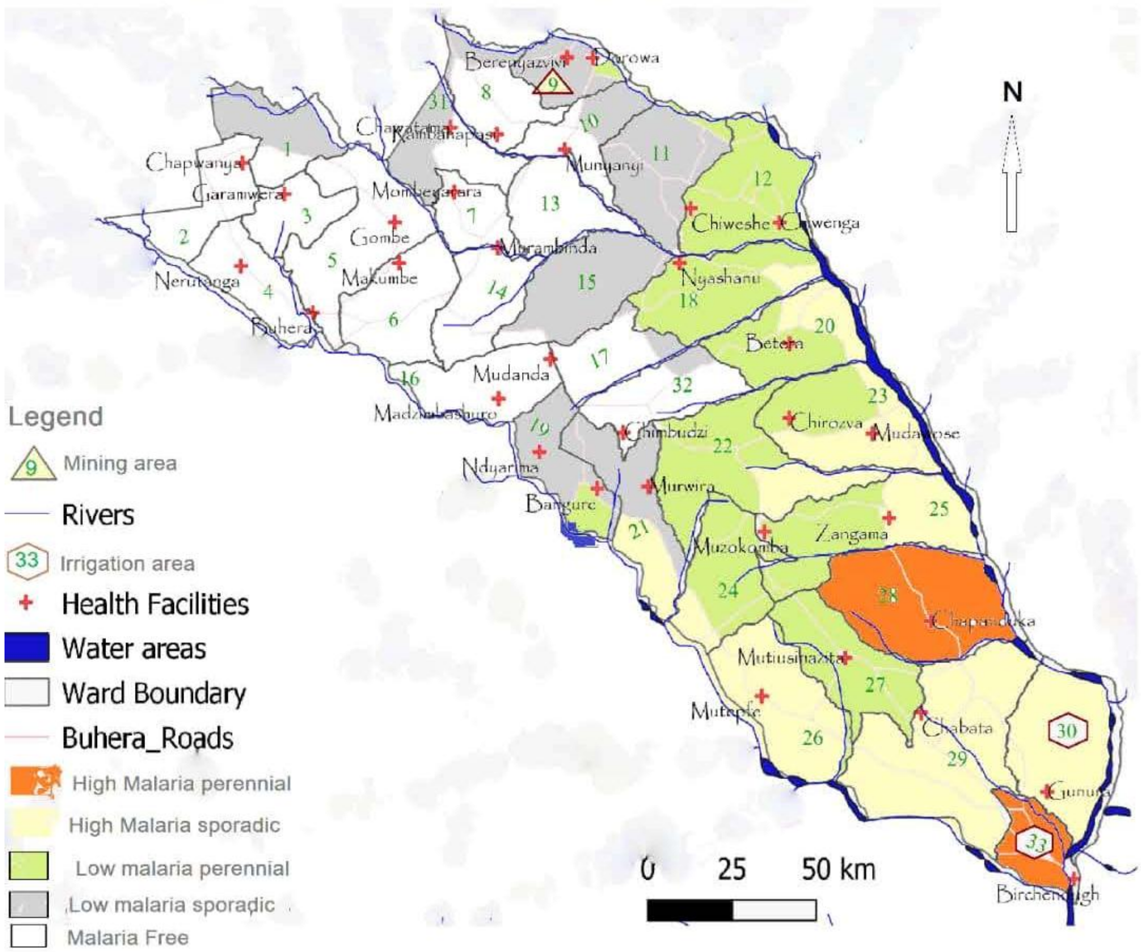

Figure 7.3: Malaria hotspots and distribution in the Buhera district

After mapping malaria hotspots in the district, the researcher selected high malaria sporadic wards namely, Ward 28 (Chapanduka) and Ward 33 (Birchenough Bridge) as hotspot areas as shown in Figure 7.4. Malaria data were further analysed to determine malaria trends in Ward

28 and Ward 33. The malaria incidences per ward/population were calculated using the number of malaria cases and the total population per ward. The estimated population of Birchenough Bridge and Chapanduka are 9808 and 9981 total population, respectively, as per Zimbabwe National Statistics Agency (Zimbabwe National Statistics Agency, 2012). Therefore, malaria incidences per ward are shown in Figure 7.4. To ensure uniformity and consistency in reporting yearly malaria deaths and cases, Figure 7.4 shows incidences from 2015 (January) to -2019 (December).

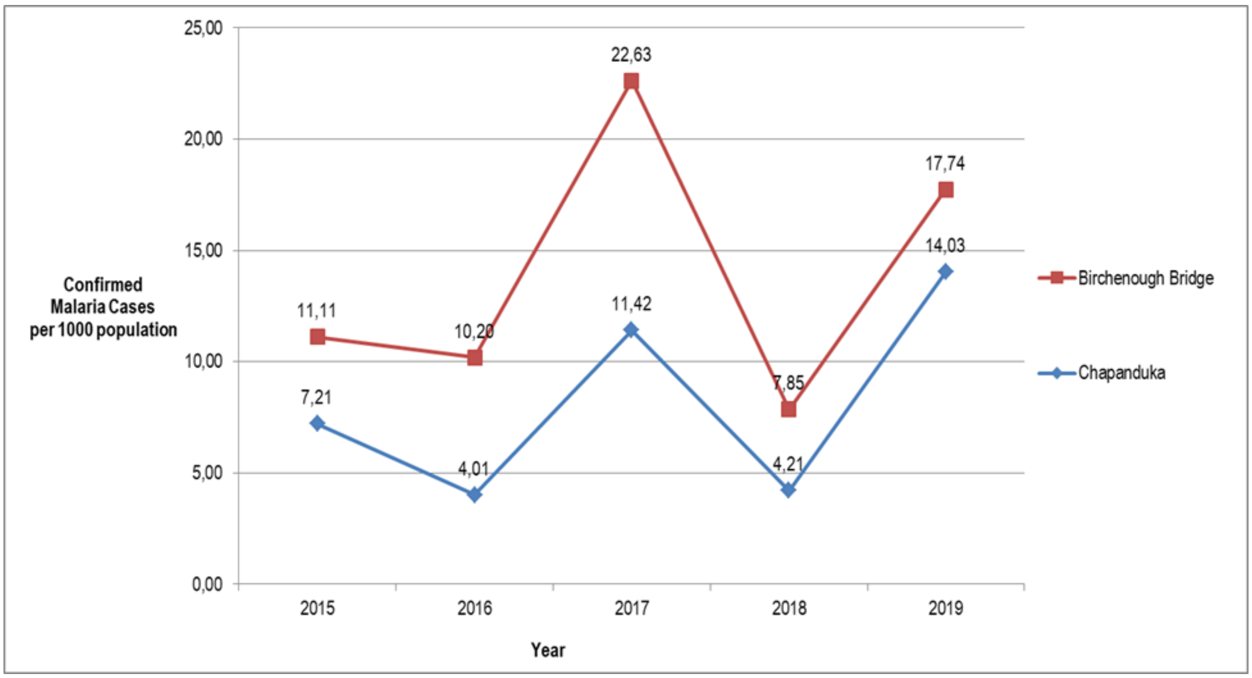

Figure 7.4: Malaria incidences per ward in Birchenough Bridge and Chapanduka

Figure 7.4 shows malaria trends in the Chapanduka Ward and Birchenough Bridge from the 2015-2019 period. Birchenough Bridge recorded the highest malaria incidences from 2015-2019. In 2017, Birchenough Bridge recorded the highest malaria peak with 22.63 malaria cases per 1000 population while Chapanduka recorded its highest cases per 1000 population, 14.03, in 2019.

7.5 Micro-spatial modelling of malaria cases associated with environmental factors in malaria hotspot wards in Buhera district

Malaria transmission is heterogenous, unstable, and strongly seasonal, influenced by multiple factors such as malaria control interventions, land use, socio-economic determinants, and climatic and environmental variables. Hasyim et al.(2018) reiterated that climatic and environmental variables such as rainfall, and temperature among others are risk factors for malaria as they influence the development of the parasite, vector and the relationship between the vector and host. Alemu et al. (2011) also state that changes in climatic and environmental risk factors such as rainfall, temperature as well as relative humidity modify the life cycle of the parasite and also influence the geographical distribution and behaviour of malaria vectors. For example, the life cycle of the malaria vector takes approximately 9 to 10 days when the temperature is between 17^{o}C and 28^{o}C. The minimum temperature for parasite development of plasmodium falciparum and plasmodium *vivax* is approximately 18°C and 15°C, respectively (Craig et al., 1999). Rainfall determines the habitat suitability of malaria vectors by proving the breeding sites. A combination of these risk factors might translate into increased malaria incidences. Some scholars including Craig et al. (1999) and Fastring & Griffith (2009), Sewe et al. (2016) incorporated normalised difference vegetation index (NDVI) in spatial modelling of environmental factors and malaria mortality. The normalised difference vegetation index is the characterisation of vegetative density based on the amount and wavelength of the radiation reflected by the leaves of a plant (Fastring & Griffith, 2009). When vegetation is photosynthetically active, it has a high reflectance in the near-infrared region of the spectrum and a low reflectance in the red portion of the spectrum. Chirombo et al. (2020) highlighted that those seasonal changes of NDVI are influenced by rainfall patterns, thereby, influencing the greenness of the vegetation cover. Therefore, NDVI becomes a significant predictor of malaria outbreaks (Gaudart et al., 2009).

In Zimbabwe, malaria transmissions are highly influenced by rainfall and temperature variations, especially in malaria-endemic areas (Manyangadze et al., 2017). A study conducted by Gunda et al. (2017) was the first of its kind to determine the association between malaria cases and climatic factors such as rainfall and temperature to understand their roles in the trends of malaria incidences in high-malarial districts in Zimbabwe. The study also found that the period of high malaria risk is associated with precipitation and temperature between 1-4 months before a seasonal cycle. This reflects that malaria is sensitive to climatic or environmental factors, especially rainfall, NDVI and temperature highly determine malaria transmission patterns. Kim et al. (2019) state that more rainfall increases mosquitoes' breeding sites and probably leads to high transmission even though its intensity might destroy mosquitoes' larvae and reduce their population. Manyangadze et al. (2017b) also state that high temperatures shorten the life cycle of mosquitoes and increase their biting rate. Kumar et al. (2014) applied socio-economic determinants with unconfirmed malaria cases to determine malaria prevalence in Chennai. Instead of using socio-economic determinants, several studies applied associated climatic factors to understand malaria cases, mostly at the regional or national level (Alemu et al., 2011; Fastring & Griffith, 2009; Kumar et al., 2014). None of the studies in the published literature modelled the spatial patterns of malaria cases and correlated environmental factors in malaria hotspot wards in Buhera rural district. Accurately modelling spatial patterns of malaria cases and correlated environmental factors is imperative for the development of malaria early warning systems and the effective execution of malaria control programmes. Modelling malaria local spatial variations provides intuitive and meaningful insights into malaria control strategies. Therefore, after mapping malaria hotspots in the Buhera district, the study identified Chapanduka and Birchenough Bridge as high malaria perennial wards in the Buhera district. Chapanduka (ward 28) and Birchenough (ward 33) are both located in Buhera district as shown in Figure 7.5

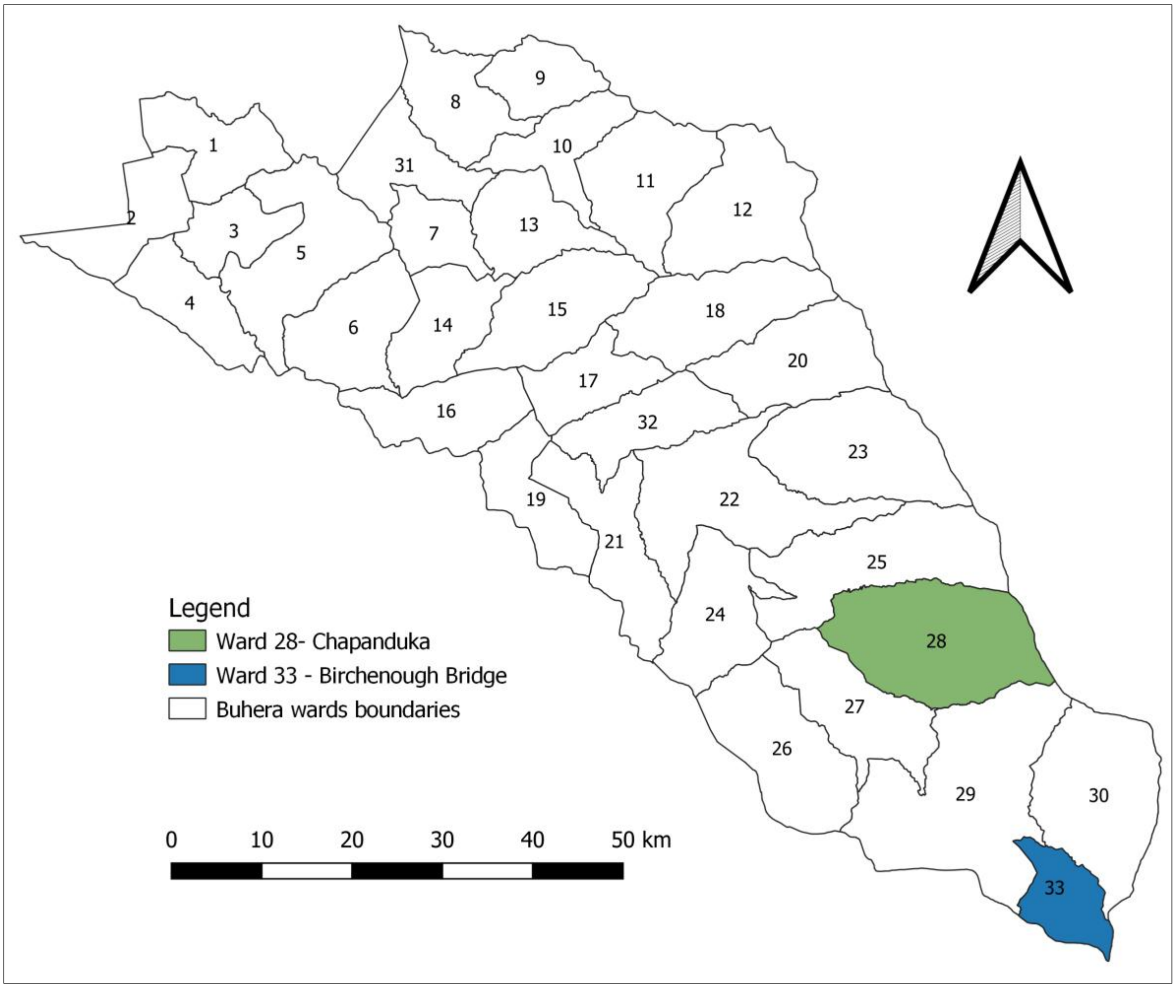

Figure 7.5: Buhera map showing Wards 28 and 33

In this study, the environmental data considered are rainfall, NDVI, EVI and land surface temperature (day and night), as they influence the geographical distribution of malaria in the wards under study. The researcher used the daily day and night surface temperature (LST) and NDVI data from the Moderate Resolution Imaging Spectroradiometer (MODIS) product MOD11A2 Global Land Surface Temperature (LST) and Emissivity on Sinusoidal projection grid, at a 1 kilometre (km) spatial resolution to calculate monthly means LST (day and night) for each ward. MOD11A2 is comprised of daytime and night-time LSTs, quality assessment, observation times, view angles, bits of clear sky days and nights, and emissivities estimated in bands 31 and 32 from land cover types. MODIS LSTs (day and night) are measured in Kelvin

(^{o}K), therefore, to convert LSTs from Kelvin to Celsius (^{o}C), subtract LSTs values by 273.15. Rainfall data were collected from the climate hazards group infrared precipitation with station data (CHIRPS) database. These environmental data were collected from satellites with a spatial resolution of 5km and 1km for CHIRPS and MODIS respectively. Malaria cases as non-environmental variables and environmental factors such as rainfall, land surface temperatures (day and night), NDVI and EVI were considered in the study as depicted in Table 7.1.

Table 7.1: Environmental risk factors data sources (for Ward 28 and 33)

Variables	Description	Spatial Resolution	Temporal Resolution	Source
Malaria cases	Total positive malaria cases reported and confirmed by the health centres in each ward	Ward	Monthly	DHIS2
Rainfall	Rainfall estimates (mm/day) in each ward	5km	Monthly	CHIRPS
Day LST_{mean}	Day land surface temperature estimates at	1km	Monthly	MODIS/ LP DAAC

	ward level (^oK)			
Night LST$_{mean}$	Night land surface temperature estimates at ward level (^oK)	1km	Monthly	MODIS/ LP DAAC
NDVI	NDVI estimates at the ward level	250m	Monthly	MODIS/ LP DAAC
EVI	EVI estimates at the ward level	1km	Monthly	MODIS/ LP DAAC

7.6 Statistical Analysis

In this study, malaria cases are the dependent or response variable, while rainfall, day LST, night LST and NDVI are explanatory or independent variables. Before performing the GWPR model, the correlation analysis between environmental factors and malaria cases was conducted using SPSS to ensure that the variables in Table 7.1 do not have multicollinearity. Vatcheva et al. (2016) state that multicollinearity causes unstable and biased standard errors leading to very unstable p-values for assessing the statistical significance of independent variables, which could result in unrealistic and untenable interpretations. According to Hasyim et al. (2018), multicollinearity occurs when two or more independent variables are highly linearly related in a multiple-regression model. Therefore, to avoid multicollinearity, the study applied a variance inflation vector (VIF) to test all explanatory variables, variables with VIF>5 were considered to be collinear (L. V. Bui et al., 2018) and were excluded from the model. For example, VIF for enhanced vegetation index (EVI) and normalised difference vegetation index (NDVI) was above 5; and EVI was excluded from the model. This is because both enhanced vegetation index and normalised difference vegetation index are both influenced by vegetation index features of vegetation (Matsushita et al., 2007). Variables with a p-value of <0.05 were considered statistically significant.

7.7 Spatial analysis

Geographically Weighted Poisson Regression (GWPR) spatial analysis was employed to model spatial varying relationships between malaria cases and rainfall, day land surface temperature, night land surface temperature and normalised difference vegetation index. GWPR is found in the Geographically Weighted Regression (GWR) 4.09 package (Tomoki Nakaya et al., 2005) and has been applied to measure the spatial association between possible factors and epidemiological patterns (Manyangadze et al., 2017b). GWR 4.09 package calibrates geographically weighted regression (GWR) models, which can be used to explore geographically varying relationships between dependent or response variables and independent or explanatory variables (Nakaya et al., 2009). GWPR incorporates non-stationary spatial structures of data into statistical models to generate local coefficients to elucidate spatial variations in relationships between covariates and dependent variables that follow the Poisson distribution (Bui et al., 2018). According to Nakaya et al. (2005), GWPR is an extension of Geographically Weighted Regression (GWR) that provides more of an appropriate basis for spatial associations across the study area than conventional generalised linear models (GLMs) and the traditional Ordinary Least Square (OLS). The OLS and GLMs have been utilised for modelling epidemiological patterns and varying associations but they disregard the potential varying spatial associations (Bui, et al., 2018). Another outstanding advantage of GWPR over conventional GLMs is the provision of a set of local spatial parameters where the weights are linked to the distance between the observation and the location where independent variables in the models are measured (Hadayeghi, et al., 2010). GWPR allows the analysis of the spatial varying associations over time by using the semiparametric GWPR, which is expressed in local and global terms. Therefore, in this study, it was assumed that malaria cases follow Poisson distribution in each malaria hotspot ward namely, Chapanduka (Ward 28) and Birchenough Bridge (Ward 33). Therefore, the GWPR model and its semiparametric variant are denoted in Equation 7.1 and Equation 7.2, respectively.

$$Y_i \sim \text{Poisson}\left[\mathrm{N}_i \exp\left(\sum_k \beta_k \,(u_i, v_i) x_{k,i}\right)\right], \quad (7.1)$$

$$Y_i \sim \text{Poisson}\left[\mathrm{N}_i \exp\left(\sum_k \beta_k \,(u_i, v_i) x_{k,i} + \sum_l \gamma_l \, z_{l,i}\right)\right] \quad (7.2)$$

Where, Y_i denotes dependent variable-number of confirmed malaria cases per ward in Buhera district, $x_{k,i}$ are the observed values of the independent variable kth in ward i, and N_i the offset variable (population in the ward i). The i in Equations 7.1 and 7.2 represents the ward number, and $z_{l,i}$is the lth independent variable with a fixed coefficient γ_l; (u_i, v_i) is the geographic coordinate (longitude and latitude) of the ith ward, and coefficients $\beta_k(u_i, v_i)$ are varying conditionals on their location. Thus, the model mixes geographically local and global terms. The intercept term is usually specified as a varying term since other varying coefficients often cause a variation in the intercept (Nakaya et al., 2009).

The latest GWR4.09 software with GWPR, calibrated with GWR and semiparametric equations presented in Equation 7.2 and Equation 7.3 was used. Malaria cases and environmental data with sixty (60) records were uploaded in GWR4.09 software as a comma-separated values (CSV) file. The latitude and longitude coordinates of each ward were entered as well as respective dependent and explanatory variables. Adaptive bi-square kernels and geographically weighted likelihood principles were used to estimate local parameters and local coefficients based on latitude and longitude as described by Nakaya et al. (2005). In GWR 4.09 software, the local to global variable (L=>G) selection option was selected to find the optimal combination of fixed and geographically varying exploratory variables. Bandwidth selection is necessary to estimate geographically smoother coefficients for local terms. A golden section search was selected to automatically determine the best optimal bandwidth size based on latitude and longitude and the variables provided. To measure the performance of GWPR and its semiparametric model, the study applied the Aikake information criterion (AICc) and residual deviance as explained by Cavanaugh and Neath, (2019). The minimisation of AICs influences the golden section search and the local to a global variable in finding the fitting model (Nakaya et al., 2009). According to Nakaya et al. (2005), a model with a lower AICc value (must not be less than 3) indicates a better performance fit and is considered reliable and statistically significant.

7.8 Results Analysis

In two wards in Buhera rural district, Chapanduka (Ward 28) and Birchenough Bridge (Ward 33)'s malaria cases and environmental variables were modelled using the GWPR model. These two wards are high malaria perennial with malaria intensity and seasonal variations. To understand the potential impact of environmental risk factors (exploratory variables) such as rainfall, LST (day and night), NDVI and EVI on the outbreak of malaria cases, the researcher applied the semiparametric-GWPR model. The results of the model are shown in Table 7.2 for Wards 33 and 28.

Table 7.2: Association between environmental risk factors and malaria incidences

	Ward 33	**Ward 28**
AICc	448.653259	418.437756
R-squared	0.351629	0.344567
Adjusted R-squared	0.278228	0.270367

Table 7.2 shows the AICc, R-squared (R^2) and adjusted R-squared for Ward 33 and 28, respectively. Ward 33 recorded a high R^2= 0.351626 as compared to Ward 28, this means that there is a small positive association between malaria cases and environmental risk factors. The difference between wards' R-squared is 0.007062, which means that the considered exploratory variables contribute almost the same towards malaria incidences in the 2015-2019 period. The global results of the GWPR model for two are shown in Table 7.3.

Table 7. 3: GWPR model global results for Ward 33 and Ward 28

	Ward 33	Ward 28
Variable	**Estimate**	**Estimate**
Intercept	11.292310	6.741942
Rainfall	2.521957	0.385221
LST (Day)	0.678472	3.134317
LST (night)	0.536115	-2.157315
NDVI	13.747125	10.138743
EVI	-9.170281	-3.809926

Table 7.3 shows that there is a positive association between rainfall, land surface temperature (day) and NDVI towards malaria outbreaks in both wards. Studies by Gunda et al. (2017) and Manyangadze et al.(2017) show that NDVI, rainfall and day temperature influence the biting behaviour of Anopheles mosquitos in Zimbabwe. The higher the day land surface temperature the more mosquitos become active. Also, rainfall provides the breeding site for mosquitos to complete larval and pupal development (Hasyim et al., 2018b). Thus, malaria incidences are positively linked to high rainfall and varying temperatures, especially during the rainy season. Also, the GWPR model performed geographical variability tests of local coefficients to test the variability of *k*-th varying coefficients. The summary of geographically varying coefficients from the GWPR model for Ward 33 and Ward 28 is shown in Table 7.4.

Table 7.4: GWPR model geographically varying coefficients

	Ward 33	Ward 28
Coefficients	**Mean**	**Mean**
Intercept	11.292310	6.741942
Rainfall	2.521957	0.385221
LST (Day)	0.678472	3.134317
LST (night)	0.536115	-2.157315
NDVI	13.747125	10.138743

Table 7.4 shows the model comparison using AICc. According to Nakaya, et al. (2005), if the difference of AICc of the geographical variability test of local coefficients is greater than or equal to two, the model comparison results are strongly supported, otherwise, there is no important difference. Thus, the Intercept, rainfall, and NDVI are strongly indicated as local varying coefficients for ward 33 as shown in Table 7.4. The coefficients of Intercept, LST (day) and NDVI for ward 38 are supported. However, the coefficients of day and night LST are not varying significantly for both wards, therefore, they can be changed from local variables to global variables.

7.9 Chapter Summary

Malaria outbreak is influenced by several factors including ecological, biological and socio-economic factors. This chapter shows that environmental risk factors significantly contribute to malaria outbreaks as evidenced by their positive association with malaria cases. This chapter also mapped malaria hotspot wards in Buhera rural district and determined the degree to which environmental risk factors contribute to malaria incidences. The next chapter presents a mobile health framework for integrating ICT-based malaria interventions in resource-constrained areas.

CHAPTER 8: DISCUSSION OF RESULTS

8.1 Introduction

The previous chapter mapped malaria hotspots using malaria data from DHIS and further determined the correlation between previously confirmed malaria cases and environmental risk factors. This chapter discusses the key findings of the study while addressing research objectives, and drawing recommendations for policymakers. The discussion focuses on the current strategies and information diffusion methods to help health promotion to manage malaria, the most feasible digital technology for tackling malaria, the development and piloting of the prototype, modelling predictors for the adoption of the prototype, and challenges affecting the adoption of ICTs in rural communities. The following section captures the major findings of the study and how research objectives were met.

8.2 Major findings of the study

This section discusses the salient findings of the study, from the pre-testing phase to the post-testing phase, while analysing the performance of machine learning-based malaria prediction models. Discussing key findings of the study is an iterative process that allows the researcher to move back and forth, synthesising findings reported in the previous chapters. This is imperative as it allows the researcher to link research objectives and key findings. The study revealed the following key findings.

8.2.1 Current strategies and information diffusion methods to help health promotion to manage malaria

The study sought to determine strategies and information diffusion methods being used to facilitate malaria health promotion in Buhera rural district. To gather balanced findings from the participants, the study collected data from both health workers and people living in the district. It emerged that (see Table 4.3) print media, digital platforms and community events are major platforms used by health workers to create awareness and help health promotion. The study revealed that print media such as billboards, posters and charts have been used to disseminate knowledge about malaria because they can reach all places without mobile network signals. A study conducted by Chukwuocha et al.(2020) in Nigeria also determined that posters with visual aids can help create malaria awareness among learners in hard-to-reach rural communities. The study also noted posters, banners and fliers have been used to create awareness and promote vaccination, HIV/AIDS, male circumcision, and COVID-19 among others (Mavunga & Kaguda, 2016; Mukungwa, 2015; Svongoro & Matende, 2021). However, participants also revealed that posters, flyers and charts can get torn during the rainy season and are sometimes blown away by the wind. This is supported by a study conducted by Masuku (2013). Bad weather conditions that continuously affect the rolling out of clinic posters and charts at a massive scale in rural areas, high printing costs and language barriers were also noted as impediments to the effective utilisation of print media. Therefore, the use of posters alone generally has a minimal impact (Redding & Cole, 2019). It also emerged that dramatisation, school outreach activities and community gatherings have been utilised to disseminate malaria information in Buhera rural communities. Unfortunately, such face-to-face information dissemination methods were greatly affected by the outbreak of COVID-19. COVID-19 also delayed indoor residual spraying activities and the procurement of malaria commodities due to movement restrictions, which consequently led to the outbreak of malaria in Buhera rural district (Gavi et al., 2021). The findings of this section achieved the following research objective.

- Explore and analyse current strategies and information diffusion methods to help health promotion to manage malaria.

8.2.2 The most feasible digital technology for tackling malaria in vulnerable rural communities

The study revealed that rural communities also disseminate malaria information through digital platforms such as televisions, mobile phones, and radio. The findings of the qualitative data in Table 4.3 corroborates the findings of the quantitative data in Table 4.8 which shows that radio, mobile phones and television have been used to create awareness. A study conducted by Dabengwa et al.(2022a) also highlighted that most people in rural communities use mobile phones to send and receive information. Among other digital platforms, mobile phones have been utilized to develop mobile phone-based health applications designed to perform different functions. The results in Table 4.9 shows that the majority of people prefer to use the radio (59%) and mobile phones (54.5%) to disseminate health information.

However, radio and television digital platforms lack real-time bidirectional communication between the community and health workers. In addition, it is difficult to quantify the effectiveness of such platforms, especially in resource-constrained areas where televisions and radios are not readily accessible to most of the populace and are mostly affected by poor network signals and coverage. The study also revealed that there is limited literature to determine the impact of malaria information accessed via television and radio and to determine the access frequency of listening to the radio and watching television due to completing interests such as farming activities in the Buhera district.

Despite using radio and television to disseminate malaria information, the findings of the study revealed that the majority of people in Buhera rural district have access to mobile phones. In support, a study conducted by Mavunga & Kaguda (2016) indicated that mobile phones have increasingly become part of major channels for disseminating health information.

The results in Table 4.14 shows that several mobile health applications have been developed and deployed as prototypes to improve healthcare service delivery in Zimbabwe's health systems. SMS, mobile phones and social media platforms are among the technologies used to develop mobile health interventions. For instance, in Zimbabwe, SMS platforms have been used to perform various functions including patient enrollment for cleft lip-palate surgery (Gadkaree et al., 2019a), communication between pregnant women and clinic nurses by sending notifications (N. Kumar et al., 2015), improve access to information (Dimaguila, 2015b), improving access to adolescents' sexual and reproductive health services by sending reminders (Dhakwa et al., 2021a), male circumcision follow-ups (Marongwe et al., 2022b), early warning network for human-wildlife conflicts mitigation (Le Bel et al., 2014), and follow-ups for voluntary medical male circumcision (Feldacker et al., 2020). This shows that among other mobile phone services, short message service (SMS) text messaging is the most prominent platform and can potentially be utilised to disseminate malaria information in resource-limited settings. This is evidenced by promising mobile phone penetration and usage, especially in rural communities where mobile money transactions are mostly used. The study also revealed that among other mobile phone services, text messaging or SMS services have been prominently utilised for informing patients about surgical services (Gadkaree et al., 2019b), male circumcision follow-up (Marongwe et al., 2022a), improving maternal services (Dabengwa et al., 2022a), early warning systems for issues in quality service delivery, childhood immunisation (Bangure et al., 2015), improving diagnosis and treatment for HIV and drug adherence (Venables et al., 2019), and improving access to health services to adolescents through SMS reminders (Dhakwa et al., 2021b) among others. A study conducted by Venables et al. (2019) also noted that text messaging, or SMS allows for the low-cost transmission of information, and has been used to send appointment reminders, information about HIV counselling and treatment, messages to encourage adherence and information on nutrition and side-effects of drugs. The study revealed that SMS costs, inconsistent power supply, poor mobile phone battery life, intermittent network signals and coverage, digital divide, digital literacy, language barriers, religious and cultural barriers, lack of digital infrastructure and lack of technical support are some of the challenges affecting effective adoption of mobile phones in resource-constrained rural communities. In addition, the absence of an active e-health policy, lack of funding, absence of data protection policy, bureaucracy and lack of health information systems integration and standards as well as deployment of almost identical multiple prototyping text messaging health interventions are among external barriers revealed by this study. The study also revealed that there are few mobile phone-based health applications piloted in low-resource settings to stimulate the adoption of mobile health services using feasible technologies. Such mobile health applications include RoadMApp health innovation to improve maternal health delivery (Dabengwa et al., 2022a; Nyati-Jokomo et al., 2020a), *SMS for life* (Dimaguila, 2015a), Two-way texting for male circumcision follow-up (Marongwe et al., 2022a), training adolescents about HIV/AIDS (Bertman et al., 2019); and CHIEDZA to improve access to and uptake of both HIV and young people’s sexual and reproductive health services (McCarthy et al., 2022).

In terms of ICT access, Table 4.10 shows that the majority of the participants have more access to mobile phones and radio as compared to other digital platforms such as television, Murambinda works (community network), and computers. This is exacerbated by the use of mobile money platforms to make financial transactions digitally (through Ecocash, Onemoney and Telecash) supported by high mobile phone penetration in rural communities (Dabengwa et al., 2022b).

The results in Table 4.9 shows that the community rarely use social media platforms such as Facebook, and WhatsApp to send and receive personal health information. However, there is an indication that some community members share general health-related information through WhatsApp groups. This corroborates with a study conducted by Chidhau et al.(2021b) indicated that during COVID-19 some people were sharing COVID-19 information using WhatsApp social media platforms. Nevertheless, sharing health-related information is generally discouraged to ensure security and privacy as well as the distribution of misinformation.

The study further revealed that the use of mobile phone-based interventions to disseminate malaria information in resource-constrained communities might be a feasible technology; however, such interventions can exacerbate inequity and the digital divide, especially if the interventions require internet connectivity and other extra costs associated with service provision. The findings of this section achieved the following research objective;

- Explore and implement the most feasible digital technology, which includes investigating mobile technology and alternatives, for malaria health information dissemination and digital awareness, based on the previous investigation, to reduce malaria incidences in rural communities.

8.2.3 Development and piloting of an ICT-based malaria intervention prototype to disseminate malaria information in rural communities

Key findings of this study revealed that routine malaria data are reported from two important systems in the national health surveillance systems. The two primary sources are rapid disease notification systems (RDNS) (Takarinda et al., 2022b) and health management information systems (HMIS). The monthly aggregated malaria data from all health facilities are sent through HMIS and RDNS weekly SMS reports collected from health facilities (Hannah et al., 2019). Malaria cases and deaths are inputted into DHIS2 at the district level and remotely accessible at the provincial and national levels (Maponga et al., 2014). Satellite health centres such as clinics report aggregated malaria monthly cases using T5 forms to the district, which are further captured by DHIS2 after being validated by health information officers at the district level (McCarthy et al., 2022). However, such reporting processes may cause data discrepancies and underestimation of cases. For instance, a recent Global Fund audit suggests that Zimbabwe seems to do well against the 90-90-90 targets because of a likely underestimation of people living with HIV (Global Fund, 2020). The audit detected a high discrepancy between data from Zimbabwe's National HIV Testing Services Strategy for 2017-2020 and the HIV programme data; and implausible estimates that suggest data inaccuracies (Ozano, 2022). Therefore, there is a need to develop measures to curb data discrepancies and reporting inconsistencies at the district level. Such measures might include developing smart applications that can detect data inconsistencies and anomalies at the district level during the data validation stage by health information officers.

In addition, the study revealed that the available applications such as DHIS2, HMIS, RDNS and WDSS are generally designed for reporting, surveillance, and detection of disease outbreaks at district, provincial and national levels. There are few digital interventions (radio and television) developed to create malaria awareness and intensify social and behaviour change communication (SBCC) at the ward level, especially in malaria hotspot areas. Even though radio and television programmes have been utilised for SBCC, the effectiveness of these interventions is not yet known (Ozano, 2022). There is a need for continued sensitisation of vulnerable communities through feasible technologies to intensify information, education, and communication programmes in rural districts to enhance the uptake of malaria interventions; and in the case of LLINs, to counter misuse and inconsistent use. Assessing digital literacy and the impact of information diffusion methods including digital technologies in creating malaria awareness in vulnerable resource-constrained rural communities is another gap that has not yet been filled. A report from the US-based President's Malaria Initiative (PMI) responsible for evaluating malaria outbreak detection and response, predominately at the national and provincial levels, corroborated these findings, citing poor completeness and timeliness of the outbreak detection and response system as a serious challenge to early detection of malaria outbreaks. A study conducted by Hannah et al.(2019) also cited a dearth of digital interventions and foci response guidelines in low-incidence districts working to achieve malaria elimination, changes in vector behaviour, resistance to insecticides, and reduced use of long-lasting insecticide nets as contributors to continued malaria transmission.

Key findings of this study also revealed that rural health centres have traditionally been disseminating malaria information through dramatisation, school outreach programmes, community gatherings, posters, billboards, and pamphlets among others, some of which may not be feasible during pandemics such as COVID-19. Therefore, it is imperative to develop feasible information dissemination methods, such as through mobile phones, radio, and television to ensure continued malaria sensitisation and awareness. Therefore, to explore the premise that integrating feasible digital malaria interventions in vulnerable resource-constrained rural communities may create awareness and improve malaria healthcare services, the study developed and explored an ICT-based malaria intervention prototype to disseminate malaria information in rural communities. The development of the prototype was guided by design science methodology. The key findings of this section achieved the following objective.

- Develop an ICT intervention system to disseminate information in rural communities.

8.2.4 Modelling predictors for the adoption of ICT-based malaria intervention by health workers in rural communities.

After developing and deploying an ICT-based malaria intervention prototype to disseminate malaria information in rural communities, the study assessed predictors for the adoption of such interventions by health workers to create awareness and intensify SBCC in vulnerable wards. The study utilised a modified UTAUT model to assess predictors for the adoption of the prototype. The modified UTAUT model shown in Figure 6.1 was used to develop constructs and hypotheses that were further tested using partial least squares structural equation modelling. The findings of this study show that social influence, facilitating conditions, and effort expectancy smooth the adoption of mobile phone-based interventions to create malaria awareness, reporting, and surveillance as well as sharing and receiving malaria data to and from satellite health centres. Among these predictors, facilitating conditions and effort expectancy influence health workers' attitudes towards mobile phone-based malaria interventions. These results are in line with previous studies such as Kijsanayotin et al. (2009) and Hoque & Sorwar (2017b) which posit that social influence, facilitating conditions and effort expectancy positively influence users to adopt digital interventions. For instance, a study conducted by Shiferaw & Mehari (2019) indicated that performance expectancy, social influence and attitude have a significant influence on participants' intention to use an electronic medical record system. The study further found that social influence ($\beta = 0.032$, $p<0.05$) positively influences health workers' behavioural intention to use mobile phone-based malaria interventions, leading to the acceptance of H4. This is in line with a study conducted by Shiferaw & Mehari (2019).

Furthermore, the study revealed that facilitating conditions also influence positively behavioural intention ($\beta = 0.023$, $p<0.05$) and attitude of health workers towards using mobile phone-based malaria interventions ($\beta = 0.002$, $p<0.05$). Providing health workers with resources and technological infrastructure such as mobile phones, training, internet access and connectivity, good network signals and reliable power supply among others can motivate them to effectively utilise mobile phone-based interventions to fight malaria in resource-constrained communities. Several studies noted that facilitating conditions are imperative for technology adoption, especially in the health sector (Alam et al., 2020; Hoque & Sorwar, 2017b; Kijsanayotin et al., 2009; Rajak & Shaw, 2021; Shiferaw & Mehari, 2019). In addition, the expected expectancy has a positive reverberation on the health workers' attitude ($\beta = 0.005$, $p<0.05$) and behavioural intention to use mobile phone-based malaria interventions ($\beta = 0.012$, $p<0.05$). These findings are supported by previous studies such as Arfi et al. (2021) and Barua & Barua (2020). Therefore, H4, H5, H6, H7 and H8 were supported in this study. The findings of this section achieved the following research objective;

- Explore the views, attitudes and perceptions of healthcare professionals and communities towards the adoption and use of low-cost malaria intervention systems to disseminate malaria information.

8.2.5 Mapping malaria hotspots and modelling micro-spatial patterns of malaria cases and environmental risk factors in malaria-endemic areas.

After modelling predictors for prototype adoption, the study collected secondary data, malaria cases and deaths from DHIS2, for the period 2015-2019 to determine the spatial distribution of malaria cases in the district. This is because there are limited studies focused on the micro-geographical scale, especially in malaria-endemic wards. The findings of this study revealed that malaria cases vary substantially within the district because of several factors, including environmental risk factors, distribution of LLINs, IRS activities and coverage among others. Due to these factors, administrative wards within the district were clustered into different groups such as malaria-free, low malaria sporadic, high malaria sporadic and high malaria perennial based on malaria intensity (cases). The study revealed that Ward 28 (Chapanduka) and Ward 33 (Birchenough Bridge) are high malaria perennial wards and hotspot wards. After identifying malaria hotspot wards, the researcher collected environmental data (such as day land surface temperature, night land surface temperature, rainfall, NDVI and EVI) from CHIRPS and MODIS. Previously confirmed malaria cases were collected from DHIS2. The spatial analysis and varying relationships between malaria cases and environmental risk factors were performed using Geographically Weighted Poisson Regression (GWPR). The association between environmental risk factors and malaria incidences was measured using AICc, R-squared (R^2) and adjusted R-squared values for ward 33 and 28. The study revealed that Ward 33 recorded a high R^2= 0.351626 as compared to Ward 28, this means that there is a small positive association between malaria cases and environmental risk factors. The difference between wards' R-squared is 0.007062, which means that the considered exploratory variables contribute almost the same towards malaria incidences in the period recorded. Key findings of this study show that there is a positive association between rainfall, land surface temperature (day) and NDVI and malaria cases in both wards. These findings may be helpful in different ways including developing timely malaria interventions specifically targeting malaria hotspot areas, stocking malaria commodities on time, effective allocation of resources, determining the right time for carrying out IRS activities, intensifying awareness, and mapping spatial patterns of malaria cases. The findings of this section achieved one of the research objectives of this study, namely;

- Mapping malaria hotspots and modelling micro-spatial patterns of malaria cases and environmental risk factors in malaria-endemic areas.

However, malaria outbreak is also associated with other factors including socioeconomic factors (wealth index, family income), implementation of malaria prevention and control measures including indoor residual spraying, distribution of insecticidal-treated nets, and artemisinin-based therapy. Additionally, excessive rains, resistance to the antimalarial drug, and lack of funding also contribute towards malaria outbreaks. These factors were not included because of several reasons including lack of data, lack of funding and malaria commodities

8.2.6 Predicting malaria using malaria cases and environmental risk factors in malaria-endemic areas.

Key findings of this study revealed that malaria outbreaks can be predicted using environmental risk factors. After confirming the spatial distribution of malaria cases in the district as well as associated environmental risk factors, the study further applied machine learning models such as logistic regression, support vector machine, decision tree and random forest to predict malaria in Birchenough Bridge ward. Among the high malaria perennial wards, Birchenough Bridge ward reported the highest number of malaria cases as compared to Chapanduka Ward. Hence, the selection of the ward for prediction purposes. The study applied SMOTE to address the class imbalance in the target class and assess the performance of machine learning-based malaria prediction models. The models' performance was assessed using evaluation metrics such as accuracy, recall, F1-score, and precision.

Table 8.1: Performance of malaria prediction models

Model	Accuracy	Precision	Recall	F1-score
Logistic regression	0.83	0.82	1.00	0.90
Support vector machines	0.77	0.78	1.00	0.88
Decision tree	0.66	0.79	0.79	0.79
Random forest classifier	0.83	0.87	0.93	0.90

The findings revealed that logistic regression and random forest classifier both achieved 83% prediction accuracy. However, the random forest classifier achieved 87% precision and the decision tree was least performed with a prediction accuracy of 66%, a precision of 79%, a recall of 79% and an F1-score of 79% as shown in Table 8.1. This study shows that human, financial, and physical (vehicles and amount of ITNs) resources, intervention policy and optimising the distribution and deployment of indoor residual spraying teams and spray equipment can help high sporadic wards such as Birchenough Bridge and Chapanduka to strengthen malaria prevention and control measures. The findings of this section achieved the following research objective;

- Predict malaria outbreak using malaria cases and environmental data in malaria-endemic rural areas.

8.2.7 Adoption of ICT-based interventions to improve access to healthcare service

The results of this study show that social influence, facilitating conditions, and effort expectancy facilitate the adoption of mobile phone-based interventions to create malaria awareness, reporting, and surveillance as well as sharing and receiving malaria data to and from satellite health centres. Among these predictors, facilitating conditions and effort expectancy influence health workers' attitudes towards using mobile phone-based malaria interventions. These results are in line with previous studies such as Kijsanayotin et al. (2009) and Hoque & Sorwar (2017b) which posit that social influence, facilitating conditions and effort expectancy positively influence users to adopt digital interventions. For instance, a study conducted by Shiferaw & Mehari (2019) indicated that performance expectancy, social influence and attitude have a significant influence on participants' intention to use electronic medical record systems. The study further found that social influence ($\beta = 0.032$, $p<0.05$) positively influences health workers' behavioural intention to use mobile phone-based malaria interventions, leading to the acceptance of H4. This is in line with a study conducted by Shiferaw & Mehari (2019). However, social influence was found to negatively influence attitude ($\beta = 0.251$, $p<0.05$), leading to the rejection of H3. This is in support of a study conducted by (Sitar-Tăut, 2021b). Furthermore, facilitating conditions also positively influence behavioural intention ($\beta = 0.023$, $p<0.05$) and the attitude of health workers towards using mobile phone-based malaria interventions ($\beta = 0.002$, $p<0.05$). Providing health workers with resources and technological infrastructure such as mobile phones, training, internet access and connectivity, good network signals and reliable power supply among others can motivate them to effectively utilise mobile phone-based interventions to fight malaria in resource-constrained communities. Several studies argue that facilitating conditions are imperative for technology adoption, especially in the health sector (Alam et al., 2020; Hoque & Sorwar, 2017b; Kijsanayotin et al., 2009; Rajak & Shaw, 2021; Shiferaw & Mehari, 2019). In addition, effort expectancy has a positive reverberation on the health workers' attitudes ($\beta = 0.005$, $p<0.05$) and behavioural intention to use mobile phone-based malaria interventions ($\beta = 0.012$, $p<0.05$). These findings are supported by previous studies such as Arfi et al. (2021) and Barua & Barua (2020). Therefore, H4, H5, H6, H7 and H8 were supported in this study. However, performance expectancy was insignificant as regards BI ($\beta = 0.107$, $p<0.05$) and health workers' attitudes towards using mobile phone-based malaria interventions ($\beta = 0.097$, $p<0.05$). The results corroborate the findings of Dwivedi et al.(2020) and H. Wang et al.(2020). Also, the hypothesised relationships such as SI and AT ($\beta = 0.251$, $p<0.05$), and AT and BI ($\beta = 0.177$, $p<0.05$) were insignificant and not supported in this study. Furthermore, mediation analysis was performed to assess the mediating role of attitude outcomes with other constructs (PE, EE, FC, SI). The results show that there was a mediation effect between SI->AT-BI ($\beta = 0.326$, $p<0.05$), PE->AT->BI ($\beta = 0.204$, $p<0.05$), EE->AT->BI ($\beta = 0.201$, $p<0.05$) and FC->AT-BI ($\beta = 0.206$, $p<0.05$).

8.2.7.1 Theoretical, methodological, and practical implications

This study presents good opportunities to integrate digital malaria interventions in rural health systems to alleviate malaria. Therefore, this study has theoretical, methodological, and practical implications. Theoretically, the study empirically assesses the role of health workers in adopting mobile phone-based interventions that could be utilised to alleviate malaria in the rural community. Methodologically, the study contributes through the design, development and deployment of an artefact while demonstrating the applicability of the modified UTAUT model for understanding technology acceptance by health workers in malaria-endemic rural communities. Several studies investigate the adoption of technology by the general population or certain professionals. In addition, this study took an important step towards exploring several less-examined constructs and relationships integrating malaria mobile applications in rural communities.

Practically, the study contributes to the existing literature on the effective integration of digital malaria intervention that could probably lead to the development of malaria applications customised to address specific malaria challenges faced by rural communities. In addition, this could lead to the development of mobile health frameworks and policies that incorporates emerging technologies such as mobile phones in the delivery of malaria healthcare services, especially in resource-constrained areas. Understanding important indicators and constructs such as facilitating conditions, social influence constructs and effort expectancy can facilitate the adoption and use of mobile phones to improve healthcare services and subsequently reduce malaria in rural communities by integrating mobile phone-based malaria interventions. Specifically, the results of this study suggest that improving digital literacy, network connectivity, resource availability and accessibility, digital infrastructure, and digital devices such as mobile phones, tablets, laptops and computers can increase the possibility of high technology adoption in rural communities.

8.3 Challenges affecting the adoption of ICTs in rural communities to improve healthcare service

Table 4.12 shows that network challenges, poor access to electricity, high cost of ICT devices, unavailability of ICT devices, poor access to ICT devices, digital literacy, lack of health information written in vernacular language, cultural issues, religious issues, use of technical language, poor data security, lack of patients' data privacy, lack of mobile health policy, and incompatibility of mobile health applications are among barriers affecting the adoption of ICTs in Buhera rural health systems. These findings correlate with the findings of the following researchers.

(i) Internet access and network coverage

Despite the substantial increase in mobile phone penetration, internet access and network coverage remain a challenge for integrating mobile health applications to improve access to care in rural communities The study revealed that (see Figure 4.14) 44% of the participants have internet access and 56% do not have internet access. A study conducted by Marufu & Maboe (2017a) states that access to internet access is slow and too unreliable to warrant mobile health interventions as a reliable channel of providing healthcare services, especially in rural communities. Intermittent and connectivity challenges and local perceptions of mental health interventions may affect the uptake, feasibility, and acceptability of mobile health solutions in Zimbabwe (Dambi et al., 2022). These challenges affect the adoption and use of mobile technology to improve healthcare service delivery.

(ii) Absence of personal emotions

The information in Table 4.14 shows that providing care to patients with chronic conditions requires face-to-human interaction to assess and diagnose which might be difficult through mHealth interventions (Marufu & Maboe, 2017a). This is a major drawback, especially for patients with chronic conditions.

(iii)Lack of Knowledge and digital skills

Using mobile health interventions to deliver healthcare services requires digital skills and training. A study by Marufu & Maboe (2017a) also alluded that 50% of medical doctors lacked the knowledge or were not aware of the use of m-Health in supporting the chronically ill. In support, a study conducted by Furusa & Coleman (2018) state that inadequate ICT skills and knowledge among the medical doctors in the health sector in Zimbabwe explains the low adoption of e-health in public hospitals. Despite digital skills, in rural communities, smartphone ownership is lower than in urban areas (Maphosa, 2022b), making it difficult to roll out mobile health smart applications. Therefore, there is a need to develop low cost feasible digital solutions that utilize SMS or USSD technologies to disseminate health information.

(iv) Lack of funding and weak health systems

A study conducted by Dabengwa et al.(2022b) also alluded that lack of funding and reliance on donor funding affect the rolling out and sustainability of mobile health applications as well as procurement of infrastructure. Their study further revealed that improving birth preparedness and complications readiness while reducing maternal complications is greatly affected by poor transport networks, lack of safety on transport choices, the high cost of travel and poor ambulance system fueled with macroeconomic barriers such as the lack of employment, and inflation. Because of these challenges, communities may develop apathy for mobile health technology. Zimbabwe's healthcare infrastructure is experiencing challenges due to the lack of funding and economic meltdown which consequently led to inadequate healthcare facilities and high staff turnover of health workers (Maphosa, 2022b). In addition, the lack of coherence and cooperation between Ministries, donors, and implementing partners remains a major challenge for digital health to deliver maximum benefits to vulnerable communities as alluded by Marongwe et al.(2022b).

Additionally, a study conducted by care Nyati-Jokomo et al.(2020b) also highlighted distal, proximal and transit factors that affect the adoption and rollout of mobile health interventions and access to care (Nyati-Jokomo et al., 2020b). Proximal factors include meteorological and terrain barriers; transit factors include ergonomics, transport time and support from health regulators; and lastly, proximal factors consist of available transport options, religion, culture and finance (Nyati-Jokomo et al., 2020b). In some instances, where health facilities are distant from recipients of care, socioeconomic status plays an important role to determine the mode of transport and associated transport costs.

(v) Consistent power outages

Other challenges emanating from the findings include lack and inconsistent power supply in rural communities. Mobile phones require constant battery charging, which might not always be possible because of constant load shedding. In some hard-to-reach communities, there is no electricity connection which consequently deprives the community of utilizing mobile health technologies. This corroborates with the findings of a study conducted by Nyati-Jokomo et al.(2020b) on implementation challenges for the RoadMApp mobile application to enhance maternal health delivery in low-resource settings. A study also conducted by Maphosa (2022b) alluded that some rural communities have limited or no Wi-Fi access and communities may struggle to buy data and face network challenges due to intermittent power and load shedding.

(vi) Lack of active mobile health policy and framework

Even though the nation has an e-health plan (draft version 2012–2017) that was created with the assistance of WHO based on the ITU/WHO toolkit, there is a lack of the necessary policies to direct e-health development and technological dissemination in public hospitals. A study conducted by Furusa & Coleman (2018) highlighted that doctors identified problems with health policies that do not support the implementation of e-health systems in Zimbabwe. In light of this, a lack of a defined health strategy may hinder the effort to adopt e-health systems at all levels of healthcare. Moreso, the interoperability of existing digital health tools in health systems also affect the scaling-up of evidence-based innovations, especially in rural communities (Gaobotse et al., 2022) despite the progress made by the previous prototypes and Health Information Systems (HIS) as well as electronic medical records (EMR) (Marongwe et al., 2022b). Therefore, there is a need for developing policies that support the integration and scaling of mobile health applications to improve access to care (Mbunge et al., 2022).

(vii) *Corruption*

A study conducted by Chidhau et al.(2021b) alluded that corruption has remained a stumbling block, bedevilling the use of digital health interventions in Zimbabwe. For instance, during COVID-19, the former Health Minister was charged with criminal abuse of office over the alleged awarding of a $60 million contract for COVID-19 to Drax International LLC (Chidhau et al., 2021b). Corruption drains the budget allocated to the health section leading to critical financing and funding gap with most partners focusing on humanitarian needs supporting the most immediate requirements of the people of Zimbabwe, especially during the COVID-19 pandemic.

(viii)Theft of mobile phones

A study conducted by Feldacker et al.(2020) highlighted that barriers such as phone theft, damage, phone sharing, change of phone numbers, SIM card issues, poor electricity access, or poor cell networks jeopardized potential client contacts the rolling out, usability and acceptability of a two-way texting intervention for post-operative follow-up for voluntary medical male circumcision in Zimbabwe.

CHAPTER 9: M-HEALTH FRAMEWORK FOR INTEGRATING ICT-BASED MALARIA INTERVENTIONS IN RESOURCE-CONSTRAINED AREAS

9.1 Introduction

The previous chapter focused on the discussion of findings emanating from literature and data collected during the pre-test and post-test phases. This chapter presents the proposed mobile health framework for integrating ICT-based malaria interventions.

9.2 m-Health Framework for disseminating malaria information in rural communities

Several scholars proposed mobile health frameworks (see Table 9.1) to improve access to care through digital technologies in sub-Saharan Africa. The findings of this study revealed that several frameworks (see Table 9.1) were developed before the outbreak of coronavirus disease in 2019. However, the outbreak of COVID-19 brought a new dimension to delivering healthcare services by incorporating customised mobile health interventions that address specific health needs and challenges. For instance, providing care while observing social distancing measures requires robust and feasible mobile health interventions supported by both health workers and patients to ensure real-time communication, reporting and surveillance of malaria. However, using existing m-Health frameworks (including those in Table 9.1) to improve care services for people living in resource-constrained areas during the pandemic becomes contentious due to the unavailability of mobile health interventions in some resource-constrained rural communities (Osei & Mashamba-Thompson, 2021). This might also have contributed to malaria resurgence in some areas during COVID-19 in sub-Saharan African countries, Zimbabwe without exception.

Table 9. 1: Summary of mobile health frameworks in sub-Saharan African countries

References	Purpose	Setting	Limitations
(Mwendera et al., 2017)	The contextual framework intends to improve the utilisation of malaria research for	National level in Malawi	The framework focuses only on malaria policies to promote coordinated and integrated approaches to knowledge translation. The

	policy and practice to reduce malaria		framework does not include the use of ICTs in malaria research
(Thobias & Kiwanuka, 2018)	m-Health data framework to improve health information access for antenatal care using SMS.	Low resource settings of Chamwino district, Tanzania	No real-time bidirectional communication between health workers and pregnant mothers. Also, the framework only considers one form of communication, the SMS platform, which might not be the only feasible platform for other settings. Pregnant mothers are expected to regularly visit health facilities for regular check-ups, which is the best practice under normal circumstances, however, because of COVID-19, alternative means are required to improve care services delivery
(Mark & Ngwira, 2011)	Ubiquitous framework for planning, management of patients' records and basic diagnostic support	African states	The framework is generalised to African states to collect patients and resource allocation and utilisation. However, each African state has its own ICT infrastructure and health policies which can differ from each because of factors such as network penetration, mobile technology usage, and policies among others.
(Ndayizigamiye & Maharaj, 2016)	Framework for adoption of m-Health in Burundi	m-Health adoption in Burundi	The framework assesses Burundi's readiness to adopt m-Health into the health system focusing more on perceived challenges.
(Mukami et al., 2019)	ICT framework for mitigating the	Kajiado North, Kenya	The framework does not specify the kind of ICT technology to be used and

	determinants of maternal and neonatal mortality		assumes that due diligence towards the implementation of the technology has been conducted. Also, the framework does not cluster maternal healthcare services based on highlighted extrinsic variables and underlying factors.
(Agbehadji et al., 2019)	Framework for delivering basic healthcare services to the aged person using mobile technology	Volta Region, Ghana	The framework focuses only on the provision of care to aged persons by utilising mobile phone platforms.

The findings of this study also revealed that the adoption and utilisation of m-Health interventions to improve malaria healthcare services is still low in Zimbabwe despite the existence e-Health strategy (2012-2017). A study conducted by Nyati-Jokomo et al.(2020a) also noted that there is a lack of guidelines and standards for guiding the design, development, testing, deployment and integration of mobile health interventions to improve health services delivery. Mobile health interventions including remote patient monitoring applications, smart wearables devices and smart health applications present unprecedented opportunities to transform healthcare services by supporting virtual care and ultimately strengthen healthcare services, especially in resource-constrained areas. Such technologies provide different services beyond simple voice calls and capture and transmit reports through text messaging by incorporating emerging digital health technologies into the health system. For instance, during the COVID-19, several digital health interventions such as telemedicine, electronic health records, drones, smart mobile health applications, and smart wearable devices substantially improved health service delivery while reducing risk exposure and maintaining social and physical distancing guidelines (Alharbi & Abdur Rahman, 2021; Ting et al., 2020).

However, fewer digital health interventions are evaluated and those that are and that show a positive effect on health outcomes are not always implemented (McCarthy et al., 2022), especially in resource-constrained rural communities. The adoption of digital health interventions can help to alleviate malaria and other neglected diseases in vulnerable rural communities through improved awareness, community engagement, disease surveillance, detection, mapping, reporting and data management. A study conducted by Marufu & Maboe (2017b) also noted that there is little evidence of m-Health utilisation as well as a lack of documentation on the m-Health projects which consequently leads to the development of multiple prototypes with almost similar functionalities. Therefore, there is a need for revising the e-health strategy 2012-2017 and developing a m-Health framework guiding the integration of ICTs into health systems especially in resource-constrained rural communities to ensure inclusive and universal access to care and health information. Hence the study developed a micro-tailored m-Health framework for improving malaria information dissemination in rural communities, giving special reference to Buhera rural district as one of the malaria-endemic areas in Zimbabwe. The proposed framework shown in Figure 9.1 was developed informed by study findings, literature analysis, Ministry health systems and best practices around the world when deploying mobile health interventions while contextualising this to rural settings in Zimbabwe.

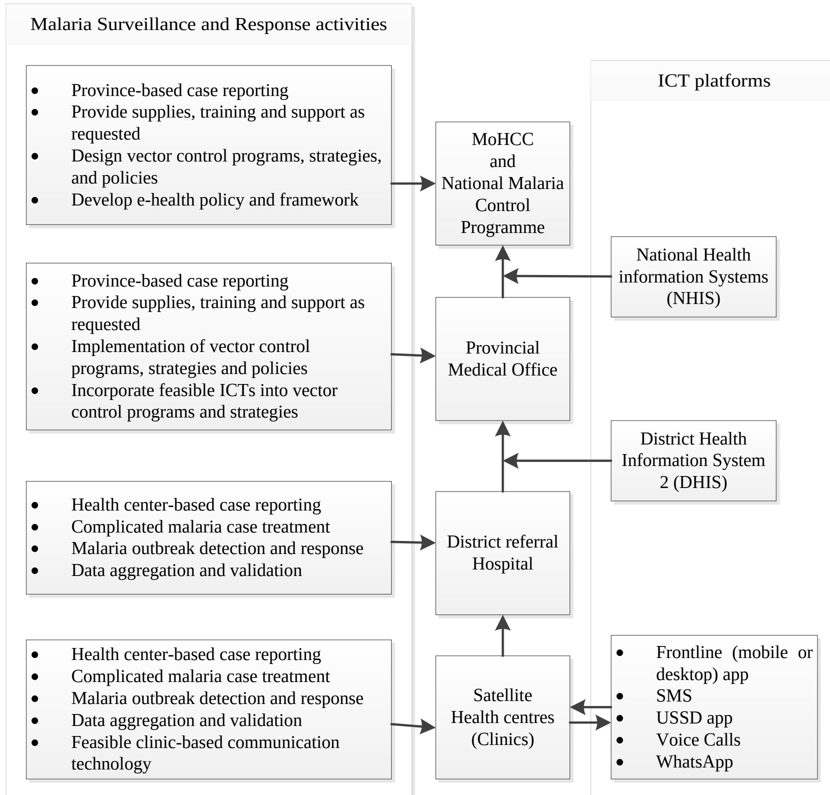

Figure 9. 1 Proposed m-Health for improving malaria information dissemination in rural communities

The proposed m-Health framework for improving malaria information dissemination shown in Figure 9.1 consists of malaria surveillance and response activities, mobile health interventions and health facilities. This is an additional uniqueness of this study as it incorporates feasible digital technologies to disseminate health information in rural communities. Digital technologies included in the proposed framework shown in Figure 9.1 were gathered during the pre-test stage to determine the most feasible health information dissemination platforms. The proposed framework fits within the existing Zimbabwe health system structure. Zimbabwe's malaria reporting structure generally consists of the MoHCC (National Malaria Control Programme - a malaria wing within the Ministry), Provincial Medical Office, the District referral hospital, and satellite health centres. Malaria surveillance and response activities as well as malaria health interventions at each level within the structure are explained in the subsequent sections. The proposed framework is based on Zimbabwean rural communities, but can it be adapted worldwide, especially in developing countries. The framework can be utilised in resource-constrained areas that rely on mobile phones for communication. The utilisation of the framework requires rigorous and inclusive participation and engagement of stakeholders such as health workers, communities, and regulatory authorities to develop feasible mobile health applications that address community-based health information dissemination challenges. Community engagement can be done at the initial stage, and the development and deployment stage through baseline surveys and interviews to understand the problem related to health communication as well as testing the prototype. There is also a need for multisectoral involvement and partnerships among government ministries especially MoHCC and the Ministry of ICTs to improve network coverage, health data security and privacy, and craft mobile health framework and policies that guide the development and deployment of mobile health applications.

(i) MoHCC and National Malaria Control Programme (NMCP)

The MoHCC is a government ministry responsible for health in Zimbabwe. Within the Ministry, there is a wing (National Malaria Control Programme) responsible for coordinating malaria prevention and control measures to tackle malaria. The National Malaria Control Programme should develop national malaria control and prevention strategies, policies and frameworks guiding national malaria eradication activities. This involves developing guidelines and initiatives for resource mobilisation, malaria funding, facilitating malaria eradication cross-border initiatives, coordinating partnerships, and rolling out malaria digital interventions for nationwide malaria reporting, monitoring, and surveillance. To ensure effective nationwide malaria monitoring, reporting and surveillance, the Ministry utilises national health information systems to collate monthly malaria cases from all provinces (Osei & Mashamba-Thompson, 2021). The province receives monthly malaria data from several districts through DHIS software and rapid disease notification systems, which are further synchronised with NHIS. With such big data, the Ministry can advocate the development of data-driven mobile health interventions as part of malaria control measures, as shown in Figure 9.2. Such interventions can be used to effectively develop malaria early warning systems, map malaria hotspots, predict malaria in real-time, understand vector breeding and biting behaviour, e-surveillance, real-time monitoring, and reporting as well as effective resources, giving priority to endemic wards. This can be achieved through the massive collection of data contributing to malaria outbreaks at the data acquisition stage, as shown in Figure 9.2.

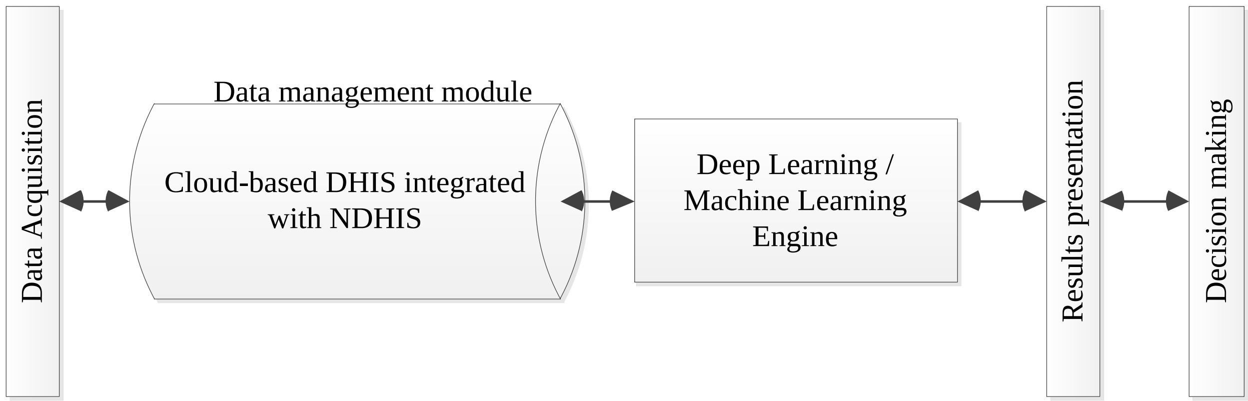

Figure 9. 2: Data-driven malaria digital intervention

A. Data Acquisition

The data acquisition stage involves the collection of data associated with high malaria incidences. Such data include climatic and environmental risk factors (Gunda et al., 2017), socio-economic factors of the vulnerable populace (Manyangadze et al., 2021a), indoor residual spraying activities and coverage. Malaria transmission and intensity vary, therefore, there is a need to collect massive data at the micro-level (especially wards) to identify specific factors contributing to high malaria incidence and develop customised interventions tailored to address their specific needs. Malaria cases captured weekly can be effectively utilised to understand malaria transmission, map hotspot areas at the ward level, understand vector biting behaviour and breeding sites and subsequently inform health workers about the need for taking remedial action. Automating data acquisition can assist in reducing human errors.

B. Data management module

The data management module stores input data collected in the data acquisition phase. The data management module should be able to upload and store different input data formats for further analysis when integrated into the NHIS as it tends to increase its size and capacity. Emerging features such as big data storage capacity (cloud-based storage), enhanced scalability to handle the increased load, concurrent access, and significant performance improvements, especially for large-scale tracker implementations have been implemented in the latest DHIS v2.36 and Android v2.4. These functionalities pose tremendous opportunities in storing, processing, analysing, and tracking malaria incidence at a massive scale.

C. Deep learning or machine learning engines

Deep learning or machine learning engines should process and analyse data from the data management module to extract meaningful patterns to assist health workers and policymakers to make informed decisions. The study revealed that text messaging platforms have been predominantly used to report malaria cases and send reminders. However, there is a need to re-orient malaria control and prevention measures by incorporating emerging technologies such as deep learning, machine learning and mobile technology cognitive computing. These emerging computational techniques are increasingly becoming important in tackling malaria, for instance, (Masud et al., 2020) developed a smart mobile application to detect malaria parasites using deep learning and microscopic images. Such applications can be used to identify malaria parasites in areas that experience different malaria parasites or specificities. Integrating intelligent-based computational techniques such as deep learning and machine learning can assist to develop malaria decision support systems (Yang et al., 2020), early warning systems, predicting malaria (Kamana et al., 2022), detection of malaria from microscopic images (Vijayalakshmi & Rajesh, 2020), cluster malaria hotspot districts and ultimately assist to intensify malaria prevention and control measures in resource-limited areas. However, in this study malaria machine learning models were utilised to predict malaria in malaria hotspot areas using environmental risk factors.

D. Results presentation and decision making

The results presentation displays processed data from deep learning or machine learning engines. The processed results can be presented graphically and could be used for real-time reporting. Decision-makers can utilise the results to make informed decisions for effective resource allocation, prepare for malaria outbreaks, intensify case management (Harp et al., 2021), automate alerts and warning systems (Wimberly et al., 2022); map malaria hotspots at micro-level cascading down to endemic wards. Such integrating technologies may enable better policymaking that addresses malaria-specific challenges in different areas as some wards move towards pre-elimination.

(ii) Provincial Medical Officer

Various district health offices use DHIS to send malaria data to the provincial medical office, which is immediately synchronised with the MoHCC through NHIS. The provincial office should facilitate the implementation of malaria control strategies, guidelines, and policies from the NMCP through routine training and support as requested, as well as enabling resource allocation and province-based reporting. In addition to reporting malaria, the provincial office can also facilitate the development of guidelines and standards for developing and deploying feasible malaria digital health interventions to intensify malaria awareness, social and behaviour change communication, community engagement, distribution of insecticide-treated nets, and strategic timing of indoor residual spraying activities among others, as shown in Figure 10.2. Once guidelines and standards for integrating feasible technology are developed, they can be implemented at the district level in routine consultation with the provincial office.

(iii) District Referral Hospital

The district referral hospital is responsible for malaria data aggregation and validation. Data captured using T5 forms from satellite health centres are mostly aggregated and validated on weekly basis at the district level before being accessed through DHIS (Hannah et al., 2019). This allows the synchronisation and consolidation of malaria data as well as the coordination of malaria surveillance activities in all satellite health centres. Digital technologies such as text messaging, WhatsApp, voice calls, and frontline applications can be utilised to report malaria. Rural communities also utilise these platforms to report malaria to health workers stationed in the satellite health centres.

(iv) Satellite health centres

The findings of this study revealed that the majority of satellite health centres use posters, flyers, charts, outreach activities and community gatherings to create awareness. However, due to the high cost of printing, bad weather and COVID-19, these traditional awareness methods are not all that effective at intensifying malaria awareness. To curb these impediments, the proposed framework suggests the development, deployment, and integration of feasible mobile malaria health interventions to disseminate malaria information in resource-constrained communities. Such interventions may include text messaging services, USSD services, voice calls and the development of customised zero-rated frontline mobile applications. The development of such interventions should follow guidelines and standards from the Ministry. However, the development and deployment of mobile malaria digital interventions such as text messaging, mobile apps and USSD apps should include all stakeholders and follow the following steps shown in Figure 9.3.

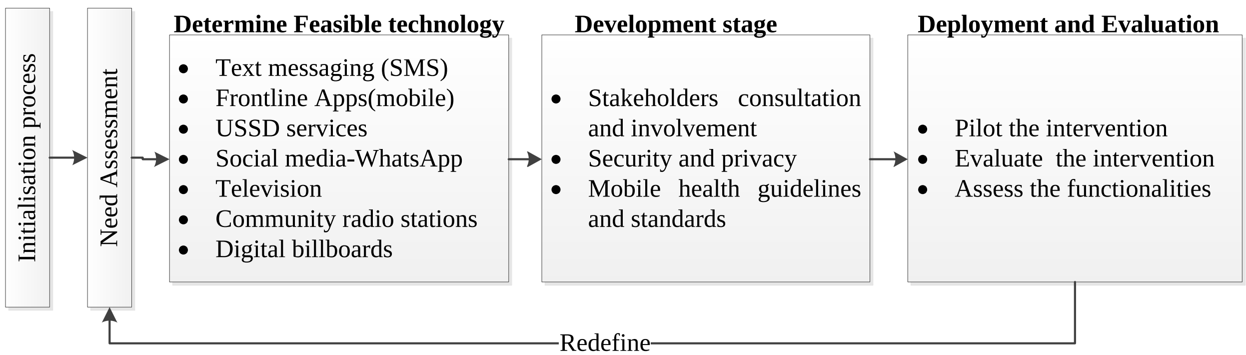

Figure 9. 3: Malaria digital intervention development phases

A. Initialisation process

As shown in Figure 9.3, it is the starting point for developing malaria digital interventions. This stage involves the identification of high malaria perennial wards and initiating the investigation of major causes of high malaria incidences. The initiation process can be done by consulting health workers, policymakers, and the community to understand the major causes and malaria cases. At this stage, the problem being investigated, objectives and potential contribution of the findings should be clearly outlined.

B. Need assessment

After the initialisation process, the next step is to collect data from the participants. The data collected from the participants include user requirements, user expectations, and possible feasible technologies to be adopted to address the problem. To carry out a need assessment, the research should apply for ethical clearance and engage relevant stakeholders to get more detailed information. Some authors including (Nyati-Jokomo et al., 2020a) suggest that a comprehensive systematic review of published reports, conference papers and journal papers can be used to gather more during the need assessment. A study conducted by (Nyapwere et al., 2021b) also indicated that need assessment can be done through survey questionnaires (baseline survey), interviews and focus discussion groups to gather more information before system development. In this study, the researcher used a systematic literature review, document analysis (published malaria reports and malaria cases from DHIS2), and survey questionnaires during the pre-test and post-test phases.

C. Determining feasible technology

The findings of the need assessment can assist researchers in determining the most feasible technology to adopt or develop to address the problem. This can be achieved by understanding the characteristics of the target population, the common technology being used by the participants and supporting digital infrastructure. In this study, the key findings of the survey questionnaire during the pre-test phase show that the majority of participants have access to mobile phones. However, some participants indicated that they have feature phones - hence the development of SMS modules and mobile applications as interventions to disseminate malaria information in resource-constrained rural communities.

D. Development stage

The development stage involves the actual development of the malaria mobile application. After analysing the findings of the need assessment, the researcher can identify mobile application development tools, technologies required to host the artefact and their respective cost implications for potential users. More so, the development process of an artefact should follow guidelines for system development. For instance, this study utilised design science methodology to guide the development of the proposed intervention. Nyati-Jokomo et al.(2020a) adopted an Agile software development model where project implementation is done iteratively or incrementally. During the development stage, user requirements and expectations should be carefully observed.

E. Deployment and evaluation

After the initial development, the intervention should be tested to check whether it conforms to user requirements and expectations. Before deployment, an artefact can be tested using unit testing, module testing and system testing to check faults and errors. During the deployment phase, the application must be tested by both the client and the end-users. Client testing involved both functionality and usability testing to check the application's functionality and compare it with the user requirements. The end-user testing involved usability testing to check the application's link validation, multiple browsers' support, and screen resolution. During the evaluation phase after deployment, health workers and the community can evaluate the performance of the artefact to check usability, functionality, user experience, and security. This is an iterative process which involves getting feedback from end-user and redefining the artefact to accommodate end-users' feedback (Nyapwere et al., 2021b; Nyati-Jokomo et al., 2020a). This section achieved the following research objective.

- Develop a contextual m-Health framework for improving malaria information dissemination using feasible digital technology in resource-constrained areas.

9.3 Chapter Summary

Therefore, this chapter summarized the key findings of the study while addressing one of the study objectives namely, "*Develop a contextual m-Health framework for improving malaria information dissemination using feasible digital technology in resource-constrained areas*." The chapter further analysed previous frameworks deployed in the context of mobile health and subsequently developed an m-Health framework for integrating feasible ICT-based mobile health interventions in rural health systems. The proposed framework was developed informed by study findings, literature analysis, and best practices around the world when deploying mobile health interventions while contextualising these to rural settings in Zimbabwe. Integrating mobile health interventions into the rural health system requires collaborative and collective efforts from all stakeholders to ensure inclusiveness and equal participation. This chapter also draws recommendations for policymakers and future researchers who might need to adopt the framework when developing mobile health applications to improve access to care in rural communities. The next chapter focuses on recommendations for the effective integration of digital health intervention in resource-constrained communities, a conclusion, and a direction for future work.

Chapter 10: Recommendations, conclusion, and future work

10.1 Introduction

The previous chapter summarised the key findings of the study and proposed a mobile health framework for integrating ICT-based malaria intervention in resource-constrained rural communities. The chapter highlighted key components of the proposed framework as well as key steps and procedures to be followed when developing digital interventions to disseminate malaria information in rural communities. This chapter presents the recommendations for the effective integration of ICT-based interventions into rural health systems. These recommendations tackle challenges that emerged from the findings and literature. In addition, this chapter also highlights the limitations of the study and future work. Therefore, the following section presents the recommendations for these aspects of the study.

10.2 Recommendations for effective integration of ICT-based interventions into rural health systems

- The key findings of this study revealed that mobile phones are the digital technology used in Buhera rural community. Such technology can be used to improve healthcare service delivery in various ways especially in rural communities by introducing low-cost feasible mobile health technologies. Adopting mobile health interventions can assist to intensify health promotion, improve health service delivery, and disseminate health information, education, and communication. Additionally, mobile health technologies can assist in collecting health data collection and management; training health workers and communities; disease reporting; detection; surveillance; mapping; reminders; treatment compliance and follow-ups. However, there is limited evidence on the utilisation of mobile health interventions to improve access to care at a large scale in rural health systems despite the high mobile phone penetration rate (Hatzold et al., 2014; Nyapwere et al., 2021b). Such information is imperative to inform the development of low-cost feasible mobile health interventions to ensure equitable and universal access to care.

Therefore, there is a need for future research to investigate factors influencing sustainability and continuous utilisation of mobile health applications deployed in resource-constrained rural communities.

- The findings of this study show that infrastructural barriers (Venables et al., 2019), technological barriers (Nyati-Jokomo et al., 2020a), socioeconomic challenges (Doyle et al., 2021), policy/regulatory barriers (lack of policy and m-Health frameworks), funding challenges, lack of standardised and reporting digital interventions, lack of effective digital awareness platforms (Gadkaree et al., 2019b), security, and ethical issues are among the factors contributing to low adoption mobile health digital interventions in resource-constrained rural communities.

- Another major challenge hindering the adoption of mobile health interventions in rural communities is inconsistent funding of m-Health interventions. Hence, relying more on donor funding poses a challenge to the sustainability of mobile health interventions in the long term. A study conducted by Leon et al.(2012) also noted that among other barriers, integrating new technology into an existing health information system is also an obstacle to the adoption of mobile health interventions. To address this, there is a need for establishing sustainable m-Health funding strategies and methods through private-public partnerships and joining available international initiatives advocating the integration of digital health interventions in resource-constrained communities. Financial and political commitments are required to expedite the modification and updating of the existing e-health strategy 2012-2017; m-Health policy, standards and guidelines; setting up digital health technologies and the support of m-Health research and development. Private-public partnerships should foster digital health sustainability, calling for significant investments from capacity strengthening through supportive infrastructure.

- Security and privacy were noted as major setbacks in disseminating sensitive health information using mobile phones. A study conducted by Venables et al.(2019) also noted that unintentional disclosure of sensitive health data due to sharing mobile phones is a major barrier; however, such concerns should not prevent the adoption of mobile health digital innovations but rather improve security. Therefore, there is a need to craft mobile health policies and guidelines for developing, deploying and integrating mobile health interventions into rural health systems. The study revealed that multiple similar prototypes are being developed and tested in various health centres to improve healthcare delivery for patients with different conditions such as HIV/AIDS (Bertman et al., 2019), using a two-way text-based tool (Venables et al., 2019), and also for maternal mothers (Nyati-Jokomo et al., 2020a). This shows positive progress towards the adoption of mobile health technologies, however, there is a need to develop guiding frameworks, policies, legislations, and ethical standards to govern mobile health interventions. Integrating mobile health interventions to improve malaria reporting, surveillance and detection requires inclusive participation of all stakeholders including health workers, supporting staff members, and the community. The study recommends training, as well as the provision of supporting systems and resources to ensure all stakeholders participate and utilise mobile health interventions in resource-constrained communities.

- Technological barriers such as intermittent internet signals, unreliable mobile network coverage, cost of internet bundles, and unreliable power supply especially in hard-to-reach communities (Osei & Mashamba-Thompson, 2021) are challenges that hinder the effective adoption of mobile health interventions in rural communities. This study also noted socioeconomic barriers such as the digital divide, language barrier (Mavunga & Kaguda, 2016; Svongoro & Matende, 2021), cultural and religious practices, and digital literacy as some of the major obstacles to mobile health interventions adoption. To alleviate these challenges, there is a need for establishing community networks (Gwaka et al., 2022), and expanding mobile network coverage to improve internet access and bridge the digital divide in rural areas. There is also a need for establishing multisectoral coherence and cooperation between Ministries and donors to increase network coverage and implement mobile health interventions in resource-constrained rural communities. In addition, access to some mobile health applications such as USSD and SMS-based interventions can be zero-rated in vulnerable resource-constrained rural communities. Sustainable means of supplying power to charge mobile phones such as central community-electricity hubs powered with solar energy can be explored to avoid the risk of exacerbating inequalities and exclusion in some rural communities.

- The study noted that clinic malaria reporting protocols are well-established, however, lack of daily reporting digital platforms, malaria data quality and inconsistencies and interoperability issues with other platforms (WhatsApp, voice calls, SMS) with NHIS (Venables et al., 2019) can subsequently lead to delayed reporting. This consequently creates challenges in timely malaria outbreak detection and surveillance. This corroborates the findings of a study conducted by Hannah et al.(2019). In addition, lack of clear guidance regarding when to scale back vector control interventions, lack of data for evidence-based decision-making, and failure to strengthen surveillance systems was also indicated as challenges by Sande et al.(2017). Therefore, there is a need to develop standardised and daily malaria reporting digital platforms for satellite health centres to address malaria data inconsistencies. Developing effective malaria reporting, surveillance and detection platforms using emerging digital technologies that can be easily synchronised with DHIS and NHIS might assist health workers and policymakers to strengthen malaria outbreak detection at the ward level, improve data quality and consistency by detecting anomalies at the clinic level, improve health workers' readiness for malaria outbreak response, and ultimately lead to timelier and effective outbreak response.

- The effectiveness of traditional information dissemination methods such as posters, dramatisation, community gatherings, flyers, radio and television as SBCC interventions is not yet known (Robert Avis, 2022). Therefore, the study recommends adopting utilising mobile phones for continued sensitisation of vulnerable rural communities and intensifying social and behaviour change communication through information, education and communication programmes. This will create awareness while enhancing the uptake of malaria interventions and facilitate the assessment of its impact in the long term. Applying the proposed framework such be done holistically by assessing the appropriateness and 'fit' of mobile health digital interventions such as mobile phones in the rural health system, as well as how mobile technology may be employed to add value in improving universal access to care, delivery of health services and health outcomes. Therefore, this study recommends the following:

- There is a need to assess rural communities' level of digital literacy to determine their ability to effectively use mobile health interventions (Nyati-Jokomo et al., 2020b).

- There is a need for iterative application upgrades to increase usability, which will, in turn, improve the scaling up of the existing mobile health solutions in Zimbabwe (Dambi et al., 2022)

- Develop a mobile health policy that supports the integration of low-cost and feasible mobile health technologies in marginalized communities.

- Assess progress made by previous prototypes and incrementally improve them rather than developing new multiple concurrent prototypes that intend to achieve and deliver almost similar healthcare goals.

- There is a need to develop sustainable public-private partnerships to fund mobile health technologies designed and developed to improve care.

- To support digital solutions in underprivileged regions, health policies could increase public awareness of the possibilities of mHealth apps, influence the creation of a strong network, lower data costs, and encourage investment in solar power (Maphosa, 2022a).

- There is need a need for mobile health policy and framework that support the integration of emerging digital technologies including artificial intelligence, blockchain (protect health data- security and privacy), and 5G technology (improve internet speed) in health systems.

- Establishment of community networks in rural and marginalized communities to improve access to health information.

10.3 Limitations of the study

The use of online questionnaire for Category A during the post-test phase due to COVID restrictions is one of the limitations of this study. Therefore, there is a need to assess the perceived perceptions and views of health workers using face-to-face interviews or focus group discussions. In addition, the study developed and tested an ICT-based malaria intervention prototype at a small scale (ward level), therefore, there is a need to improve the prototype and further assess its performance at a large scale at the district level. Due to COVID-19 and movement restrictions, the prototype was tested and evaluated by health workers. There is a need to evaluate the prototype at a massive scale including for people staying in the community who need access to care. There is a need to assess their digital literacy. Thus, the study findings cannot be generalised to the entire rural district because of the small sample size that evaluated the prototype. However, the findings are important to advise policymakers on the potential integration of mobile health digital interventions to improve malaria healthcare service delivery in resource-constrained rural communities.

The study used behavioural intention to explore health workers' intention to use mobile phone-based malaria interventions, instead of actual use because it is difficult to measure potential users' actual usage behaviour, especially at the prototyping stage. Behavioural intention is a valid indicator to represent acceptance and has been widely used in previous studies (Chao, 2019; Hoque & Sorwar, 2017b; Kijsanayotin et al., 2009; Rajak & Shaw, 2021; Sobti, 2019; Talukder et al., 2019). However, exploring factors influencing health workers' actual usage behaviours can be more precise in reflecting user acceptance, especially in the post-implementation stage of mobile phone-based malaria interventions in rural communities.

Another limitation is that the study was conducted during COVID-19, which took place within a short period. Health workers' perceptions of identified constructs within the UTAUT model can change over time as new challenges and policies emerge. Therefore, there is a need to conduct a longitudinal study to obtain more accurate findings from a specific group of healthcare professionals working in malaria-endemic wards.

Finally, this study examined constructs of technology acceptance from health workers' perspectives and mobile phone-based malaria intervention using a modified UTAUT model. However, some other theories applied in health-related studies (health belief theory), motivational theories (hedonic theory or social cognitive theory) (Sitar-Tăut, 2021b) and other scenario-related factors (perceived challenges, policies, resources availability, and perceived benefits) (Shiferaw & Mehari, 2019) might also contribute to technology acceptance. Therefore, further studies can be redesigned to longitudinally observe and integrate these theories into practice as part of future explorations.

10.4 Future Work

The study investigated an ICT-based malaria intervention framework to disseminate information in rural communities. Future explorations may focus on policy and standards for developing mobile health digital interventions for tackling malaria in rural communities. The study further assessed the adoption of the intervention by health workers, however, for such intervention to include everyone at a large scale, the digital literacy of other end-users in the community should be assessed as part of future work. Also, the future development of mobile health digital interventions requires developing alternative digital means such as building community digital centres to provide access for people without digital devices such as mobile phones, and internet access and who have lower digital literacy levels. The study also predicted malaria using environmental risk factors such as day land surface temperature, night land surface temperature, rainfall, NDVI and EVI. Other factors including socioeconomic factors, residual spraying coverage, and LLINs distribution may need to be assessed for their impact on predicting malaria in the future

As regards the modified UTAUT model, the study used behavioural intentions, to explore health workers' intention to use mobile phone-based malaria interventions, instead of actual use because it is difficult to measure potential users' actual usage behaviour, especially at the prototyping stage. However, exploring factors influencing health workers' actual usage behaviours can be more precise in reflecting user acceptance, especially in the post-implementation stage of mobile phone-based malaria interventions. Another limitation is that the study was cross-sectional and conducted during the period when the country experienced a high medical staff turnover, as well as COVID-19. Also, data collection was done within a short period due to restrictive measures on movements. of people, hence few participants in Phase 2. Health workers' perceptions of identified constructs within the UTAUT model can change over time as new challenges and policies emerge. Therefore, future studies could employ a longitudinal design to obtain more accurate findings from a specific group of health workers working in malaria-endemic wards.

Finally, this study examined a few constructs of technology acceptance from health workers' perspectives and mobile phone-based malaria intervention using a modified UTAUT model. In addition, some other theories applied in health-related studies (health belief theory), motivational theories (hedonic theory or social cognitive theory) (Sitar-Tăut, 2021b) and other scenario-related factors (perceived challenges, policies, resources availability, and perceived benefits) (Shiferaw & Mehari, 2019) might also contribute to technology acceptance. Therefore, further studies can be redesigned, to observe longitudinally and integrate these theories into practice as part of future explorations.

10.5 Conclusion

The ubiquitous and pervasiveness of mobile phones continue to present unprecedented opportunities in bringing a transformative and dynamic shift in healthcare service delivery in sub-Saharan Africa. This is necessitated by the increase in mobile phone penetration as evidenced by increased usage and mobile network coverage. The adoption of m-Health interventions to improve malaria healthcare services in many rural communities is still nascent in SSA countries, including Zimbabwe. Therefore, this study proposed a framework for integrating ICT-based malaria interventions to disseminate malaria information in resource-constrained rural communities. Malaria incidences from DHIS were analysed and mapped in Buhera rural district map to determine the spatial distribution and association between malaria cases and environmental risk factors. The study further clustered wards within the district into several categories based on malaria intensity. Birchenough Bridge and Chapanduka were identified as high perennial malaria wards. The study selected these wards and further revealed that environmental risk factors significantly contribute to malaria outbreaks. These factors were further utilised to predict malaria outbreaks using machine learning techniques. The study revealed that logistic regression and random forest classifier both achieved a high prediction accuracy of 83%. Malaria prediction models can assist in developing early warning systems, effective resource allocation, and giving more priority to high perennial malarious wards. Due to the scarcity of malaria digital intervention in resource-constrained rural communities, the study proposed a framework for integrating mobile health digital interventions in rural areas. The study revealed that the adoption of mobile health digital intervention faces several hindrances including infrastructural challenges, technological barriers, socioeconomic barriers, funding challenges, lack of mobile health policy and frameworks guiding the development and deployment of mobile health digital interventions, intermittent network signals and lack of power supply among others. Furthermore, the study proposed recommendations including private-public partnerships, development of m-Health policy and its alignment with national health policy, advocating multi-sectorial and ministerial partnerships to foster digital health sustainability, and calling for significant investments from capacity strengthening through supportive infrastructure in resource-constrained rural communities.

References

Abbad, M. M. M. (2021). Using the UTAUT model to understand students' usage of e-learning systems in developing countries. *Education and Information Technologies*, *26*(6), 7205–7224. https://doi.org/10.1007/S10639-021-10573-5/TABLES/9

Aborode, A. T., David, K. B., Uwishema, O., Nathaniel, A. L., Imisioluwa, J. O., Onigbinde, S. B., & Farooq, F. (2021). Fighting COVID-19 at the Expense of Malaria in Africa: The Consequences and Policy Options. *The American Journal of Tropical Medicine and Hygiene*, *104*(1), 26. https://doi.org/10.4269/AJTMH.20-1181

Aceto, G., Persico, V., & Pescapé, A. (2018). The role of Information and Communication Technologies in healthcare: taxonomies, perspectives, and challenges. *Journal of Network and Computer Applications*, *107*, 125–154. https://doi.org/10.1016/J.JNCA.2018.02.008

Agbehadji, I. E., Abdultaofeek, A., Millham, R., Biney, E. A., & Yeboah, K. O. (2019). Framework on mobile technology utilization for assisted healthcare service request and delivery for aged persons: A case of Ghana. *ACM International Conference Proceeding Series*. https://doi.org/10.1145/3368756.3369034

Agbehadji, I. E., Awuzie, B. O., Ngowi, A. B., & Millham, R. C. (2020). Review of Big Data Analytics, Artificial Intelligence and Nature-Inspired Computing Models towards Accurate Detection of COVID-19 Pandemic Cases and Contact Tracing. *International Journal of Environmental Research and Public Health 2020, Vol. 17, Page 5330*, *17*(15), 5330. https://doi.org/10.3390/IJERPH17155330

Aïkpon, R. Y., Padonou, G., Dagnon, F., Ossè, R., Ogouyemi Hounto, A., Tokponon, F., Aïkpon, G., Lyikirenga, L., & Akogbéto, M. (2020). Upsurge of malaria transmission after indoor residual spraying withdrawal in Atacora region in Benin, West Africa. *Malaria Journal*, *19*(1), 1–9. https://doi.org/10.1186/S12936-019-3086-2/FIGURES/4

Akhlaq, A., McKinstry, B., Muhammad, K. Bin, & Sheikh, A. (2016). Barriers and facilitators to health information exchange in low- and middle-income country settings: a systematic review. *Health Policy and Planning*, *31*(9), 1310–1325. https://doi.org/10.1093/HEAPOL/CZW056

Akinnuwesi, B. A., Uzoka, F.-M. E., Fashoto, S. G., Mbunge, E., Odumabo, A., Amusa, O. O., Okpeku, M., & Owolabi, O. (2022). A modified UTAUT model for the acceptance and use of digital technology for tackling COVID-19. *Sustainable Operations and Computers*, *3*, 118–135. https://doi.org/10.1016/J.SUSOC.2021.12.001

Akter, H., Ahmed, W., Sentosa, I., & Hizam, S. M. (2022). Crafting employee engagement through talent management practices in telecom sector. *SA Journal of Human Resource Management*, *20*. https://doi.org/10.4102/SAJHRM.V20I0.1775

Alaa Khaleel, F., & Al-Bakry, A. M. (2021). Diagnosis of diabetes using machine learning algorithms. *Materials Today: Proceedings*. https://doi.org/10.1016/J.MATPR.2021.07.196

Alam, M. Z., Hoque, M. R., Hu, W., & Barua, Z. (2020). Factors influencing the adoption of mHealth services in a developing country: A patient-centric study. *International Journal of Information Management*, *50*, 128–143. https://doi.org/10.1016/J.IJINFOMGT.2019.04.016

Aldila, D., & Seno, H. (2019). A Population Dynamics Model of Mosquito-Borne Disease Transmission, Focusing on Mosquitoes' Biased Distribution and Mosquito Repellent Use. *Bulletin of Mathematical Biology*, *81*(12), 4977–5008. https://doi.org/10.1007/S11538-019-00666-1/FIGURES/5

Alemu, A., Abebe, G., Tsegaye, W., & Golassa, L. (2011). Climatic variables and malaria transmission dynamics in Jimma town, South West Ethiopia. *Parasites and Vectors*, *4*(1), 1–11. https://doi.org/10.1186/1756-3305-4-30/TABLES/4

Alharbi, A., & Abdur Rahman, M. (2021). Review of Recent Technologies for Tackling COVID-19. *SN Computer Science 2021 2:6*, *2*(6), 1–27. https://doi.org/10.1007/S42979-021-00841-Z

Ali, F., Rasoolimanesh, S. M., Sarstedt, M., Ringle, C. M., & Ryu, K. (2018). An assessment of the use of partial least squares structural equation modeling (PLS-SEM) in hospitality research. *International Journal of Contemporary Hospitality Management*, *30*(1), 514–538. https://doi.org/10.1108/IJCHM-10-2016-0568/FULL/XML

Alwan, A., Ali, M., Aly, E., Badr, A., Doctor, H., Mandil, A., Rashidian, A., & Shideed, O. (2016).

Strengthening national health information systems: challenges and response. *Eastern Mediterranean Health Journal*, *22*(11).

Amoran, O. E. (2013). Impact of health education intervention on malaria prevention practices among nursing mothers in rural communities in Nigeria. *Nigerian Medical Journal : Journal of the Nigeria Medical Association*, *54*(2), 115. https://doi.org/10.4103/0300-1652.110046

Anwar, A., Malik, M., Raees, V., & Anwar, A. (2020). Role of Mass Media and Public Health Communications in the COVID-19 Pandemic. *Cureus*, *12*(9). https://doi.org/10.7759/CUREUS.10453

Arfi, W. Ben, Nasr, I. Ben, Kondrateva, G., & Hikkerova, L. (2021). The role of trust in intention to use the IoT in eHealth: Application of the modified UTAUT in a consumer context. *Technological Forecasting and Social Change*, *167*, 120688. https://doi.org/10.1016/J.TECHFORE.2021.120688

Asongu, S. A. (2015). Conditional Determinants of Mobile Phones Penetration and Mobile Banking in Sub-Saharan Africa. *Journal of the Knowledge Economy 2015 9:1*, *9*(1), 81–135. https://doi.org/10.1007/S13132-015-0322-Z

Atieli, H. E., Zhou, G., Afrane, Y., Lee, M.-C., Mwanzo, I., Githeko, A. K., & Yan, G. (2011). Insecticide-treated net (ITN) ownership, usage, and malaria transmission in the highlands of western Kenya. *Parasites & Vectors 2011 4:1*, *4*(1), 1–10. https://doi.org/10.1186/1756-3305-4-113

Aungst, T. D. (2013). Medical applications for pharmacists using mobile devices. *Annals of Pharmacotherapy*, *47*(7–8), 1088–1095. https://doi.org/10.1345/aph.1S035

Avgerou, C., Hayes, N., & La Rovere, R. L. (2016). Growth in ICT Uptake in Developing Countries: New Users, New Uses, New Challenges: *Https://Doi.Org/10.1057/S41265-016-0022-6*, *31*(4), 329–333. https://doi.org/10.1057/S41265-016-0022-6

Aziz, H. A. (2017). A review of the role of public health informatics in healthcare. *Journal of Taibah University Medical Sciences*, *12*(1), 78–81.

https://doi.org/10.1016/J.JTUMED.2016.08.011

Azizi, S. C. (2020). Uptake of intermittent preventive treatment for malaria during pregnancy with Sulphadoxine-Pyrimethamine in Malawi after adoption of updated World Health Organization policy: An analysis of demographic and health survey 2015-2016. *BMC Public Health*, *20*(1), 1–12. https://doi.org/10.1186/S12889-020-08471-5/TABLES/5

Bahl, S., Singh, R. P., Javaid, M., Khan, I. H., Vaishya, R., & Suman, R. (2020). Telemedicine Technologies for Confronting COVID-19 Pandemic: A Review. *Https://Doi.Org/10.1142/S2424862220300057*. https://doi.org/10.1142/S2424862220300057

Balatsoukas, P., Kennedy, C. M., Buchan, I., Powell, J., & Ainsworth, J. (2015). The Role of Social Network Technologies in Online Health Promotion: A Narrative Review of Theoretical and Empirical Factors Influencing Intervention Effectiveness. *J Med Internet Res 2015;17(6):E141 Https://Www.Jmir.Org/2015/6/E141*, *17*(6), e3662. https://doi.org/10.2196/JMIR.3662

Bali, S. (2018). Barriers to Development of Telemedicine in Developing Countries. *Telehealth*. https://doi.org/10.5772/INTECHOPEN.81723

Banerjee, A., Chitnis, U. B., Jadhav, S. L., Bhawalkar, J. S., & Chaudhury, S. (2009). Hypothesis testing, type I and type II errors. *Industrial Psychiatry Journal*, *18*(2), 127. https://doi.org/10.4103/0972-6748.62274

Bangure, D., Chirundu, D., Gombe, N., Marufu, T., Mandozana, G., Tshimanga, M., & Takundwa, L. (2015). Effectiveness of short message services reminder on childhood immunization programme in Kadoma, Zimbabwe - A randomized controlled trial, 2013. *BMC Public Health*, *15*(1), 1–8. https://doi.org/10.1186/S12889-015-1470-6/TABLES/2

Barron, P., Peter, J., LeFevre, A. E., Sebidi, J., Bekker, M., Allen, R., Parsons, A. N., Benjamin, P., & Pillay, Y. (2018). Mobile health messaging service and helpdesk for South African mothers (MomConnect): history, successes and challenges. *BMJ Global Health*, *3*(Suppl 2), e000559. https://doi.org/10.1136/BMJGH-2017-000559

Barua, Z., & Barua, A. (2020). Acceptance and usage of mHealth technologies amid COVID-19 pandemic in a developing country: the UTAUT combined with situational constraint and health consciousness. *Journal of Enabling Technologies*, *15*(1), 1–22. https://doi.org/10.1108/JET-08-2020-0030/FULL/PDF

Bashshur, R., Doarn, C. R., Frenk, J. M., Kvedar, J. C., & Woolliscroft, J. O. (2020). Telemedicine and the COVID-19 Pandemic, Lessons for the Future. *Https://Home.Liebertpub.Com/Tmj*, *26*(5), 571–573. https://doi.org/10.1089/TMJ.2020.29040.RB

Batani, J., & Maharaj, M. S. (2022). Towards Data-Driven Pediatrics in Zimbabwe. *2022 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (IcABCD)*, 1–7. https://doi.org/10.1109/ICABCD54961.2022.9855907

Bawack, R. E., & Kala Kamdjoug, J. R. (2018). Adequacy of UTAUT in clinician adoption of health information systems in developing countries: The case of Cameroon. *International Journal of Medical Informatics*, *109*, 15–22. https://doi.org/10.1016/J.IJMEDINF.2017.10.016

Becker, J. M., Ringle, C. M., Sarstedt, M., & Völckner, F. (2015). How collinearity affects mixture regression results. *Marketing Letters*, *26*(4), 643–659. https://doi.org/10.1007/S11002-014-9299-9/TABLES/3

Bello, I. M., Moyo, T. N., Munyanyi, M., Akpan, G. U., Isibor, I., Sunganai, L. C., Umar, A. S., Krishnan, R. S. S. G., Touray, K., Rupfutse, M., Manangazira, P., Ntale, A. G., Fussum, D., & Mkanda, P. (2021). Use of geographic information systems web mapping application to support active case search to guide public health and social measures in the context of COVID-19 in Zimbabwe: a preliminary report to guide replication of methods in similar resource settings. *The Pan African Medical Journal*, *38*, 1–9. https://doi.org/10.11604/PAMJ.2021.38.159.27143

Benoot, C., Hannes, K., & Bilsen, J. (2016). The use of purposeful sampling in a qualitative evidence synthesis: A worked example on sexual adjustment to a cancer trajectory. *BMC*

Medical Research Methodology, *16*(1), 1–12. https://doi.org/10.1186/S12874-016-0114-6/TABLES/5

Beratarrechea, A., Moyano, D., Irazola, V., & Rubinstein, A. (2017). mHealth Interventions to Counter Noncommunicable Diseases in Developing Countries: Still an Uncertain Promise. *Cardiology Clinics*, *35*(1), 13–30. https://doi.org/10.1016/J.CCL.2016.08.009

Berg, V., Birkeland, J., Nguyen-Duc, A., Pappas, I. O., & Jaccheri, L. (2018). Software startup engineering: A systematic mapping study. *Journal of Systems and Software*, *144*, 255–274. https://doi.org/10.1016/J.JSS.2018.06.043

Berndt, A. E. (2020). Sampling Methods. *Journal of Human Lactation*, *36*(2), 224–226. https://doi.org/10.1177/0890334420906850

Bertman, V., Petracca, F., Makunike-Chikwinya, B., Jonga, A., Dupwa, B., Jenami, N., Nartker, A., Wall, L., Reason, L., Kundhlande, P., & Downer, A. (2019). Health worker text messaging for blended learning, peer support, and mentoring in pediatric and adolescent HIV/AIDS care: A case study in Zimbabwe. *Human Resources for Health*, *17*(1), 1–8. https://doi.org/10.1186/S12960-019-0364-6/PEER-REVIEW

Bhochhibhoya, S., Dobbs, P. D., & Maness, S. B. (2021). Interventions using mHealth strategies to improve screening rates of cervical cancer: A scoping review. *Preventive Medicine*, *143*, 106387. https://doi.org/10.1016/J.YPMED.2020.106387

Bhuyan, S., Kim, H., Isehunwa, O. O., Kumar, N., Bhatt, J., Wyant, D. K., Kedia, S., Chang, C. F., & Dasgupta, D. (2017). Privacy and security issues in mobile health: Current research and future directions. *Health Policy and Technology*, *6*(2), 188–191. https://doi.org/10.1016/J.HLPT.2017.01.004

Biradar, S., Saumya, S., & Chauhan, A. (2022). Combating the infodemic: COVID-19 induced fake news recognition in social media networks. *Complex & Intelligent Systems 2022*, 1–13. https://doi.org/10.1007/S40747-022-00672-2

Bisman, J. E., & Highfield, C. (2013). The Road Less Travelled: An Overview and Example of

Constructivist Research in Accounting. *Australasian Accounting, Business and Finance Journal*, *6*(5), 3–22. https://doi.org/10.14453/aabfj.v6i5.2

Bitar, H., & Alismail, S. (2021). The role of eHealth, telehealth, and telemedicine for chronic disease patients during COVID-19 pandemic: A rapid systematic review. *Digital Health*, *7*. https://doi.org/10.1177/20552076211009396

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research*, *19*(4), 426–432. https://doi.org/10.1108/QMR-06-2016-0053/FULL/PDF

Bonache, J., & Festing, M. (2020). Research paradigms in international human resource management: An epistemological systematisation of the field: *Https://Doi.Org/10.1177/2397002220909780*, *34*(2), 99–123. https://doi.org/10.1177/2397002220909780

Bosman, A., & Mendis, K. N. (2007). A Major Transition in Malaria Treatment: The Adoption and Deployment of Artemisinin-Based Combination Therapies. *The American Journal of Tropical Medicine and Hygiene*, *77*(6_Suppl), 193–197. https://doi.org/10.4269/AJTMH.2007.77.193

Boulos, M. N. K., Wheeler, S., Tavares, C., & Jones, R. (2011). How smartphones are changing the face of mobile and participatory healthcare: An overview, with example from eCAALYX. *BioMedical Engineering Online*, *10*. https://doi.org/10.1186/1475-925X-10-24

Bromwich, M., & Bromwich, R. (2016). Privacy risks when using mobile devices in health care. *CMAJ*, *188*(12), 855–856. https://doi.org/10.1503/CMAJ.160026/-/DC1

Brooke, B. D., Raman, J., Frean, J., Rundle, K., Maartens, F., Misiani, E., Mabuza, A., Barnes, K. I., Moonasar, D. P., Dlamini, Q., Charles, S., & Blumberg, L. (2020). Implementing malaria control in South Africa, Eswatini and southern Mozambique during the COVID-19 pandemic. *SAMJ: South African Medical Journal*, *110*(11), 1072–1076. https://doi.org/10.7196/SAMJ.2020.V110I11.15286

Brown, B. J., Manescu, P., Przybylski, A. A., Caccioli, F., Oyinloye, G., Elmi, M., Shaw, M. J., Pawar, V., Claveau, R., Shawe-Taylor, J., Srinivasan, M. A., Afolabi, N. K., Rees, G., Orimadegun, A. E., Ajetunmobi, W. A., Akinkunmi, F., Kowobari, O., Osinusi, K., Akinbami, F. O., … Fernandez-Reyes, D. (2020a). Data-driven malaria prevalence prediction in large densely populated urban holoendemic sub-Saharan West Africa. *Scientific Reports 2020 10:1*, *10*(1), 1–17. https://doi.org/10.1038/s41598-020-72575-6

Brown, B. J., Manescu, P., Przybylski, A. A., Caccioli, F., Oyinloye, G., Elmi, M., Shaw, M. J., Pawar, V., Claveau, R., Shawe-Taylor, J., Srinivasan, M. A., Afolabi, N. K., Rees, G., Orimadegun, A. E., Ajetunmobi, W. A., Akinkunmi, F., Kowobari, O., Osinusi, K., Akinbami, F. O., … Fernandez-Reyes, D. (2020b). Data-driven malaria prevalence prediction in large densely populated urban holoendemic sub-Saharan West Africa. *Scientific Reports*, *10*(1). https://doi.org/10.1038/S41598-020-72575-6

Budd, J., Miller, B. S., Manning, E. M., Lampos, V., Zhuang, M., Edelstein, M., Rees, G., Emery, V. C., Stevens, M. M., Keegan, N., Short, M. J., Pillay, D., Manley, E., Cox, I. J., Heymann, D., Johnson, A. M., & McKendry, R. A. (2020). Digital technologies in the public-health response to COVID-19. *Nature Medicine 2020 26:8*, *26*(8), 1183–1192. https://doi.org/10.1038/s41591-020-1011-4

Bui, L. V., Mor, Z., Chemtob, D., Ha, S. T., & Levine, H. (2018). Use of Geographically Weighted Poisson Regression to examine the effect of distance on Tuberculosis incidence: A case study in Nam Dinh, Vietnam. *PLOS ONE*, *13*(11), e0207068. https://doi.org/10.1371/JOURNAL.PONE.0207068

Bui, Q. T., Nguyen, Q. H., Pham, V. M., Pham, M. H., & Tran, A. T. (2018). Understanding spatial variations of malaria in Vietnam using remotely sensed data integrated into GIS and machine learning classifiers. *Https://Doi.Org/10.1080/10106049.2018.1478890*, *34*(12), 1300–1314. https://doi.org/10.1080/10106049.2018.1478890

Carter, R. A., Antón, A. I., Dagnino, A., & Williams, L. (2001). Evolving beyond requirements creep: A risk-based evolutionary prototyping model. *Proceedings of the IEEE International Conference on Requirements Engineering*, 94–101. https://doi.org/10.1109/ISRE.2001.948548

Cavanaugh, J. E., & Neath, A. A. (2019). The Akaike information criterion: Background, derivation, properties, application, interpretation, and refinements. *Wiley Interdisciplinary Reviews: Computational Statistics*, *11*(3), e1460. https://doi.org/10.1002/WICS.1460

Chakraborty, K., Bhatia, S., Bhattacharyya, S., Platos, J., Bag, R., & Hassanien, A. E. (2020). Sentiment Analysis of COVID-19 tweets by Deep Learning Classifiers—A study to show how popularity is affecting accuracy in social media. *Applied Soft Computing*, *97*, 106754. https://doi.org/10.1016/J.ASOC.2020.106754

Chao, C. M. (2019). Factors determining the behavioral intention to use mobile learning: An application and extension of the UTAUT model. *Frontiers in Psychology*, *10*(JULY), 1652. https://doi.org/10.3389/FPSYG.2019.01652/BIBTEX

Charles-Smith, L. E., Reynolds, T. L., Cameron, M. A., Conway, M., Lau, E. H. Y., Olsen, J. M., Pavlin, J. A., Shigematsu, M., Streichert, L. C., Suda, K. J., & Corley, C. D. (2015). Using Social Media for Actionable Disease Surveillance and Outbreak Management: A Systematic Literature Review. *PLOS ONE*, *10*(10), e0139701. https://doi.org/10.1371/JOURNAL.PONE.0139701

Chawurura, T., Chikomo, S., Manhibi, R., van Dijk, J., & van Stam, G. (2022). Developing a Digital Information and Consultation Platform in Zimbabwe. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*, *443 LNICST*, 80–92. https://doi.org/10.1007/978-3-031-06374-9_6/COVER

Chekol, B. E., & Hagras, H. (2019). Employing Machine Learning Techniques for the Malaria Epidemic Prediction in Ethiopia. *2018 10th Computer Science and Electronic Engineering Conference, CEEC 2018 - Proceedings*, 89–94. https://doi.org/10.1109/CEEC.2018.8674210

Chidawanyika, H., Nyika, P., Katiyo, J., Sox, A., Chokuda, T., Peter, K., Gonese, E., Tapfumanei, O., & Mukwiza, R. (2014). Success in Revitalizing Weekly Disease Surveillance System in Zimbabwe Using Cell-phone Mediated Data Transmission, 2009-2013. *Online Journal of Public Health Informatics*, *6*(1). https://doi.org/10.5210/OJPHI.V6I1.5171

Chidhau, S., Mutizwa, B., & Muzama, T. R. (2021a). The Impact of the Digital Health

Interventions in Curbing COVID-19 in Zimbabwe. *International Journal of Clinical Inventions and Medical Science*, *3*(1), 40–52. https://doi.org/10.36079/LAMINTANG.IJCIMS-0301.203

Chidhau, S., Mutizwa, B., & Muzama, T. R. (2021b). The Impact of the Digital Health Interventions in Curbing COVID-19 in Zimbabwe. *International Journal of Clinical Inventions and Medical Sciences (IJCIMS)*, *3*(1), 40–52. https://doi.org/10.36079/LAMINTANG.IJCIMS-0301.203

Chigwedere, C., Takavarasha, S., & Chisaka, B. (2022). *Regulatory Frameworks in Developing Countries: An Integrative Literature Review*. 170–185. https://doi.org/10.1007/978-3-031-15688-5_15

Chimberengwa, P. T., Masuka, N., Gombe, N. T., Tshimanga, M., Takundwa, L., & Bangure, D. (2015). Indoor household residual spraying program performance in Matabeleland South province, Zimbabwe: 2011 to 2012; a descriptive cross-sectional study. *Pan African Medical Journal*, *20*(1). https://doi.org/10.4314/pamj.v20i1.

Chin, W., Cheah, J. H., Liu, Y., Ting, H., Lim, X. J., & Cham, T. H. (2020). Demystifying the role of causal-predictive modeling using partial least squares structural equation modeling in information systems research. *Industrial Management and Data Systems*, *120*(12), 2161–2209. https://doi.org/10.1108/IMDS-10-2019-0529/FULL/PDF

Chin, W. W. (2010). How to Write Up and Report PLS Analyses. *Handbook of Partial Least Squares*, 655–690. https://doi.org/10.1007/978-3-540-32827-8_29

Chirombo, J., Ceccato, P., Lowe, R., Terlouw, D. J., Thomson, M. C., Gumbo, A., Diggle, P. J., & Read, J. M. (2020). Childhood malaria case incidence in Malawi between 2004 and 2017: Spatio-temporal modelling of climate and non-climate factors. *Malaria Journal*, *19*(1), 1–13. https://doi.org/10.1186/S12936-019-3097-Z/FIGURES/5

Chitungo, I., Mhango, M., Dzobo, M., Denhere, K., Chimene, M., Musuka, G., & Dzinamarira, T. (2021). Towards virtual doctor consultations: A call for the scale-up of telemedicine in sub-Saharan Africa during COVID-19 lockdowns and beyond. *Smart Health*, *21*, 100207.

https://doi.org/10.1016/J.SMHL.2021.100207

Chitungo, I., Mhango, M., Mbunge, E., Dzobo, M., Musuka, G., & Dzinamarira, T. (2021). Utility of telemedicine in sub-Saharan Africa during the COVID-19 pandemic. A rapid review. *Human Behavior and Emerging Technologies*, *3*(5), 843–853. https://doi.org/10.1002/HBE2.297

Chiwara, T. B. (2012). *the Impact of Billboards on Hiv and Aids Awareness in Zimbabwe*. *March*.

Choi, L., McIntyre, S., & Furnival-Adams, J. (2019). Indoor residual spraying for preventing malaria. *The Cochrane Database of Systematic Reviews*, *2019*(3). https://doi.org/10.1002/14651858.CD013300

Chou, W. H., Lai, Y. T., & Liu, K. H. (2012). User requirements of social media for the elderly: a case study in Taiwan. *Http://Dx.Doi.Org/10.1080/0144929X.2012.681068*, *32*(9), 920–937. https://doi.org/10.1080/0144929X.2012.681068

Chukwuocha, U. M., Iwuoha, G. N., Ogara, C. M., & Dozie, I. N. S. (2020). Malaria classroom corner: a school-based intervention to promote basic malaria awareness and common control practices among school-age children. *Health Education*, *120*(1), 107–119. https://doi.org/10.1108/HE-11-2019-0050/FULL/PDF

Chung, A. M., Case, P., Gosling, J., Gosling, R., Madinga, M., Chikodzore, R., Hove, M., Viljoen, G., Chitapi, P., Gumbi, M., Mnguni, P., Murungu, J., Dube, B., Dhliwayo, P., & Mberikunashe, J. (2020). Scaling up malaria elimination management and leadership: a pilot in three provinces in Zimbabwe, 2016–2018. *Malaria Journal 2020 19:1*, *19*(1), 1–14. https://doi.org/10.1186/S12936-020-03255-Z

Clark, H., Babu, A. S., Wiewel, E. W., Opoku, J., & Crepaz, N. (2017). Diagnosed HIV Infection in Transgender Adults and Adolescents: Results from the National HIV Surveillance System, 2009–2014. *AIDS and Behavior*, *21*(9), 2774–2783. https://doi.org/10.1007/S10461-016-1656-7/TABLES/2

Cock, I. E., Selesho, M. I., & van Vuuren, S. F. (2019). A review of the traditional use of southern

African medicinal plants for the treatment of malaria. *Journal of Ethnopharmacology*, *245*, 112176. https://doi.org/10.1016/J.JEP.2019.112176

Cohen, S. M., Gray, K. M., Ocfemia, M. C. B., Johnson, A. S., & Hall, H. I. (2014). The status of the national HIV surveillance system, United States, 2013. *Public Health Reports*, *129*(4), 335–341. https://doi.org/10.1177/003335491412900408

Coleman, E. W., & Delea, K. C. (2013). The Use of Public Health Informatics to Improve Environmental Health Practice. *Journal of Environmental Health*, *76*(5), 44. /pmc/articles/PMC4620053/

Combi, C., Pozzani, G., & Pozzi, G. (2016). Telemedicine for developing countries: A survey and some design issues. *Applied Clinical Informatics*, *7*(4), 1025–1050. https://doi.org/10.4338/ACI-2016-06-R-0089/ID/OR0089-64

Craig, M., Le Sueur, D., & Snow, B. (1999). A Climate-based Distribution Model of Malaria Transmission in Sub-Saharan Africa. *Parasitology Today*, *15*(3), 105–111. https://doi.org/10.1016/S0169-4758(99)01396-4

Creswell, J. W. (2008). Editorial: Mapping the Field of Mixed Methods Research: *Http://Dx.Doi.Org/10.1177/1558689808330883*, *3*(2), 95–108. https://doi.org/10.1177/1558689808330883

Creswell, J. W. (2015). *Revisiting Mixed Methods and Advancing Scientific Practices*. https://doi.org/10.1093/OXFORDHB/9780199933624.013.39

Creswell, J. W., & Clark, V. L. P. (2013). Designing and Conducting Mixed Methods Research. *Australian and New Zealand Journal of Public Health*, *31*(4), 388–388. https://doi.org/10.1111/j.1753-6405.2007.00096.x

Creswell, J. W., Hanson, W. E., Clark Plano, V. L., & Morales, A. (2016). Qualitative Research Designs: Selection and Implementation. *Http://Dx.Doi.Org/10.1177/0011000006287390*, *35*(2), 236–264. https://doi.org/10.1177/0011000006287390

Dabengwa, I. M., Nyati-Jokomo, Z., Chikoko, L., Makanga, P. T., Nyapwere, N., & Makacha, L.

(2022a). A participatory learning approach for the development of a maternal mobile health technology in Zimbabwe. *Https://Doi.Org/10.1080/0376835X.2022.2059449*. https://doi.org/10.1080/0376835X.2022.2059449

Dabengwa, I. M., Nyati-Jokomo, Z., Chikoko, L., Makanga, P. T., Nyapwere, N., & Makacha, L. (2022b). A participatory learning approach for the development of a maternal mobile health technology in Zimbabwe. *Https://Doi.Org/10.1080/0376835X.2022.2059449*. https://doi.org/10.1080/0376835X.2022.2059449

Dambi, J., Norman, C., Doukani, A., Potgieter, S., Turner, J., Musesengwa, R., Verhey, R., & Chibanda, D. (2022). A Digital Mental Health Intervention (Inuka) for Common Mental Health Disorders in Zimbabwean Adults in Response to the COVID-19 Pandemic: Feasibility and Acceptability Pilot Study. *JMIR Ment Health 2022;9(10):E37968 Https://Mental.Jmir.Org/2022/10/E37968*, *9*(10), e37968. https://doi.org/10.2196/37968

Davies, C., Graffy, R., Shandukani, M., Baloyi, E., Gast, L., Kok, G., Mbokazi, F., Zita, A., Zwane, M., Magagula, R., Mabuza, A., Ramkrishna, W., Morris, N., Porteous, J., Shirreff, G., Blumberg, L., Misiani, E., & Moonasar, D. (2019). Effectiveness of 24-h mobile reporting tool during a malaria outbreak in Mpumalanga Province, South Africa. *Malaria Journal*, *18*(1), 1–9. https://doi.org/10.1186/S12936-019-2683-4/FIGURES/6

De Angelis, G., Wells, G. A., Davies, B., King, J., Shallwani, S. M., McEwan, J., Cavallo, S., & Brosseau, L. (2018). The use of social media among health professionals to facilitate chronic disease self-management with their patients: A systematic review. *Digital Health*, *4*, 2055207618771416. https://doi.org/10.1177/2055207618771416

de Jager, C., Kruger, T., & Tosh, C. (2019). *Research, Innovation and Education Towards Malaria Elimination: Improving in Africa*. 179–200. https://doi.org/10.1007/978-3-030-15367-0_9

De Veer, A. J. E., Peeters, J. M., Brabers, A. E. M., Schellevis, F. G., Rademakers, J. J. D. J. M., & Francke, A. L. (2015). Determinants of the intention to use e-Health by community dwelling older people. *BMC Health Services Research*, *15*(1). https://doi.org/10.1186/S12913-015-0765-8

Debon, R., Coleone, J. D., Bellei, E. A., & De Marchi, A. C. B. (2019). Mobile health applications for chronic diseases: A systematic review of features for lifestyle improvement. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *13*(4), 2507–2512. https://doi.org/10.1016/J.DSX.2019.07.016

Dehnavieh, R., Haghdoost, A. A., Khosravi, A., Hoseinabadi, F., Rahimi, H., Poursheikhali, A., Khajehpour, N., Khajeh, Z., Mirshekari, N., Hasani, M., Radmerikhi, S., Haghighi, H., Mehrolhassani, M. H., Kazemi, E., & Aghamohamadi, S. (2019). The District Health Information System (DHIS2): A literature review and meta-synthesis of its strengths and operational challenges based on the experiences of 11 countries. *Health Information Management Journal*, *48*(2), 62–75. https://doi.org/10.1177/1833358318777713

DeLorenzo, M. E., & Fulton, M. H. (2012). Comparative risk assessment of permethrin, chlorothalonil, and diuron to coastal aquatic species. *Marine Pollution Bulletin*, *64*(7), 1291–1299. https://doi.org/10.1016/J.MARPOLBUL.2012.05.011

Dhakwa, D., Mudzengerere, F. H., Mpofu, M., Tachiwenyika, E., Mudokwani, F., Ncube, B., Pfupajena, M., Nyagura, T., Ncube, G., & Tafuma, T. A. (2021a). Use of mHealth Solutions for Improving Access to Adolescents' Sexual and Reproductive Health Services in Resource-Limited Settings: Lessons From Zimbabwe. *Frontiers in Reproductive Health*, *3*, 24. https://doi.org/10.3389/FRPH.2021.656351

Dhakwa, D., Mudzengerere, F. H., Mpofu, M., Tachiwenyika, E., Mudokwani, F., Ncube, B., Pfupajena, M., Nyagura, T., Ncube, G., & Tafuma, T. A. (2021b). Use of mHealth Solutions for Improving Access to Adolescents' Sexual and Reproductive Health Services in Resource-Limited Settings: Lessons From Zimbabwe. *Frontiers in Reproductive Health*, *0*, 24. https://doi.org/10.3389/FRPH.2021.656351

Dhiman, S., & Veer, V. (2014). Culminating anti-malaria efforts at long lasting insecticidal net? *Journal of Infection and Public Health*, *7*(6), 457–464. https://doi.org/10.1016/J.JIPH.2014.06.002

Dijkstra, T. K., & Henseler, J. (2015). Consistent and asymptotically normal PLS estimators for linear structural equations. *Computational Statistics & Data Analysis*, *81*, 10–23. https://doi.org/10.1016/J.CSDA.2014.07.008

Dimaguila, G. L. (2015a). SMS for life in Burundi and Zimbabwe: A comparative evaluation. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *9085*, 231–240. https://doi.org/10.1007/978-3-319-19156-0_24/COVER/

Dimaguila, G. L. (2015b). SMS for life in Burundi and Zimbabwe: A comparative evaluation. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *9085*, 231–240. https://doi.org/10.1007/978-3-319-19156-0_24/COVER

Dinku, T., Funk, C., Peterson, P., Maidment, R., Tadesse, T., Gadain, H., & Ceccato, P. (2018). Validation of the CHIRPS satellite rainfall estimates over eastern Africa. *Quarterly Journal of the Royal Meteorological Society*, *144*, 292–312. https://doi.org/10.1002/QJ.3244

DiStefano, C., Liu, J., Jiang, N., & Shi, D. (2017). Examination of the Weighted Root Mean Square Residual: Evidence for Trustworthiness? *Https://Doi.Org/10.1080/10705511.2017.1390394*, *25*(3), 453–466. https://doi.org/10.1080/10705511.2017.1390394

Dixon, B. E., Grannis, S. J., Mcandrews, C., Broyles, A. A., Mikels-Carrasco, W., Wiensch, A., Williams, J. L., Tachinardi, U., & Embi, P. J. (2021). Leveraging data visualization and a statewide health information exchange to support COVID-19 surveillance and response: Application of public health informatics. *Journal of the American Medical Informatics Association*, *28*(7), 1363–1373. https://doi.org/10.1093/JAMIA/OCAB004

Dlamini, N., Zulu, Z., Kunene, S., Geoffroy, E., Ntshalintshali, N., Owiti, P., Sikhondze, W., Makadzange, K., & Zachariah, R. (2018). From diagnosis to case investigation for malaria elimination in Swaziland: is reporting and response timely? *Public Health Action*, *8*(1), S8–S12. https://doi.org/10.5588/PHA.17.0043

Do, N. V., Barnhill, R., Heermann-Do, K. A., Salzman, K. L., & Gimbel, R. W. (2011). The military health system's personal health record pilot with Microsoft HealthVault and Google

Health. *Journal of the American Medical Informatics Association*, *18*(2), 118–124. https://doi.org/10.1136/JAMIA.2010.004671

Dodoo, J. E., Al-Samarraie, H., & Alsswey, A. (2022). The development of telemedicine programs in Sub-Saharan Africa: Progress and associated challenges. *Health and Technology*, *12*(1), 33–46. https://doi.org/10.1007/S12553-021-00626-7/FIGURES/3

Dogba, M. J., Dossa, A. R., Breton, E., & Gandonou-Migan, R. (2019). Using information and communication technologies to involve patients and the public in health education in rural and remote areas: A scoping review. *BMC Health Services Research*, *19*(1), 1–7. https://doi.org/10.1186/S12913-019-3906-7/TABLES/3

Doraiswamy, S., Abraham, A., Mamtani, R., & Cheema, S. (2020). Use of Telehealth During the COVID-19 Pandemic: Scoping Review. *J Med Internet Res 2020;22(12):E24087 Https://Www.Jmir.Org/2020/12/E24087*, *22*(12), e24087. https://doi.org/10.2196/24087

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J. R. G., Gruber, B., Lafourcade, B., Leitão, P. J., Münkemüller, T., Mcclean, C., Osborne, P. E., Reineking, B., Schröder, B., Skidmore, A. K., Zurell, D., & Lautenbach, S. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography*, *36*(1), 27–46. https://doi.org/10.1111/J.1600-0587.2012.07348.X

Doyle, A. M., Bandason, T., Dauya, E., McHugh, G., Grundy, C., Dringus, S., Chikwari, C. D., & Ferrand, R. A. (2021). Mobile Phone Access and Implications for Digital Health Interventions Among Adolescents and Young Adults in Zimbabwe: Cross-Sectional Survey. *JMIR Mhealth Uhealth 2021;9(1):E21244 Https://Mhealth.Jmir.Org/2021/1/E21244*, *9*(1), e21244. https://doi.org/10.2196/21244

Dubbelink, S. I., Soria, C. H., & Constantinides, E. (2021). Social Media Marketing as a Branding Strategy in Extraordinary Times: Lessons from the COVID-19 Pandemic. *Sustainability 2021, Vol. 13, Page 10310*, *13*(18), 10310. https://doi.org/10.3390/SU131810310

Dube, B., Mberikunashe, J., Dhliwayo, P., Tangwena, A., Shambira, G., Chimusoro, A., Madinga, M., & Gambinga, B. (2019). How far is the journey before malaria is knocked out malaria in

Zimbabwe: Results of the malaria indicator survey 2016. *Malaria Journal*, *18*(1), 1–10. https://doi.org/10.1186/S12936-019-2801-3/TABLES/7

Dwivedi, Y. K., Rana, N. P., Tamilmani, K., & Raman, R. (2020). A meta-analysis based modified unified theory of acceptance and use of technology (meta-UTAUT): a review of emerging literature. *Current Opinion in Psychology*, *36*, 13–18. https://doi.org/10.1016/J.COPSYC.2020.03.008

Dzinamarira, T., & Musuka, G. (2021). Brain drain: An ever-present; significant challenge to the Zimbabwean public health sector. *Public Health in Practice*, *2,* 100086. https://doi.org/10.1016/J.PUHIP.2021.100086

Eilu, E., & Pettersson, J. S. (2019). Mobile Social Media for Preventing the Ebola Virus Disease Spread in Liberia and Nigeria: A Comparative Analysis. *EAI/Springer Innovations in Communication and Computing*, 173–188. https://doi.org/10.1007/978-3-319-93491-4_9

Elallaoui, M., Nafil, K., & Touahni, R. (2018). Automatic Transformation of User Stories into UML Use Case Diagrams using NLP Techniques. *Procedia Computer Science*, *130*, 42–49. https://doi.org/10.1016/J.PROCS.2018.04.010

Elfil, M., & Negida, A. (2017). Sampling methods in Clinical Research; an Educational Review. *Emergency*, *5*(1), 52. https://doi.org/10.1136/eb-2014

Elreedy, D., & Atiya, A. F. (2019). A Comprehensive Analysis of Synthetic Minority Oversampling Technique (SMOTE) for handling class imbalance. *Information Sciences*, *505*, 32–64. https://doi.org/10.1016/J.INS.2019.07.070

Erhart, A., Thang, N. D., Xa, N. X., Thieu, N. Q., Hung, L. X., Hung, N. Q., Nam, N. V., Toi, L. V., Tung, N. M., Bien, T. H., Tuy, T. Q., Cong, L. D., Thuan, L. K., Coosemans, M., & D’Alessandro, U. (2007). Accuracy of the health information system on malaria surveillance in Vietnam. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *101*(3), 216–225. https://doi.org/10.1016/J.TRSTMH.2006.07.003/2/M_101-3-216-FIG001.GIF

Erickson, B. J., & Kitamura, F. (2021). Magician’s Corner: 9. Performance Metrics for Machine

LearningModels. *Radiology: Artificial Intelligence*, *3*(3). https://doi.org/10.1148/RYAI.2021200126

Eskenazi, B., Quirós-Alcalá, L., Lipsitt, J. M., Wu, L. D., Kruger, P., Ntimbane, T., Nawn, J. B., Bornman, M. S. R., & Seto, E. (2014). mSpray: A mobile phone technology to improve malaria control efforts and monitor human exposure to malaria control pesticides in Limpopo, South Africa. *Environment International*, *68*, 219–226. https://doi.org/10.1016/J.ENVINT.2014.03.003

Espinoza, J. L. (2019). Malaria Resurgence in the Americas: An Underestimated Threat. *Pathogens*, *8*(1). https://doi.org/10.3390/PATHOGENS8010011

Eyesan, O. L., & Okuboyejo, S. R. (2013). Design and Implementation of a Voice-based Medical Alert System for Medication Adherence. *Procedia Technology*, *9*, 1033–1040. https://doi.org/10.1016/J.PROTCY.2013.12.115

Faggini, M., Cosimato, S., Nota, F. D., & Nota, G. (2018). Pursuing Sustainability for Healthcare through Digital Platforms. *Sustainability 2019, Vol. 11, Page 165*, *11*(1), 165. https://doi.org/10.3390/SU11010165

Farhadi, M., Ismail, R., & Fooladi, M. (2012). Information and Communication Technology Use and Economic Growth. *PLOS ONE*, *7*(11), e48903. https://doi.org/10.1371/JOURNAL.PONE.0048903

Farrelly, M. C., Hussin, A., & Bauer, U. E. (2007). Effectiveness and cost effectiveness of television, radio and print advertisements in promoting the New York smokers' quitline. *Tobacco Control*, *16*(Suppl 1), i21–i23. https://doi.org/10.1136/TC.2007.019984

Fashoto, S. G., Mbunge, E., Ogunleye, G., & den Burg, J. Van. (2021). *Implementation of machine learning for predicting maize crop yields using multiple linear regression and backward elimination / Stephen Gbenga Fashoto ... [et al.]*. https://mjoc.uitm.edu.my

Fastring, D. R., & Griffith, J. A. (2009). Malaria incidence in Nairobi, Kenya and dekadal trends in NDVI and climatic variables. *Http://Dx.Doi.Org/10.1080/10106040802491835*, *24*(3), 207–221. https://doi.org/10.1080/10106040802491835

Feachem, R. G. A., Chen, I., Akbari, O., Bertozzi-Villa, A., Bhatt, S., Binka, F., Boni, M. F., Buckee, C., Dieleman, J., Dondorp, A., Eapen, A., Sekhri Feachem, N., Filler, S., Gething, P., Gosling, R., Haakenstad, A., Harvard, K., Hatefi, A., Jamison, D., … Mpanju-Shumbusho, W. (2019). Malaria eradication within a generation: ambitious, achievable, and necessary. *The Lancet*, *394*(10203), 1056–1112. https://doi.org/10.1016/S0140-6736(19)31139-0

Feldacker, C., Holeman, I., Murenje, V., Xaba, S., Korir, M., Wambua, B., Makunike-Chikwinya, B., Holec, M., Barnhart, S., & Tshimanga, M. (2020). Usability and acceptability of a two-way texting intervention for post-operative follow-up for voluntary medical male circumcision in Zimbabwe. *PLOS ONE*, *15*(6), e0233234. https://doi.org/10.1371/JOURNAL.PONE.0233234

Feng, D. C., Liu, Z. T., Wang, X. D., Chen, Y., Chang, J. Q., Wei, D. F., & Jiang, Z. M. (2020). Machine learning-based compressive strength prediction for concrete: An adaptive boosting approach. *Construction and Building Materials*, *230*, 117000. https://doi.org/10.1016/J.CONBUILDMAT.2019.117000

Fertleman, C., Aubugeau-Williams, P., Sher, C., Lim, A. N., Lumley, S., Delacroix, S., & Pan, X. (2018). A Discussion of Virtual Reality As a New Tool for Training Healthcare Professionals. *Frontiers in Public Health*, *6*(FEB), 44. https://doi.org/10.3389/FPUBH.2018.00044

Fokam, E. B., Kindzeka, G. F., Ngimuh, L., Dzi, K. T. J., & Wanji, S. (2017). Determination of the predictive factors of long-lasting insecticide-treated net ownership and utilisation in the Bamenda Health District of Cameroon. *BMC Public Health*, *17*(1), 1–10. https://doi.org/10.1186/S12889-017-4155-5/TABLES/6

Forenbacher, I., Husnjak, S., Cvitić, I., & Jovović, I. (2019). Determinants of mobile phone ownership in Nigeria. *Telecommunications Policy*, *43*(7), 101812. https://doi.org/10.1016/J.TELPOL.2019.03.001

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39.

https://doi.org/10.2307/3151312

Fougerouse, P.-A., Yasini, M., Marchand, G., & Aalami, O. O. (2017). A Cross-Sectional Study of Prominent US Mobile Health Applications: Evaluating the Current Landscape. *AMIA Annual Symposium Proceedings*, *2017*, 715. /pmc/articles/PMC5977729/

Fox, Grimm, R., & Caldeira, R. (2016). *An Introduction to Evaluation*. https://doi.org/10.4135/9781473983151

Fox, N., Hunn, A., & Mathers, N. (2009). Sampling and Sample Size Calculation. *National Institutes for Health Research. Research Design Service for the East Midlands/Yorkshire*, *23*(2), 1–6. www.rds-yh.nihr.ac.uk

Francis, F., Ishengoma, D. S., Mmbando, B. P., Rutta, A. S. M., Malecela, M. N., Mayala, B., Lemnge, M. M., & Michael, E. (2017). Deployment and use of mobile phone technology for real-time reporting of fever cases and malaria treatment failure in areas of declining malaria transmission in Muheza district north-eastern Tanzania. *Malaria Journal*, *16*(1), 1–14. https://doi.org/10.1186/S12936-017-1956-Z/TABLES/5

Furusa, S. S., & Coleman, A. (2018). Factors influencing e-health implementation by medical doctors in public hospitals in Zimbabwe. *SA Journal of Information Management*, *20*(1). https://doi.org/10.4102/SAJIM.V20I1.928

Gadkaree, S. K., Tollefson, T. T., Fuller, J. C., Muchemwa, F. C., Gonga, A., & Shaye, D. A. (2019a). Role of mobile health on patient enrollment for cleft lip-palate surgery: A comparative study using SMS blast text messaging in Zimbabwe. *Laryngoscope Investigative Otolaryngology*, *4*(4), 383–386. https://doi.org/10.1002/LIO2.287

Gadkaree, S. K., Tollefson, T. T., Fuller, J. C., Muchemwa, F. C., Gonga, A., & Shaye, D. A. (2019b). Role of mobile health on patient enrollment for cleft lip-palate surgery: A comparative study using SMS blast text messaging in Zimbabwe. *Laryngoscope Investigative Otolaryngology*, *4*(4), 383–386. https://doi.org/10.1002/LIO2.287

Gaobotse, G., Mbunge, E., Batani, J., & Muchemwa, B. (2022). The future of smart implants towards personalized and pervasive healthcare in Sub-Saharan Africa: Opportunities, barriers and policy recommendations. *Sensors International*, *3*, 100173. https://doi.org/10.1016/J.SINTL.2022.100173

Gaudart, J., Touré, O., Dessay, N., Dicko, A. L., Ranque, S., Forest, L., Demongeot, J., & Doumbo, O. K. (2009). Modelling malaria incidence with environmental dependency in a locality of Sudanese savannah area, Mali. *Malaria Journal*, *8*(1), 1–12. https://doi.org/10.1186/1475-2875-8-61/FIGURES/9

Gavi, S., Tapera, O., Mberikunashe, J., & Kanyangarara, M. (2021). Malaria incidence and mortality in Zimbabwe during the COVID-19 pandemic: analysis of routine surveillance data. *Malaria Journal*, *20*(1), 1–9. https://doi.org/10.1186/S12936-021-03770-7/FIGURES/3

Gibson, D. G., Ochieng, B., Kagucia, E. W., Were, J., Hayford, K., Moulton, L. H., Levine, O. S., Odhiambo, F., O'Brien, K. L., & Feikin, D. R. (2017). Mobile phone-delivered reminders and incentives to improve childhood immunisation coverage and timeliness in Kenya (M-SIMU): a cluster randomised controlled trial. *The Lancet Global Health*, *5*(4), e428–e438. https://doi.org/10.1016/S2214-109X(17)30072-4

Githinji, S., Kigen, S., Memusi, D., Nyandigisi, A., Mbithi, A. M., Wamari, A., Muturi, A. N., Jagoe, G., Barrington, J., Snow, R. W., & Zurovac, D. (2013). Reducing Stock-Outs of Life Saving Malaria Commodities Using Mobile Phone Text-Messaging: SMS for Life Study in Kenya. *PLOS ONE*, *8*(1), e54066. https://doi.org/10.1371/JOURNAL.PONE.0054066

Githinji, S., Kigen, S., Memusi, D., Nyandigisi, A., Wamari, A., Muturi, A., Jagoe, G., Ziegler, R., Snow, R. W., & Zurovac, D. (2014). Using mobile phone text messaging for malaria surveillance in rural Kenya. *Malaria Journal*, *13*(1), 1–9. https://doi.org/10.1186/1475-2875-13-107/FIGURES/4

Global Fund. (2020). *Global Fund Grants in Zimbabwe*. https://www.theglobalfund.org/media/9476/oig_gf-oig-20-008_report_en.pdf

Goldkhul, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. *European Journal of Information Systems*, *21*(2), 135–146.

Gong, M., Liu, L., Sun, X., Yang, Y., Wang, S., & Zhu, H. (2020). Cloud-Based System for Effective Surveillance and Control of COVID-19: Useful Experiences From Hubei, China. *J Med Internet Res 2020;22(4):E18948 Https://Www.Jmir.Org/2020/4/E18948*, *22*(4), e18948. https://doi.org/10.2196/18948

Gonzalez-Cuautle, D., Hernandez-Suarez, A., Sanchez-Perez, G., Toscano-Medina, L. K., Portillo-Portillo, J., Olivares-Mercado, J., Perez-Meana, H. M., & Sandoval-Orozco, A. L. (2020). Synthetic Minority Oversampling Technique for Optimizing Classification Tasks in Botnet and Intrusion-Detection-System Datasets. *Applied Sciences 2020, Vol. 10, Page 794*, *10*(3), 794. https://doi.org/10.3390/APP10030794

Graser, A., & Olaya, V. (2015). Processing: A Python Framework for the Seamless Integration of Geoprocessing Tools in QGIS. *ISPRS International Journal of Geo-Information 2015, Vol. 4, Pages 2219-2245*, *4*(4), 2219–2245. https://doi.org/10.3390/IJGI4042219

Graves, P. M., Ngondi, J. M., Hwang, J., Getachew, A., Gebre, T., Mosher, A. W., Patterson, A. E., Shargie, E. B., Tadesse, Z., Wolkon, A., Reithinger, R., Emerson, P. M., & Richards, F. O. (2011). Factors associated with mosquito net use by individuals in households owning nets in Ethiopia. *Malaria Journal*, *10*(1), 1–12. https://doi.org/10.1186/1475-2875-10-354/TABLES/5

Green, M. S., Mathew, J. J., Gundigi Venkatesh, A., Green, P., & Tariq, R. (2018). Utilization of Smartphone Applications by Anesthesia Providers. *Anesthesiology Research and Practice*, *2018*. https://doi.org/10.1155/2018/8694357

Grobbelaar, S. S., & Uriona-Maldonado, M. (2020). Using technology to improve access to healthcare: The case of the MomConnect programme in South Africa: *Https://Doi.Org/10.1177/0269094219897544*. https://doi.org/10.1177/0269094219897544

Gunda, R., Chimbari, M. J., Shamu, S., Sartorius, B., & Mukaratirwa, S. (2017a). Malaria incidence trends and their association with climatic variables in rural Gwanda, Zimbabwe, 2005-2015. *Malaria Journal*, *16*(1), 1–13. https://doi.org/10.1186/S12936-017-2036-0/FIGURES/7

Gunda, R., Chimbari, M. J., Shamu, S., Sartorius, B., & Mukaratirwa, S. (2017b). Malaria incidence trends and their association with climatic variables in rural Gwanda, Zimbabwe, 2005–2015. *Malaria Journal 2017 16:1*, *16*(1), 1–13. https://doi.org/10.1186/S12936-017-2036-0

Guo, X., Yin, Y., Dong, C., Yang, G., & Zhou, G. (2008). On the class imbalance problem. *Proceedings - 4th International Conference on Natural Computation, ICNC 2008*, *4*, 192–201. https://doi.org/10.1109/ICNC.2008.871

Gwaka, L. (2017). Digital Technologies and Sustainable Livestock Systems in Rural Communities. *The Electronic Journal of Information Systems in Developing Countries*, *81*(1), 1–24. https://doi.org/10.1002/J.1681-4835.2017.TB00598.X

Gwaka, L., Haseki, M., & Yoo, C. S. (2022a). Community networks as models to address connectivity gaps in underserved communities: *Https://Doi.Org/10.1177/02666669221089658*, 026666692210896. https://doi.org/10.1177/02666669221089658

Gwaka, L., Haseki, M., & Yoo, C. S. (2022b). Community networks as models to address connectivity gaps in underserved communities: *Https://Doi.Org/10.1177/02666669221089658*, 026666692210896. https://doi.org/10.1177/02666669221089658

Gwaka, L., May, J., & Tucker, W. (2018). Towards low-cost community networks in rural communities: The impact of context using the case study of Beitbridge, Zimbabwe. *The Electronic Journal of Information Systems in Developing Countries*, *84*(3), e12029. https://doi.org/10.1002/ISD2.12029

Hagg, E., Dahinten, V. S., & Currie, L. M. (2018). The emerging use of social media for health-related purposes in low and middle-income countries: A scoping review. *International Journal of Medical Informatics*, *115*, 92–105. https://doi.org/10.1016/J.IJMEDINF.2018.04.010

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). Thousand Oaks. *Sage*, 165.

Hair, Joe F., Howard, M. C., & Nitzl, C. (2020). Assessing measurement model quality in PLS-SEM using confirmatory composite analysis. *Journal of Business Research*, *109*, 101–110. https://doi.org/10.1016/J.JBUSRES.2019.11.069

Hair, Joe, Hollingsworth, C. L., Randolph, A. B., & Chong, A. Y. L. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial Management and Data Systems*, *117*(3), 442–458. https://doi.org/10.1108/IMDS-04-2016-0130/FULL/PDF

Hair, Joseph F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, *31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203/FULL/PDF

Hair, Joseph, & Sarstedt, M. (2021). Data, measurement, and causal inferences in machine learning: opportunities and challenges for marketing. *Https://Doi.Org/10.1080/10696679.2020.1860683*, *29*(1), 65–77. https://doi.org/10.1080/10696679.2020.1860683

Hannah, H., Brezak, A., Hu, A., Chiwanda, S., Simckes, M., Revere, D., Shambira, G., Tshimanga, M., Mberikunashe, J., Juru, T., Gombe, N., Kasprzyk, D., Montaño, D., & Baseman, J. (2019a). Field-based evaluation of malaria outbreak detection and response in Mudzi and Goromonzi districts, Zimbabwe–2017. *Global Public Health*, *14*(12), 1898–1910. https://doi.org/10.1080/17441692.2019.1642367

Hannah, H., Brezak, A., Hu, A., Chiwanda, S., Simckes, M., Revere, D., Shambira, G., Tshimanga, M., Mberikunashe, J., Juru, T., Gombe, N., Kasprzyk, D., Montaño, D., & Baseman, J. (2019b). Field-based evaluation of malaria outbreak detection and response in Mudzi and Goromonzi districts, Zimbabwe – 2017. *Https://Doi.Org/10.1080/17441692.2019.1642367*, *14*(12), 1898–1910. https://doi.org/10.1080/17441692.2019.1642367

Harp, R. D., Colborn, J. M., Karnauskas, K. B., Candrinho, B., Colborn, K. L., Zhang, L., & Horton, D. E. (2021). Towards using climate to increase lead time of a malaria early warning system in Mozambique. *The Lancet Planetary Health*, *5*, S4. https://doi.org/10.1016/S2542-

5196(21)00088-7

Harst, L., Lantzsch, H., & Scheibe, M. (2019). Theories Predicting End-User Acceptance of Telemedicine Use: Systematic Review. *J Med Internet Res 2019;21(5):E13117 Https://Www.Jmir.Org/2019/5/E13117*, *21*(5), e13117. https://doi.org/10.2196/13117

Harvey, D., Valkenburg, W., & Amara, A. (2021). Predicting malaria epidemics in Burkina Faso with machine learning. *PLOS ONE*, *16*(6), e0253302. https://doi.org/10.1371/JOURNAL.PONE.0253302

Hassan, Z. A., Schattner, P., & Mazza, D. (2006). Doing A Pilot Study: Why Is It Essential? *Malaysian Family Physician : The Official Journal of the Academy of Family Physicians of Malaysia*, *1*(2–3), 70. /pmc/articles/PMC4453116/

Hasyim, H., Nursafingi, A., Haque, U., Montag, D., Groneberg, D. A., Dhimal, M., Kuch, U., & Müller, R. (2018a). Spatial modelling of malaria cases associated with environmental factors in South Sumatra, Indonesia. *Malaria Journal*, *17*(1), 87. https://doi.org/10.1186/s12936-018-2230-8

Hasyim, H., Nursafingi, A., Haque, U., Montag, D., Groneberg, D. A., Dhimal, M., Kuch, U., & Müller, R. (2018b). Spatial modelling of malaria cases associated with environmental factors in South Sumatra, Indonesia. *Malaria Journal*, *17*(1), 1–15. https://doi.org/10.1186/S12936-018-2230-8/TABLES/4

Hatzold, K., Mavhu, W., Jasi, P., Chatora, K., Cowan, F. M., Taruberekera, N., Mugurungi, O., Ahanda, K., & Njeuhmeli, E. (2014). Barriers and Motivators to Voluntary Medical Male Circumcision Uptake among Different Age Groups of Men in Zimbabwe: Results from a Mixed Methods Study. *PLOS ONE*, *9*(5), e85051. https://doi.org/10.1371/JOURNAL.PONE.0085051

Hayawi, K., Shahriar, S., Serhani, M. A., Taleb, I., & Mathew, S. S. (2022). ANTi-Vax: a novel Twitter dataset for COVID-19 vaccine misinformation detection. *Public Health*, *203*, 23–30. https://doi.org/10.1016/J.PUHE.2021.11.022

Hayes, M. (2020). Social media and inspiring physical activity during COVID-19 and beyond. *Https://Doi.Org/10.1080/23750472.2020.1794939*, 1–8. https://doi.org/10.1080/23750472.2020.1794939

Helbostad, J. L., Vereijken, B., Becker, C., Todd, C., Taraldsen, K., Pijnappels, M., Aminian, K., & Mellone, S. (2017). Mobile Health Applications to Promote Active and Healthy Ageing. *Sensors 2017, Vol. 17, Page 622*, *17*(3), 622. https://doi.org/10.3390/S17030622

Hemingway, J., Ranson, H., Magill, A., Kolaczinski, J., Fornadel, C., Gimnig, J., Coetzee, M., Simard, F., Roch, D. K., Hinzoumbe, C. K., Pickett, J., Schellenberg, D., Gething, P., Hoppé, M., & Hamon, N. (2016). Averting a malaria disaster: will insecticide resistance derail malaria control? *The Lancet*, *387*(10029), 1785–1788. https://doi.org/10.1016/S0140-6736(15)00417-1

Henry, M., Florey, L., Youll, S., & Gutman, J. R. (2018). An analysis of country adoption and implementation of the 2012 WHO recommendations for intermittent preventive treatment for pregnant women in sub-Saharan Africa. *Malaria Journal*, *17*(1), 1–10. https://doi.org/10.1186/S12936-018-2512-1/FIGURES/4

Henseler, J. (2018). Partial least squares path modeling: Quo vadis? *Quality and Quantity*, *52*(1), 1–8. https://doi.org/10.1007/S11135-018-0689-6/FIGURES/1

Henseler, J., Fassott, G., Dijkstra, T. K., & Wilson, B. (2011). Analysing quadratic effects of formative constructs by means of variance-based structural equation modelling. *European Journal of Information Systems 2011 21:1*, *21*(1), 99–112. https://doi.org/10.1057/EJIS.2011.36

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135. https://doi.org/10.1007/S11747-014-0403-8/FIGURES/8

Heuschen, A. K., Lu, G., Razum, O., Abdul-Mumin, A., Sankoh, O., von Seidlein, L., D’Alessandro, U., & Müller, O. (2021). Public health-relevant consequences of the COVID-19 pandemic on malaria in sub-Saharan Africa: a scoping review. *Malaria Journal*, *20*(1), 1–

16. https://doi.org/10.1186/S12936-021-03872-2/FIGURES/2

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly: Management Information Systems*, *28*(1), 75–105. https://doi.org/10.2307/25148625

Hewitt, B., Dolezel, D., & McLeod, A. (2017). Mobile Device Security: Perspectives of Future Healthcare Workers. *Perspectives in Health Information Management*, *14*(Winter). /pmc/articles/PMC5430111/

Hirata, E., Giannotti, M. A., Larocca, A. P. C., & Quintanilha, J. A. (2018). Flooding and inundation collaborative mapping – use of the Crowdmap/Ushahidi platform in the city of Sao Paulo, Brazil. *Journal of Flood Risk Management*, *11*, S98–S109. https://doi.org/10.1111/JFR3.12181

Hoque, R., & Sorwar, G. (2017a). Understanding factors influencing the adoption of mHealth by the elderly: An extension of the UTAUT model. *International Journal of Medical Informatics*, *101*(September 2015), 75–84. https://doi.org/10.1016/j.ijmedinf.2017.02.002

Hoque, R., & Sorwar, G. (2017b). Understanding factors influencing the adoption of mHealth by the elderly: An extension of the UTAUT model. *International Journal of Medical Informatics*, *101*, 75–84. https://doi.org/10.1016/J.IJMEDINF.2017.02.002

Hove, M., & Chenzi, V. (2020). Social media, civil unrest and government responses: the Zimbabwean experience. *Https://Doi.Org/10.1080/02589001.2020.1746750*, *38*(1), 121–137. https://doi.org/10.1080/02589001.2020.1746750

Hussain, M., Zaidan, A. A., Zidan, B. B., Iqbal, S., Ahmed, M. M., Albahri, O. S., & Albahri, A. S. (2018). Conceptual framework for the security of mobile health applications on Android platform. *Telematics and Informatics*, *35*(5), 1335–1354. https://doi.org/10.1016/J.TELE.2018.03.005

In, J. (2017). Introduction of a pilot study. *Korean Journal of Anesthesiology*, *70*(6), 601–605. https://doi.org/10.4097/kjae.2017.70.6.601

International Telecommunication Union (ITU). (2018). Measuring the Information Society Report 2018 - Volume 1. Geneva, Switzerland. In *ITU Publications* (Vol. 1). https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2018/MISR-2018-Vol-1-E.pdf

Inzaule, S. C., Tessema, S. K., Kebede, Y., Ogwell Ouma, A. E., & Nkengasong, J. N. (2021). Genomic-informed pathogen surveillance in Africa: opportunities and challenges. *The Lancet Infectious Diseases*, *21*(9), e281–e289. https://doi.org/10.1016/S1473-3099(20)30939-7

Iskandar, K., Molinier, L., Hallit, S., Sartelli, M., Hardcastle, T. C., Haque, M., Lugova, H., Dhingra, S., Sharma, P., Islam, S., Mohammed, I., Naina Mohamed, I., Hanna, P. A., Hajj, S. El, Jamaluddin, N. A. H., Salameh, P., & Roques, C. (2021). Surveillance of antimicrobial resistance in low- and middle-income countries: a scattered picture. *Antimicrobial Resistance & Infection Control 2021 10:1*, *10*(1), 1–19. https://doi.org/10.1186/S13756-021-00931-W

Jalloh, M. F., Kinsman, J., Conteh, J., Kaiser, R., Jambai, A., Ekström, A. M., Bunnell, R. E., & Nordenstedt, H. (2021). Barriers and facilitators to reporting deaths following Ebola surveillance in Sierra Leone: implications for sustainable mortality surveillance based on an exploratory qualitative assessment. *BMJ Open*, *11*(5), e042976. https://doi.org/10.1136/BMJOPEN-2020-042976

Jamison, D. T., Summers, L. H., Alleyne, G., Arrow, K. J., Berkley, S., Binagwaho, A., Bustreo, F., Evans, D., Feachem, R. G. A., Frenk, J., Ghosh, G., Goldie, S. J., Guo, Y., Gupta, S., Horton, R., Kruk, M. E., Mahmoud, A., Mohohlo, L. K., Ncube, M., … Yamey, G. (2013). Global health 2035: A world converging within a generation. *The Lancet*, *382*(9908), 1898–1955. https://doi.org/10.1016/S0140-6736(13)62105-4/ATTACHMENT/B1499312-0BAB-482A-83FC-6DD74E4B95DE/MMC6.MP4

Järvinen, P. (2007). Action Research is Similar to Design Science. *Quality & Quantity 2007 41:1*, *41*(1), 37–54. https://doi.org/10.1007/S11135-005-5427-1

Jiang, F., Jiang, Y., Zhi, H., Dong, Y., Li, H., Ma, S., Wang, Y., Dong, Q., Shen, H., & Wang, Y. (2017). Artificial intelligence in healthcare: past, present and future. *Stroke and Vascular*

Neurology, *2*(4), 230–243. https://doi.org/10.1136/SVN-2017-000101

Jombo, G. T. A., Mbaawuaga, E. M., Gyuse, A. N., Enenebeaku, M. N. O., Okwori, E. E., Peters, E. J., Akpan, S., Odey, F., Etukumana, E. A., & Akosu, J. T. (2010). Socio—cultural factors influencing insecticide treated bed net utilization in a malaria endemic city in north—central Nigeria. *Asian Pacific Journal of Tropical Medicine*, *3*(5), 402–406. https://doi.org/10.1016/S1995-7645(10)60098-3

Justice, C. O., Townshend, J. R. G., Vermote, E. F., Masuoka, E., Wolfe, R. E., Saleous, N., Roy, D. P., & Morisette, J. T. (2002). An overview of MODIS Land data processing and product status. *Remote Sensing of Environment*, *83*(1–2), 3–15. https://doi.org/10.1016/S0034-4257(02)00084-6

Kalipe, G., Gautham, V., & Behera, R. K. (2018a). Predicting Malarial Outbreak using Machine Learning and Deep Learning Approach: A Review and Analysis. *Proceedings - 2018 International Conference on Information Technology, ICIT 2018*, 33–38. https://doi.org/10.1109/ICIT.2018.00019

Kalipe, G., Gautham, V., & Behera, R. K. (2018b). Predicting Malarial Outbreak using Machine Learning and Deep Learning Approach: A Review and Analysis. *Proceedings - 2018 International Conference on Information Technology, ICIT 2018*, 33–38. https://doi.org/10.1109/ICIT.2018.00019

Källander, K., Tibenderana, J. K., Akpogheneta, O. J., Strachan, D. L., Hill, Z., Asbroek, A. H. A. T., Conteh, L., Kirkwood, B. R., & Meek, S. R. (2013). Mobile Health (mHealth) Approaches and Lessons for Increased Performance and Retention of Community Health Workers in Low- and Middle-Income Countries: A Review. *J Med Internet Res 2013;15(1):E17 Https://Www.Jmir.Org/2013/1/E17*, *15*(1), e2130. https://doi.org/10.2196/JMIR.2130

Kamana, E., Zhao, J., & Bai, D. (2022). Predicting the impact of climate change on the re-emergence of malaria cases in China using LSTMSeq2Seq deep learning model: a modelling and prediction analysis study. *BMJ Open*, *12*(3), e053922. https://doi.org/10.1136/BMJOPEN-2021-053922

Kanonge, T. T., & Bussin, M. H. R. (2022). Pre-conditions for employee motivation to curb Zimbabwe's academic brain drain. *SA Journal of Human Resource Management*, *20*. https://doi.org/10.4102/SAJHRM.V20I0.1819

Kanyangarara, M., Hamapumbu, H., Mamini, E., Lupiya, J., Stevenson, J. C., Mharakurwa, S., Chaponda, M., Thuma, P. E., Gwanzura, L., Munyati, S., Mulenga, M., Norris, D. E., & Moss, W. J. (2018). Malaria knowledge and bed net use in three transmission settings in southern Africa. *Malaria Journal 2018 17:1*, *17*(1), 1–12. https://doi.org/10.1186/S12936-018-2178-8

Kanyumba, B. (2022). Training as a Tool for Service Delivery: A Case Study of Health Care Workers in Gwanda, Zimbabwe. *African Journal of Inter/Multidisciplinary Studies*, *4*(1), 384–393. https://doi.org/10.51415/AJIMS.V4I1.1002

Kao, H. Y., Wei, C. W., Yu, M. C., Liang, T. Y., Wu, W. H., & Wu, Y. J. (2018). Integrating a mobile health applications for self-management to enhance Telecare system. *Telematics and Informatics*, *35*(4), 815–825. https://doi.org/10.1016/J.TELE.2017.12.011

Kebede, D., Zielinski, C., Mbondji, P. E., Piexoto, M., Kouvividila, W., & Sambo, L. G. (2014). The African Health Observatory and national health observatories as platforms for strengthening health information systems in sub-Saharan Africa: *Http://Dx.Doi.Org/10.1177/0141076813512817*, *107*, 6–9. https://doi.org/10.1177/0141076813512817

Kesse-Tachi, A., Asmah, A. E., & Agbozo, E. (2019). Factors influencing adoption of eHealth technologies in Ghana. *Digital Health*, *5*, 2055207619871425. https://doi.org/10.1177/2055207619871425

Khanday, A. M. U. D., Khan, Q. R., & Rabani, S. T. (2021). Identifying propaganda from online social networks during COVID-19 using machine learning techniques. *International Journal of Information Technology (Singapore)*, *13*(1), 115–122. https://doi.org/10.1007/S41870-020-00550-5/FIGURES/7

Khatun, F., Heywood, A. E., Ray, P. K., Bhuiya, A., & Liaw, S. T. (2016). Community readiness for adopting mHealth in rural Bangladesh: A qualitative exploration. *International Journal of*

Medical Informatics, *93*, 49–56. https://doi.org/10.1016/J.IJMEDINF.2016.05.010

Khumalo, N. B., & Mnjama, N. (2018). National standardisation for eHealth information initiatives in hospitals at Bulawayo in Zimbabwe. *Journal of the South African Society of Archivists*, *51*, 172–195. https://www.ajol.info/index.php/jsasa/article/view/186147

Kichloo, A., Albosta, M., Dettloff, K., Wani, F., El-Amir, Z., Singh, J., Aljadah, M., Chakinala, R. C., Kanugula, A. K., Solanki, S., & Chugh, S. (2020). Telemedicine, the current COVID-19 pandemic and the future: a narrative review and perspectives moving forward in the USA. *Family Medicine and Community Health*, *8*(3). https://doi.org/10.1136/FMCH-2020-000530

Kijsanayotin, B., Pannarunothai, S., & Speedie, S. M. (2009). Factors influencing health information technology adoption in Thailand's community health centers: Applying the UTAUT model. *International Journal of Medical Informatics*, *78*(6), 404–416. https://doi.org/10.1016/J.IJMEDINF.2008.12.005

Kim, J., & Lee, K. S. S. (2020). Conceptual model to predict Filipino teachers' adoption of ICT-based instruction in class: using the UTAUT model. *Https://Doi.Org/10.1080/02188791.2020.1776213*. https://doi.org/10.1080/02188791.2020.1776213

Kim, S., Lee, K.-H., Hwang, H., & Yoo, S. (2015). Analysis of the factors influencing healthcare professionals' adoption of mobile electronic medical record (EMR) using the unified theory of acceptance and use of technology (UTAUT) in a tertiary hospital. *BMC Medical Informatics and Decision Making*, *16*(1), 1–12. https://doi.org/10.1186/S12911-016-0249-8/FIGURES/5

Kim, Y., Ratnam, J. V., Doi, T., Morioka, Y., Behera, S., Tsuzuki, A., Minakawa, N., Sweijd, N., Kruger, P., Maharaj, R., Imai, C. C., Ng, C. F. S., Chung, Y., & Hashizume, M. (2019). Malaria predictions based on seasonal climate forecasts in South Africa: A time series distributed lag nonlinear model. *Scientific Reports 2019 9:1*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-53838-3

Kiskin, I., Cobb, A. D., Sinka, M., Willis, K., & Roberts, S. J. (2021). Automatic Acoustic

Mosquito Tagging with Bayesian Neural Networks. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 12978 LNAI*, 351–366. https://doi.org/10.1007/978-3-030-86514-6_22

Klasnja, P., & Pratt, W. (2012). Healthcare in the pocket: Mapping the space of mobile-phone health interventions. *Journal of Biomedical Informatics*, *45*(1), 184–198. https://doi.org/10.1016/J.JBI.2011.08.017

Koonin, L. M., Hoots, B., Tsang, C. A., Leroy, Z., Farris, K., Jolly, B., Antall, P., McCabe, B., Zelis, C. B. R., Tong, I., & Harris, A. M. (2020). Trends in the Use of Telehealth During the Emergence of the COVID-19 Pandemic — United States, January–March 2020. *Morbidity and Mortality Weekly Report*, *69*(43), 1595. https://doi.org/10.15585/MMWR.MM6943A3

Korenromp, E. L., Miller, J., Cibulskis, R. E., Cham, M. K., Alnwick, D., & Dye, C. (2003). Monitoring mosquito net coverage for malaria control in Africa: possession vs. use by children under 5 years. *Tropical Medicine & International Health*, *8*(8), 693–703. https://doi.org/10.1046/J.1365-3156.2003.01084.X

Kumar, D. S., Andimuthu, R., Rajan, R., & Venkatesan, M. S. (2014). Spatial trend, environmental and socioeconomic factors associated with malaria prevalence in Chennai. *Malaria Journal*, *13*(1), 1–9. https://doi.org/10.1186/1475-2875-13-14/FIGURES/8

Kumar, N., Brunette, W., Dell, N., Perrier, T., Kolko, B., Borriello, G., & Anderson, R. (2015). Understanding Sociotechnical Implications of Mobile Health Deployments in India, Kenya, and Zimbabwe. *Information Technologies & International Development*, *11*(4), 17–22. https://itidjournal.org/index.php/itid/article/view/1440

Kumar, S., Nilsen, W. J., Abernethy, A., Atienza, A., Patrick, K., Pavel, M., Riley, W. T., Shar, A., Spring, B., Spruijt-Metz, D., Hedeker, D., Honavar, V., Kravitz, R., Craig Lefebvre, R., Mohr, D. C., Murphy, S. A., Quinn, C., Shusterman, V., & Swendeman, D. (2013). Mobile Health Technology Evaluation: The mHealth Evidence Workshop. *American Journal of Preventive Medicine*, *45*(2), 228–236. https://doi.org/10.1016/J.AMEPRE.2013.03.017

Kushitor, M. K., & Boatemaa, S. (2018). The double burden of disease and the challenge of health access: Evidence from Access, Bottlenecks, Cost and Equity facility survey in Ghana. *PLOS ONE*, *13*(3), e0194677. https://doi.org/10.1371/JOURNAL.PONE.0194677

Kusotera, T., & Nhengu, T. G. (2020). Coronavirus-19 and malaria: The great mimics. *African Journal of Primary Health Care and Family Medicine*, *12*(1). https://doi.org/10.4102/PHCFM.V12I1.2501

Kwenti, T. E. (2018). Malaria and HIV coinfection in sub-Saharan Africa: prevalence, impact, and treatment strategies. *Research and Reports in Tropical Medicine*, *Volume 9*, 123–136. https://doi.org/10.2147/RRTM.S154501

Kyaw, B. M., Saxena, N., Posadzki, P., Vseteckova, J., Nikolaou, C. K., George, P. P., Divakar, U., Masiello, I., Kononowicz, A. A., Zary, N., & Car, L. T. (2019). Virtual Reality for Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration. *J Med Internet Res 2019;21(1):E12959 Https://Www.Jmir.Org/2019/1/E12959*, *21*(1), e12959. https://doi.org/10.2196/12959

Ladan, M. A., Wharrad, H., & Windle, R. (2018). Towards understanding healthcare professionals' adoption and use of technologies in clinical practice: Using Qmethodology and models of technology acceptance. *Journal of Innovation in Health Informatics*, *25*(1), 27–37. https://doi.org/10.14236/JHI.V25I1.965

Lahmiri, S., Dawson, D. A., & Shmuel, A. (2018). Performance of machine learning methods in diagnosing Parkinson's disease based on dysphonia measures. *Biomedical Engineering Letters*, *8*(1), 29–39. https://doi.org/10.1007/S13534-017-0051-2/FIGURES/2

Lakshmi, K. K., Gupta, H., & Ranjan, J. (2018). USSD-Architecture analysis, security threats, issues and enhancements. *2017 International Conference on Infocom Technologies and Unmanned Systems: Trends and Future Directions, ICTUS 2017*, *2018-January*, 798–802. https://doi.org/10.1109/ICTUS.2017.8286115

Laliberté, M., Beaulieu-Poulin, C., Larrivée, A. C., Charbonneau, M., Samson, É., & Feldman, D. E. (2016). Current Uses (and Potential Misuses) of Facebook: An Online Survey in Physiotherapy. *Http://Dx.Doi.Org/10.3138/Ptc.2014-41*. https://doi.org/10.3138/PTC.2014-

41

Lapointe, L., Ramaprasad, J., & Vedel, I. (2014). Creating health awareness: A social media enabled collaboration. *Health and Technology*, *4*(1), 43–57. https://doi.org/10.1007/S12553-013-0068-1/FIGURES/2

Larocca, A., Moro Visconti, R., & Marconi, M. (2016). Malaria diagnosis and mapping with m-Health and geographic information systems (GIS): evidence from Uganda. *Malaria Journal*, *15*(1), 1–12. https://doi.org/10.1186/S12936-016-1546-5/FIGURES/6

Larsen, D. A., Welsh, R., Mulenga, A., & Reid, R. (2018). Widespread mosquito net fishing in the Barotse floodplain: Evidence from qualitative interviews. *PLOS ONE*, *13*(5), e0195808. https://doi.org/10.1371/JOURNAL.PONE.0195808

Le Bel, S., Chavernac, D., Mapuvire, G., & Cornu, G. (2014). FrontlineSMS as an Early Warning Network for Human-Wildlife Mitigation: Lessons Learned from Tests Conducted in Mozambique and Zimbabwe. *The Electronic Journal of Information Systems in Developing Countries*, *60*(1), 1–13. https://doi.org/10.1002/J.1681-4835.2014.TB00427.X

Lee, K., Agrawal, A., & Choudhary, A. (2013). Real-Time disease surveillance using twitter data:Demonstration on flu and cancer. *Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, *Part F128815*, 1474–1477. https://doi.org/10.1145/2487575.2487709

Lee, S., Cho, Y. min, & Kim, S. Y. (2017a). Mapping mHealth (mobile health) and mobile penetrations in sub-Saharan Africa for strategic regional collaboration in mHealth scale-up: An application of exploratory spatial data analysis. *Globalization and Health*, *13*(1), 1–11. https://doi.org/10.1186/S12992-017-0286-9/FIGURES/2

Lee, S., Cho, Y. min, & Kim, S. Y. (2017b). Mapping mHealth (mobile health) and mobile penetrations in sub-Saharan Africa for strategic regional collaboration in mHealth scale-up: An application of exploratory spatial data analysis. *Globalization and Health*, *13*(1), 1–11. https://doi.org/10.1186/S12992-017-0286-9/FIGURES/2

Lee Ventola, C. (2014). Medical Applications for 3D Printing: Current and Projected Uses. *Pharmacy and Therapeutics*, *39*(10), 704. /pmc/articles/PMC4189697/

Lee, Y. W., Choi, J. W., & Shin, E. H. (2021). Machine learning model for predicting malaria using clinical information. *Computers in Biology and Medicine*, *129*, 104151. https://doi.org/10.1016/J.COMPBIOMED.2020.104151

Leon, N., Schneider, H., & Daviaud, E. (2012). Applying a framework for assessing the health system challenges to scaling up mHealth in South Africa. *BMC Medical Informatics and Decision Making*, *12*(1), 1–12. https://doi.org/10.1186/1472-6947-12-123/TABLES/4

Liu, C., Zhu, Q., Holroyd, K. A., & Seng, E. K. (2011). Status and trends of mobile-health applications for iOS devices: A developer's perspective. *Journal of Systems and Software*, *84*(11), 2022–2033. https://doi.org/10.1016/J.JSS.2011.06.049

Liu, X. Y., Wu, J., & Zhou, Z. H. (2009). Exploratory undersampling for class-imbalance learning. *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics*, *39*(2), 539–550. https://doi.org/10.1109/TSMCB.2008.2007853

Lo Presti, L., Testa, M., Marino, V., & Singer, P. (2019). Engagement in Healthcare Systems: Adopting Digital Tools for a Sustainable Approach. *Sustainability 2019, Vol. 11, Page 220*, *11*(1), 220. https://doi.org/10.3390/SU11010220

Lou, D., Chen, X., Zhao, Z., Xuan, Y., Xu, Z., Jin, H., Guo, X., & Fang, Z. (2013). A Wireless Health Monitoring System based on Android Operating System. *IERI Procedia*, *4*, 208–215. https://doi.org/10.1016/J.IERI.2013.11.030

Lubinda, J., Haque, U., Bi, Y., Shad, M. Y., Keellings, D., Hamainza, B., & Moore, A. J. (2021). Climate change and the dynamics of age-related malaria incidence in Southern Africa. *Environmental Research*, *197*, 111017. https://doi.org/10.1016/J.ENVRES.2021.111017

Mabweazara, H. M. (2013). 'Pirate' radio, convergence and reception in Zimbabwe. *Telematics and Informatics*, *30*(3), 232–241. https://doi.org/10.1016/J.TELE.2012.02.007

Makacha, L., & Makanga, P. T. (2021). *Mobile Health Geographies: A Case from Zimbabwe*. 191–

200. https://doi.org/10.1007/978-3-030-63471-1_14

Makoni, M. (2020). COVID-19 worsens Zimbabwe's health crisis. *Lancet (London, England)*, *396*(10249), 457. https://doi.org/10.1016/S0140-6736(20)31751-7

Makono, R., & Sibanda, S. (1999). Review of the prevalence of malaria in Zimbabwe with specific reference to parasite drug resistance (1984–1996). *Transactions of The Royal Society of Tropical Medicine and Hygiene*, *93*(5), 449–452. https://doi.org/10.1016/S0035-9203(99)90331-0

Makri, A. (2019). Bridging the digital divide in health care. *The Lancet Digital Health*, *1*(5), e204–e205. https://doi.org/10.1016/S2589-7500(19)30111-6

Mangundu, M., Roets, L., & Janse Van Rensberg, E. (2020). *African Journal of Primary Health Care & Family Medicine Affiliation*. https://doi.org/10.4102/phcfm

Manhibi, R., Ruckstuhl, L., Shamu, A., van Dijk, J., & van Stam, G. (2022). A Portfolio of Digital Platforms and Services for Digital Health Interventions, A Case in Masvingo Province, Zimbabwe. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST*, *443 LNICST*, 69–79. https://doi.org/10.1007/978-3-031-06374-9_5/COVER

Manyangadze, T., Chimbari, M. J., Macherera, M., & Mukaratirwa, S. (2017a). Micro-spatial distribution of malaria cases and control strategies at ward level in Gwanda district, Matabeleland South, Zimbabwe. *Malaria Journal*, *16*(1), 1–11. https://doi.org/10.1186/s12936-017-2116-1

Manyangadze, T., Chimbari, M. J., Macherera, M., & Mukaratirwa, S. (2017b). Micro-spatial distribution of malaria cases and control strategies at ward level in Gwanda district, Matabeleland South, Zimbabwe. *Malaria Journal*, *16*(1), 1–11. https://doi.org/10.1186/S12936-017-2116-1/TABLES/4

Manyangadze, T., Mavhura, E., Mudavanhu, C., & Pedzisai, E. (2021a). An exploratory analysis of the spatial variation of malaria cases and associated household socio-economic factors in flood-prone areas of Mbire district, Zimbabwe. *GeoJournal*, 1–16. https://doi.org/10.1007/S10708-021-10505-3/FIGURES/3

Manyangadze, T., Mavhura, E., Mudavanhu, C., & Pedzisai, E. (2021b). An exploratory analysis of the spatial variation of malaria cases and associated household socio-economic factors in flood-prone areas of Mbire district, Zimbabwe. *GeoJournal*, 1–16. https://doi.org/10.1007/S10708-021-10505-3/FIGURES/3

Manyati, T. K., & Mutsau, M. (2021). A systematic review of the factors that hinder the scale up of mobile health technologies in antenatal care programmes in sub-Saharan Africa. *African Journal of Science, Technology, Innovation and Development*, *13*(1), 125–131. https://doi.org/10.1080/20421338.2020.1765479

Maphosa, V. (2018). Enhancing Access to Socioeconomic Development Information using Mobile Phone Applications in rural Zimbabwe: The case of Matabeleland South Province. *University of KwaZulu Natal Thesis*, *Ldc*.

Maphosa, V. (2020). Using MyLSU app to enhance student engagement and promote a smart town at a rural university in Zimbabwe. *Http://Www.Editorialmanager.Com/Cogentedu*, *7*(1). https://doi.org/10.1080/2331186X.2020.1823143

Maphosa, V. (2022a). Delivering a Drug Information App to Underserved Communities: A User-Centered Design Approach. *Https://Doi.Org/10.1080/1097198X.2022.2132086*, *25*(4), 286–301. https://doi.org/10.1080/1097198X.2022.2132086

Maphosa, V. (2022b). Promoting access to COVID-19 Information by underserved communities through the development of a mHealth app. *Https://Doi.Org/10.1080/27707571.2022.2095722*, *9*(1). https://doi.org/10.1080/27707571.2022.2095722

Maphosa, V., Dube, B., & Jita, T. (2020). A UTAUT Evaluation of WhatsApp as a Tool for Lecture Delivery during the COVID-19 Lockdown at a Zimbabwean University. *International Journal of Higher Education*, *9*(5), 84–93. https://doi.org/10.5430/ijhe.v9n5p84

Maponga, B. A., Chirundu, D., Shambira, G., Gombe, N. T., Tshimanga, M., & Bangure, D. (2014). Evaluation of the notifiable diseases surveillance system in sanyati district, Zimbabwe, 2010-2011. *The Pan African Medical Journal*, *19*. https://doi.org/10.11604/PAMJ.2014.19.278.5202

Marcoux, R. M., & Vogenberg, F. R. (2016). Telehealth: Applications From a Legal and Regulatory Perspective. *Pharmacy and Therapeutics*, *41*(9), 567. /pmc/articles/PMC5010268/

Mariki, M., Mkoba, E., & Mduma, N. (2022). Combining Clinical Symptoms and Patient Features for Malaria Diagnosis: Machine Learning Approach. *Https://Doi.Org/10.1080/08839514.2022.2031826*. https://doi.org/10.1080/08839514.2022.2031826

Mark, M., & Ngwira, S. M. (2011). Ubiquitous health care framework for the rural African environment. *IEEE AFRICON Conference*. https://doi.org/10.1109/AFRCON.2011.6072068

Marongwe, P., Wasunna, B., Gavera, J., Murenje, V., Gwenzi, F., Hove, J., Mauhy, C., Xaba, S., Mugwanya, R., Makunike-Chikwinya, B., Munyaradzi, T., Korir, M., Oni, F., Khaemba, A., Barasa, M., Holec, M., Sidile-Chitimbire, V., Tshimanga, M., Holeman, I., … Feldacker, C. (2022a). Transitioning a digital health innovation from research to routine practice: Two-way texting for male circumcision follow-up in Zimbabwe. *PLOS Digital Health*, *1*(6), e0000066. https://doi.org/10.1371/JOURNAL.PDIG.0000066

Marongwe, P., Wasunna, B., Gavera, J., Murenje, V., Gwenzi, F., Hove, J., Mauhy, C., Xaba, S., Mugwanya, R., Makunike-Chikwinya, B., Munyaradzi, T., Korir, M., Oni, F., Khaemba, A., Barasa, M., Holec, M., Sidile-Chitimbire, V., Tshimanga, M., Holeman, I., … Feldacker, C. (2022b). Transitioning a digital health innovation from research to routine practice: Two-way texting for male circumcision follow-up in Zimbabwe. *PLOS Digital Health*, *1*(6), e0000066. https://doi.org/10.1371/JOURNAL.PDIG.0000066

Marshall, G. (2005). The purpose, design and administration of a questionnaire for data collection. *Radiography*, *11*(2), 131–136. https://doi.org/10.1016/J.RADI.2004.09.002

Marufu, C., & Maboe, K. A. (2017a). Utilisation of mobile health by medical doctors in a Zimbabwean health care facility. *Health SA Gesondheid*, *22*, 228–234. https://doi.org/10.1016/J.HSAG.2017.03.002

Marufu, C., & Maboe, K. A. (2017b). Utilisation of mobile health by medical doctors in a Zimbabwean health care facility. *Health SA Gesondheid*, *22*, 228–234. https://doi.org/10.1016/J.HSAG.2017.03.002

Maseko, A., & Nunu, W. N. (2020). Risk factors associated with high malaria incidence among communities in selected wards in Binga district, Zimbabwe: a case-control study. *Scientific African*, *9*, e00473. https://doi.org/10.1016/J.SCIAF.2020.E00473

Mashange, W., Martineau, T., Chandiwana, P., Chirwa, Y., Pepukai, V. M., Munyati, S., & Alonso-Garbayo, A. (2019). Flexibility of deployment: Challenges and policy options for retaining health workers during crisis in Zimbabwe. *Human Resources for Health*, *17*(1), 1–9. https://doi.org/10.1186/S12960-019-0369-1/TABLES/4

Mason, C. H., & William D. Perreault, J. (2018). Collinearity, Power, and Interpretation of Multiple Regression Analysis: *Https://Doi.Org/10.1177/002224379102800302*, *28*(3), 268–280. https://doi.org/10.1177/002224379102800302

Masud, M., Alhumyani, H., Alshamrani, S. S., Cheikhrouhou, O., Ibrahim, S., Muhammad, G., Hossain, M. S., & Shorfuzzaman, M. (2020). Leveraging Deep Learning Techniques for Malaria Parasite Detection Using Mobile Application. *Wireless Communications and Mobile Computing*, *2020*. https://doi.org/10.1155/2020/8895429

Masuku, M. (2019). Framework for electronic health records and electronic medical records standards implementation in the health sector of Zimbabwe. *University of South Africa*, *45*(45), 95–98. https://uir.unisa.ac.za/handle/10500/28241

Matingwina, T., & Raju, J. (2017). An Integrated Framework for Disseminating Health Information to Students in Zimbabwe. *Libri*, *67*(1), 35–50. https://doi.org/10.1515/LIBRI-2016-0054

Matsushita, B., Yang, W., Chen, J., Onda, Y., & Qiu, G. (2007). Sensitivity of the Enhanced Vegetation Index (EVI) and Normalized Difference Vegetation Index (NDVI) to Topographic Effects: A Case Study in High-density Cypress Forest. *Sensors 2007, Vol. 7, Pages 2636-2651*, *7*(11), 2636–2651. https://doi.org/10.3390/S7112636

Maviza, A., & Ahmed, F. (2021). Climate change/variability and hydrological modelling studies in Zimbabwe: a review of progress and knowledge gaps. *SN Applied Sciences 2021 3:5*, *3*(5), 1–28. https://doi.org/10.1007/S42452-021-04512-9

Mavunga, G., & Kaguda, D. (2016). Combatting the pandemic: An analysis of selected adverts on HIV/AIDS on Zimbabwean Broadcasting Corporation Television (September 2008 to May 2011). *Https://Doi.Org/10.1080/02572117.2016.1252010*, *36*(2), 173–188. https://doi.org/10.1080/02572117.2016.1252010

Mbondji, P. E., Kebede, D., Soumbey-Alley, E. W., Zielinski, C., Kouvividila, W., & Lusamba-Dikassa, P.-S. (2014). Resources, indicators, data management, dissemination and use in health information systems in sub-Saharan Africa: results of a questionnaire-based survey. *Journal of the Royal Society of Medicine*, *107*(1 suppl), 28–33. https://doi.org/10.1177/0141076814528690

Mbunge, E., Fashoto, S. G., Akinnuwesi, B., Metfula, A., Simelane, S., & Ndumiso, N. (2021). Ethics for integrating emerging technologies to contain COVID-19 in Zimbabwe. *Human Behavior and Emerging Technologies*, *3*(5), 876–890. https://doi.org/10.1002/HBE2.277

Mbunge, E., Millham, R. C., Sibiya, M. N., & Takavarasha, S. (2021). Diverging Mobile Technology's Cognitive Techniques into Tackling Malaria in Sub-Saharan Africa: A Review. *Lecture Notes in Networks and Systems*, *232 LNNS*, 679–699. https://doi.org/10.1007/978-3-030-90318-3_54

Mbunge, E., Millham, R., Sibiya, M. N., & Takavarasha, S. (2020). Impact of COVID-19 on Malaria Elimination: Juxtaposing Indoor Residual Spraying and Mobile Phones in Buhera Rural District, Zimbabwe. *ResearchSquare*, *2*(1), 34–42. https://doi.org/10.21203/rs.3.rs-173130/v2

Mbunge, E., Muchemwa, B., & Batani, J. (2022). Are we there yet? Unbundling the potential adoption and integration of telemedicine to improve virtual healthcare services in African health systems. *Sensors International*, *3,* 100152. https://doi.org/10.1016/J.SINTL.2021.100152

Mbunge, E., Sibiya, M. N., Millham, R. C., & Takavarasha, S. (2021a). Micro-spatial modelling of malaria cases and environmental risk factors in Buhera rural district, Zimbabwe. *2021 Conference on Information Communications Technology and Society, ICTAS 2021 - Proceedings*, 52–58. https://doi.org/10.1109/ICTAS50802.2021.9394987

Mbunge, E., Sibiya, M. N., Millham, R. C., & Takavarasha, S. (2021b). *m-health framework for improving malaria information dissemination in Buhera rural district amid COVID-19 and beyond*. 59–66. https://doi.org/10.1109/ictas50802.2021.9395020

Mbuthia, F. (2020). *A mobile health communication framework for postnatal care in rural Kenya*. http://scholar.ufs.ac.za/xmlui/handle/11660/11554

Mbuthia, F., Reid, M., & Fichardt, A. (2021). Development and validation of a mobile health communication framework for postnatal care in rural Kenya. *International Journal of Africa Nursing Sciences*, *14*, 100304. https://doi.org/10.1016/J.IJANS.2021.100304

McCarthy, O. L., Mavodza, C., Chikwari, C. D., Dauya, E., Tembo, M., Hlabangana, P., Dembetembe, R., Mpakami, N., Bandason, T., Free, C., Smith, C., & Ferrand, R. A. (2022). Adapting an evidence-based contraceptive behavioural intervention delivered by mobile phone for young people in Zimbabwe. *BMC Health Services Research*, *22*(1), 1–10. https://doi.org/10.1186/S12913-022-07501-9/FIGURES/1

McLay, L., Sutherland, D., Machalicek, W., & Sigafoos, J. (2020). Systematic Review of Telehealth Interventions for the Treatment of Sleep Problems in Children and Adolescents. *Journal of Behavioral Education 2020 29:2*, *29*(2), 222–245. https://doi.org/10.1007/S10864-020-09364-8

McLean, S., Sheikh, A., Cresswell, K., Nurmatov, U., Mukherjee, M., Hemmi, A., & Pagliari, C. (2013). The Impact of Telehealthcare on the Quality and Safety of Care: A Systematic

Overview. *PLoS ONE*, *8*(8). https://doi.org/10.1371/JOURNAL.PONE.0071238

Meuter, R. F. I., Gallois, C., Segalowitz, N. S., Ryder, A. G., & Hocking, J. (2015). Overcoming language barriers in healthcare: A protocol for investigating safe and effective communication when patients or clinicians use a second language. *BMC Health Services Research*, *15*(1), 1–5. https://doi.org/10.1186/S12913-015-1024-8/PEER-REVIEW

Mharakurwa, S., Mutambu, S. L., Mudyiradima, R., Chimbadzwa, T., Chandiwana, S. K., & Day, K. P. (2004). Association of house spraying with suppressed levels of drug resistance in Zimbabwe. *Malaria Journal*, *3*(1), 1–9. https://doi.org/10.1186/1475-2875-3-35/TABLES/7

Mharakurwa, S., Research, for the S. and C. A. I. C. of E. for M., Matsena-Zingoni, Z., Research, for the S. and C. A. I. C. of E. for M., Mudare, N., Research, for the S. and C. A. I. C. of E. for M., Matimba, C., Research, for the S. and C. A. I. C. of E. for M., Gara, T. X., Research, for the S. and C. A. I. C. of E. for M., Makuwaza, A., Research, for the S. and C. A. I. C. of E. for M., Maponga, G., Research, for the S. and C. A. I. C. of E. for M., Munyati, S., Research, for the S. and C. A. I. C. of E. for M., Gwanzura, L., Research, for the S. and C. A. I. C. of E. for M., Mutambu, S. L., … Research, for the S. and C. A. I. C. of E. for M. (2021). Steep Rebound of Chloroquine-Sensitive Plasmodium falciparum in Zimbabwe. *The Journal of Infectious Diseases*, *223*(2), 306–309. https://doi.org/10.1093/INFDIS/JIAA368

Mhlanga, D., & Ndhlovu, E. (2021). Socio-economic and Political Challenges in Zimbabwe and the Development Implications for Southern Africa. *Journal of African Foreign Affairs*, *8*(2), 75–98. https://doi.org/10.31920/2056-5658/2021/V8N2A5

Mohamadali, N. A., & Aziz, N. F. A. (2017). The Technology Factors as Barriers for Sustainable Health Information Systems (HIS) – A Review. *Procedia Computer Science*, *124*, 370–378. https://doi.org/10.1016/J.PROCS.2017.12.167

Mohammed, A., Acheampong, P. R., Otupiri, E., Osei, F. A., Larson-Reindorf, R., & Owusu-Dabo, E. (2019). Mobile phone short message service (SMS) as a malaria control tool: A quasi-experimental study. *BMC Public Health*, *19*(1), 1–11. https://doi.org/10.1186/S12889-019-7336-6/TABLES/8

Mohapatra, P., Tripathi, N. K., Pal, I., & Shrestha, S. (2021). Determining suitable machine learning classifier technique for prediction of malaria incidents attributed to climate of Odisha. *Https://Doi.Org/10.1080/09603123.2021.1905782*. https://doi.org/10.1080/09603123.2021.1905782

Monaghesh, E., & Hajizadeh, A. (2020). The role of telehealth during COVID-19 outbreak: A systematic review based on current evidence. *BMC Public Health*, *20*(1), 1–9. https://doi.org/10.1186/S12889-020-09301-4/TABLES/1

Moodley, J., Constant, D., Botha, M. H., van der Merwe, F. H., Edwards, A., & Momberg, M. (2019). Exploring the feasibility of using mobile phones to improve the management of clients with cervical cancer precursor lesions. *BMC Women's Health 2019 19:1*, *19*(1), 1–10. https://doi.org/10.1186/S12905-018-0702-1

Moodley, Mangino, J. E., & Goff, D. A. (2013). Review of Infectious Diseases Applications for iPhone/iPad and Android: From Pocket to Patient. *Clinical Infectious Diseases*, *57*(8), 1145–1154. https://doi.org/10.1093/CID/CIT455

Moonasar, D., Maharaj, R., Kunene, S., Candrinho, B., Saute, F., Ntshalintshali, N., & Morris, N. (2016). Towards malaria elimination in the MOSASWA (Mozambique, South Africa and Swaziland) region. *Malaria Journal*, *15*(1), 1–5. https://doi.org/10.1186/S12936-016-1470-8/FIGURES/2

Moore, C., Scherr, T., Matoba, J., Sing'anga, C., Lubinda, M., Thuma, P., & Wright, D. (2021). mHAT app for automated malaria rapid test result analysis and aggregation: a pilot study. *Malaria Journal 2021 20:1*, *20*(1), 1–11. https://doi.org/10.1186/S12936-021-03772-5

Morgan, D. L. (2014). Pragmatism as a Paradigm for Social Research: *Http://Dx.Doi.Org/10.1177/1077800413513733*. https://doi.org/10.1177/1077800413513733

Morris, A. L., Ghani, A., & Ferguson, N. (2021). Fine-scale estimation of key life-history parameters of malaria vectors: implications for next-generation vector control technologies. *Parasites and Vectors*, *14*(1), 1–12. https://doi.org/10.1186/S13071-021-04789-0/FIGURES/5

Mosa, A. S. M., Yoo, I., & Sheets, L. (2012). A systematic review of healthcare applications for smartphones. *BMC Medical Informatics and Decision Making*, *12*(1), 1–31. https://doi.org/10.1186/1472-6947-12-67/TABLES/12

Moyo, J., & Madziyire, G. (2020). Use of telemedicine in obstetrics and gynaecology in Zimbabwe during a lockdown period. *The Pan African Medical Journal*, *35*(Suppl 2), 1–4. https://doi.org/10.11604/PAMJ.SUPP.2020.35.2.23675

Muchena, G., Dube, B., Chikodzore, R., Pasipamire, J., Murugasampillay, S., & Mberikunashe, J. (2018). A review of progress towards sub-national malaria elimination in Matabeleland South Province, Zimbabwe (2011-2015): A qualitative study. *Malaria Journal*, *17*(1), 1–7. https://doi.org/10.1186/S12936-018-2299-0/FIGURES/7

Mudzonga, M. (2021). Migration management and health service delivery: A case of the Zimbabwe public health sector. *Https://Doi.Org/10.1080/0376835X.2021.1890547*. https://doi.org/10.1080/0376835X.2021.1890547

Muhammad, B., & Varol, A. (2021). A Symptom-Based Machine Learning Model for Malaria Diagnosis in Nigeria. *9th International Symposium on Digital Forensics and Security, ISDFS 2021*. https://doi.org/10.1109/ISDFS52919.2021.9486315

Mukami, V., Millham, R., & Puckree, T. (2019). MHealth: ICT framework for mitigating the determinants of maternal and neonatal morality. *IEEE AFRICON Conference*, *2019-September*. https://doi.org/10.1109/AFRICON46755.2019.9133795

Mukora-Mutseyekwa, F., Mundagowa, P. T., Kangwende, R. A., Murapa, T., Tirivavi, M., Mukuwapasi, W., Tozivepi, S. N., Uzande, C., Mutibura, Q., Chadambuka, E. M., & Machinga, M. (2022). Implementation of a campus-based and peer-delivered HIV self-testing intervention to improve the uptake of HIV testing services among university students in Zimbabwe: the SAYS initiative. *BMC Health Services Research*, *22*(1), 1–13. https://doi.org/10.1186/S12913-022-07622-1/FIGURES/5

Mukungwa, T. (2015). Factors Associated with full Immunization Coverage amongst children aged 12 – 23 months in Zimbabwe. *African Population Studies*, *29*(2), 1761–1774.

https://doi.org/10.11564/29-2-745

Mukwenha, S., Dzinamarira, T., Chingombe, I., Mapingure, M. P., & Musuka, G. (2021). Health emergency and disaster risk management: A case of Zimbabwe's preparedness and response to cyclones and tropical storms: We are not there yet! *Public Health in Practice*, *2*, 100131. https://doi.org/10.1016/J.PUHIP.2021.100131

Murillo, E., Muskus, C., Agudelo, L. A., Vélez, I. D., & Ruiz-Lopez, F. (2019). A new high-resolution melting analysis for the detection and identification of Plasmodium in human and Anopheles vectors of malaria. *Scientific Reports 2019 9:1*, *9*(1), 1–9. https://doi.org/10.1038/s41598-018-36515-9

Murira, N., Lützen, K., Lindmark, G., & Christensson, K. (2003). Communication patterns between health care providers and their clients at an antenatal clinic in Zimbabwe. *Health Care for Women International*, *24*(2), 83–92. https://doi.org/10.1080/07399330390170060

Musesengwa, R., & Chimbari, M. J. (2017). Experiences of community members and researchers on community engagement in an Ecohealth project in South Africa and Zimbabwe. *BMC Medical Ethics*, *18*(1), 1–15. https://doi.org/10.1186/S12910-017-0236-3/TABLES/3

Mushi, V., Mbotwa, C. H., Zacharia, A., Ambrose, T., & Moshi, F. V. (2021). Predictors for the uptake of optimal doses of sulfadoxine-pyrimethamine for intermittent preventive treatment of malaria during pregnancy in Tanzania: further analysis of the data of the 2015–2016 Tanzania demographic and health survey and malaria indicator survey. *Malaria Journal*, *20*(1), 1–9. https://doi.org/10.1186/S12936-021-03616-2/TABLES/3

Mutale, W., Chintu, N., Amoroso, C., Awoonor-Williams, K., Phillips, J., Baynes, C., Michel, C., Taylor, A., & Sherr, K. (2013). Improving health information systems for decision making across five sub-Saharan African countries: Implementation strategies from the African Health Initiative. *BMC Health Services Research*, *13*(SUPPL.2), 1–12. https://doi.org/10.1186/1472-6963-13-S2-S9/FIGURES/5

Mutsigiri, F., Mafaune, P. T., Mungati, M., Shambira, G., Bangure, D., Juru, T., Gombe, N. T., & Tshimanga, M. (2017). Malaria morbidity and mortality trends in Manicaland province, Zimbabwe, 2005-2014. *The Pan African Medical Journal*, *27*. https://doi.org/10.11604/PAMJ.2017.27.30.11130

Mwendera, C., de Jager, C., Longwe, H., Hongoro, C., Phiri, K., & Mutero, C. M. (2017). Development of a framework to improve the utilisation of malaria research for policy development in Malawi. *Health Research Policy and Systems*, *15*(1), 1–10. https://doi.org/10.1186/S12961-017-0264-Y/FIGURES/1

Nakaya, T, Fotheringham, A. S., Charlton, M., & Brunsdon, C. (2009). Semiparametric geographically weighted generalised linear modelling in GWR 4.0. *Statistics in Medicine*, *24*(17), 2695–2717.

Nakaya, Tomoki, Fotheringham, A. S., Brunsdon, C., & Charlton, M. (2005). Geographically weighted Poisson regression for disease association mapping. *Statistics in Medicine*, *24*(17), 2695–2717. https://doi.org/10.1002/SIM.2129

Ndayizigamiye, P., & Maharaj, M. (2016). Applying bridges framework to investigate challenges to the adoption of mHealth in Burundi. *2016 IST-Africa Conference, IST-Africa 2016*. https://doi.org/10.1109/ISTAFRICA.2016.7530705

Nelson, O., & Namtira, B. J. (2017). Measuring Media Campaigns Effectiveness for Environmental Health for Sustainable Development: A Study of Ebola Outbreak in Lagos State, Nigeria. *Https://Doi.Org/10.1177/0972063417727619*, *19*(4), 553–562. https://doi.org/10.1177/0972063417727619

Nema, S., Verma, A. K., Tiwari, A., & Bharti, P. K. (2021). Digital Health Care Services to Control and Eliminate Malaria in India. *Trends in Parasitology*, *37*(2), 96–99. https://doi.org/10.1016/J.PT.2020.11.002

Ngabo, F., Nguimfack, J., Nwaigwe, F., Mugeni, C., Muhoza, D., Wilson, D. R., Kalach, J., Gakuba, R., Karema, C., & Binagwaho, A. (2012). Designing and Implementing an Innovative SMS-based alert system (RapidSMS-MCH) to monitor pregnancy and reduce maternal and child deaths in Rwanda. *The Pan African Medical Journal*, *13*. /pmc/articles/PMC3542808/

Nghochuzie, N. N., Olwal, C. O., Udoakang, A. J., Amenga-Etego, L. N. K., & Amambua-Ngwa, A. (2020). Pausing the Fight Against Malaria to Combat the COVID-19 Pandemic in Africa: Is the Future of Malaria Bleak? *Frontiers in Microbiology*, *11*, 1476. https://doi.org/10.3389/FMICB.2020.01476/BIBTEX

Nhamo, G., & Chikodzi, D. (2021). *Tropical Cyclone Idai and Flood Hazard Modelling in the Eastern Parts of the Save Catchment, Zimbabwe*. 241–253. https://doi.org/10.1007/978-3-030-72393-4_14

Nhapi, T. G. (2019). Socioeconomic Barriers to Universal Health Coverage in Zimbabwe: Present Issues and Pathways Toward Progress: *Https://Doi.Org/10.1177/0169796X19826762*, *35*(1), 153–174. https://doi.org/10.1177/0169796X19826762

Nkiruka, O., Prasad, R., & Clement, O. (2021). Prediction of malaria incidence using climate variability and machine learning. *Informatics in Medicine Unlocked*, *22*, 100508. https://doi.org/10.1016/J.IMU.2020.100508

Nkya, T. E., Fillinger, U., Sangoro, O. P., Marubu, R., Chanda, E., & Mutero, C. M. (2022). Six decades of malaria vector control in southern Africa: a review of the entomological evidence-base. *Malaria Journal 2022 21:1*, *21*(1), 1–16. https://doi.org/10.1186/S12936-022-04292-6

Noordzij, M., Dekker, F. W., Zoccali, C., & Jager, K. J. (2011). Sample Size Calculations. *Nephron Clinical Practice*, *118*(4), c319–c323. https://doi.org/10.1159/000322830

Noordzij, M., Tripepi, G., Dekker, F. W., Zoccali, C., Tanck, M. W., & Jager, K. J. (2010). Sample size calculations: basic principles and common pitfalls. *Nephrology Dialysis Transplantation*, *25*(5), 1388–1393. https://doi.org/10.1093/NDT/GFP732

Nyamambi, E., Murendo, C., Sibanda, N., & Mazinyane, S. (2020). Knowledge, attitudes and barriers of cervical cancer screening among women in Chegutu rural district of Zimbabwe. *Http://Www.Editorialmanager.Com/Cogentsocsci*, *6*(1). https://doi.org/10.1080/23311886.2020.1766784

Nyapwere, N., Dube, Y. P., & Makanga, P. T. (2021a). Guidelines for developing geographically sensitive mobile health applications. *Health and Technology*, *11*(2), 379–387. https://doi.org/10.1007/S12553-020-00518-2/FIGURES/3

Nyapwere, N., Dube, Y. P., & Makanga, P. T. (2021b). Guidelines for developing geographically sensitive mobile health applications. *Health and Technology*, *11*(2), 379–387. https://doi.org/10.1007/S12553-020-00518-2/FIGURES/3

Nyati-Jokomo, Z., Dabengwa, I. M., Makacha, L., Nyapwere, N., Dube, Y. P., Chikoko, L., Vidler, M., & Makanga, P. T. (2020a). RoadMApp: A feasibility study for a smart travel application to improve maternal health delivery in a low resource setting in Zimbabwe. *BMC Pregnancy and Childbirth*, *20*(1), 1–12. https://doi.org/10.1186/S12884-020-03200-7/TABLES/2

Nyati-Jokomo, Z., Dabengwa, I. M., Makacha, L., Nyapwere, N., Dube, Y. P., Chikoko, L., Vidler, M., & Makanga, P. T. (2020b). RoadMApp: A feasibility study for a smart travel application to improve maternal health delivery in a low resource setting in Zimbabwe. *BMC Pregnancy and Childbirth*, *20*(1), 1–12. https://doi.org/10.1186/S12884-020-03200-7/TABLES/2

Nyirenda, D., Makawa, T. C., Chapita, G., Mdalla, C., Nkolokosa, M., O'byrne, T., Heyderman, R., & Desmond, N. (2018). Public engagement in Malawi through a health-talk radio programme 'Umoyo nkukambirana': A mixed-methods evaluation. *Public Understanding of Science*, *27*(2), 229–242. https://doi.org/10.1177/0963662516656110

O'Neil, S., & Koekemoer, E. (2016). Two decades of qualitative research in psychology, industrial and organisational psychology and human resource management within South Africa: A critical review. *SA Journal of Industrial Psychology*, *42*(1). https://doi.org/10.4102/SAJIP.V42I1.1350

O'Neill, S., Gryseels, C., Dierickx, S., Mwesigwa, J., Okebe, J., d'Alessandro, U., & Grietens, K. P. (2015). Foul wind, spirits and witchcraft: illness conceptions and health-seeking behaviour for malaria in the Gambia. *Malaria Journal 2015 14:1*, *14*(1), 1–10. https://doi.org/10.1186/S12936-015-0687-2

Ochieng, B. M., Smith, L., Orton, B., Hayter, M., Kaseje, M., Wafula, C. O., Ocholla, P., Onukwugha, F., & Kaseje, D. C. O. (2022). Perspectives of Adolescents, Parents, Service

Providers, and Teachers on Mobile Phone Use for Sexual Reproductive Health Education. *Social Sciences 2022, Vol. 11, Page 196*, *11*(5), 196. https://doi.org/10.3390/SOCSCI11050196

Oehler, R. L., Smith, K., & Toney, J. F. (2010). Infectious diseases resources for the iPhone. *Clinical Infectious Diseases*, *50*(9), 1268–1274. https://doi.org/10.1086/651602/2/50-9-1268-FIG002.GIF

Okagbue, H. I., Oguntunde, P. E., Obasi, E. C. M., Adamu, P. I., & Opanuga, A. A. (2021). Diagnosing malaria from some symptoms: a machine learning approach and public health implications. *Health and Technology*, *11*(1), 23–37. https://doi.org/10.1007/S12553-020-00488-5/TABLES/9

Oliveira, A. D., Prats, C., Espasa, M., Serrat, F. Z., Sales, C. M., Silgado, A., Codina, D. L., Arruda, M. E., Gomezi Prat, J., & Albuquerque, J. (2017). The Malaria System MicroApp: A New, Mobile Device-Based Tool for Malaria Diagnosis. *JMIR Research Protocols*, *6*(4), e70. https://doi.org/10.2196/RESPROT.6758

Oliver-Williams, C., Brown, E., Devereux, S., Fairhead, C., & Holeman, I. (2017). Using Mobile Phones to Improve Vaccination Uptake in 21 Low- and Middle-Income Countries: Systematic Review. *JMIR Mhealth Uhealth 2017;5(10):E148 Https://Mhealth.Jmir.Org/2017/10/E148*, *5*(10), e7792. https://doi.org/10.2196/MHEALTH.7792

Omair, A. (2014). Sample size estimation and sampling techniques for selecting a representative sample Cite this paper Related papers AO St at Met hods JHealt h Spec 2014 Sample size estimation and sampling techniques for selecting a representative sample. *Journal of Health Specialties*. https://doi.org/10.4103/1658-600X.142783

Omboni, S. (2019). Connected Health in Hypertension Management. *Frontiers in Cardiovascular Medicine*, *6*, 76. https://doi.org/10.3389/FCVM.2019.00076/BIBTEX

Omotosho, A., Ayegba, P., Emuoyibofarhe, J., & Meinel, C. (2019). Current state of ICT in healthcare delivery in developing countries. *International Journal of Online and Biomedical Engineering*, *15*(8), 91–107. https://doi.org/10.3991/IJOE.V15I08.10294

Opoku, D., Stephani, V., & Quentin, W. (2017). A realist review of mobile phone-based health interventions for non-communicable disease management in sub-Saharan Africa. *BMC Medicine*, *15*(1), 1–12. https://doi.org/10.1186/S12916-017-0782-Z/TABLES/3

Oria, P. A., Hiscox, A., Alaii, J., Ayugi, M., Mukabana, W. R., Takken, W., & Leeuwis, C. (2014). Tracking the mutual shaping of the technical and social dimensions of solar-powered mosquito trapping systems (SMoTS) for malaria control on Rusinga Island, western Kenya. *Parasites & Vectors 2014 7:1*, *7*(1), 1–12. https://doi.org/10.1186/S13071-014-0523-5

Osei, E., Kuupiel, D., Vezi, P. N., & Mashamba-Thompson, T. P. (2021). Mapping evidence of mobile health technologies for disease diagnosis and treatment support by health workers in sub-Saharan Africa: a scoping review. *BMC Medical Informatics and Decision Making*, *21*(1), 1–18. https://doi.org/10.1186/S12911-020-01381-X/FIGURES/4

Osei, E., & Mashamba-Thompson, T. P. (2021). Mobile health applications for disease screening and treatment support in low-and middle-income countries: A narrative review. *Heliyon*, *7*(3), e06639. https://doi.org/10.1016/J.HELIYON.2021.E06639

Otieno, G., Githinji, S., Jones, C., Snow, R. W., Talisuna, A., & Zurovac, D. (2014). The feasibility, patterns of use and acceptability of using mobile phone text-messaging to improve treatment adherence and post-treatment review of children with uncomplicated malaria in western Kenya. *Malaria Journal*, *13*(1), 1–7. https://doi.org/10.1186/1475-2875-13-44/TABLES/2

Ozano, K. (2022). *Cross Country Study on Integration of HIV, TB and Malaria in Uganda, Nigeria, Mozambique, DRC, Zimbabwe and Tanzania*. Institute of Development Studies. https://doi.org/10.19088/K4D.2022.066

Palasio, R. G. S., Bortoleto, A. N., Tuan, R., & Chiaravalloti-Neto, F. (2021). Geographic Information System-based association between the sewage network, geographical location of intermediate hosts, and autochthonous cases for the estimation of risk areas of schistosomiasis infection in Ourinhos, São Paulo, Brazil. *Revista Da Sociedade Brasileira de Medicina Tropical*, *54*. https://doi.org/10.1590/0037-8682-0851-2020

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015).

Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health*, *42*(5), 533. https://doi.org/10.1007/S10488-013-0528-Y

Palombi, L., & Moramarco, S. (2018). *Health in Sub-Saharan Africa: HIV, TB and Malaria Epidemiology*. 3–16. https://doi.org/10.1007/978-3-319-72763-9_1

Panicker, R. O., Soman, B., Gangadharan, K. V., & Sobhana, N. V. (2016). An adoption model describing clinician's acceptance of automated diagnostic system for tuberculosis. *Health and Technology*, *6*(4), 247–257. https://doi.org/10.1007/s12553-016-0136-4

Pankomera, R., & Greunen, D. van. (2018). A model for implementing sustainable mHealth applications in a resource-constrained setting: A case of Malawi. *The Electronic Journal of Information Systems in Developing Countries*, *84*(2), e12019. https://doi.org/10.1002/ISD2.12019

Pankomera, R., & van Greunen, D. (2018). A model for implementing sustainable mHealth applications in a resource-constrained setting: A case of Malawi. *The Electronic Journal of Information Systems in Developing Countries*, *84*(2), e12019. https://doi.org/10.1002/ISD2.12019

Papadopoulos, T., Baltas, K. N., & Balta, M. E. (2020). The use of digital technologies by small and medium enterprises during COVID-19: Implications for theory and practice. *International Journal of Information Management*, *55*, 102192. https://doi.org/10.1016/J.IJINFOMGT.2020.102192

Papageorgiou, A., Strigkos, M., Politou, E., Alepis, E., Solanas, A., & Patsakis, C. (2018). Security and Privacy Analysis of Mobile Health Applications: The Alarming State of Practice. *IEEE Access*, *6*, 9390–9403. https://doi.org/10.1109/ACCESS.2018.2799522

Parent, L. M., DeLorenzo, M. E., & Fulton, M. H. (2011). Effects of the synthetic pyrethroid insecticide, permethrin, on two estuarine fish species. *Http://Dx.Doi.Org/10.1080/03601234.2011.589316*, *46*(7), 615–622. https://doi.org/10.1080/03601234.2011.589316

Park, H. S., Cho, H., & Kim, H. S. (2016). Development of a multi-agent M-health application based on various protocols for chronic disease self-management. *Journal of Medical Systems*, *40*(1), 1–14. https://doi.org/10.1007/S10916-015-0401-5/TABLES/3

Payne, K. F. B., Wharrad, H., & Watts, K. (2012). Smartphone and medical related App use among medical students and junior doctors in the United Kingdom (UK): A regional survey. *BMC Medical Informatics and Decision Making*, *12*(1), 1–11. https://doi.org/10.1186/1472-6947-12-121/TABLES/4

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2014). A Design Science Research Methodology for Information Systems Research. *Https://Doi.Org/10.2753/MIS0742-1222240302*, *24*(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

Pellegrino, J., Tapera, O., Mberikunashe, J., & Kanyangarara, M. (2022). Malaria service provision in Manicaland Province, Zimbabwe during the coronavirus pandemic: a cross-sectional survey of health facilities. *Journal of Global Health Reports*, *6,* 1–9. https://doi.org/10.29392/001c.31597

Perrier, T., Derenzi, B., & Anderson, R. (2015). USSD: The third universal app. *ACM DEV-6 2015 - Proceedings of the 2015 Annual Symposium on Computing for Development*, 13–21. https://doi.org/10.1145/2830629.2830645

Pluess, B., Tanser, F. C., Lengeler, C., & Sharp, B. L. (2010). Indoor residual spraying for preventing malaria. *Cochrane Database of Systematic Reviews*, *4*. https://doi.org/10.1002/14651858.CD006657.PUB2

Porter, G., Hampshire, K., Abane, A., Munthali, A., Robson, E., De Lannoy, A., Tanle, A., & Owusu, S. (2019). Mobile phones, gender, and female empowerment in sub-Saharan Africa: studies with African youth. *Https://Doi.Org/10.1080/02681102.2019.1622500*, *26*(1), 180–193. https://doi.org/10.1080/02681102.2019.1622500

Pourhomayoun, M., & Shakibi, M. (2021). Predicting mortality risk in patients with COVID-19 using machine learning to help medical decision-making. *Smart Health*, *20*, 100178.

https://doi.org/10.1016/J.SMHL.2020.100178

Pousibet-Puerto, J., Salas-Coronas, J., Sánchez-Crespo, A., Molina-Arrebola, M. A., Soriano-Pérez, M. J., Giménez-López, M. J., Vázquez-Villegas, J., & Cabezas-Fernández, M. T. (2016). Impact of using artemisinin-based combination therapy (ACT) in the treatment of uncomplicated malaria from Plasmodium falciparum in a non-endemic zone. *Malaria Journal 2016 15:1*, *15*(1), 1–7. https://doi.org/10.1186/S12936-016-1408-1

Pride, M., & Tatenda, N. (2017). Human Resource Planning in an Unstable Economy: Challenges Faced. A Case of State Universities in Zimbabwe. *International Journal of Asian Social Science*, *7*(3), 206–217. https://doi.org/10.18488/JOURNAL.1/2017.7.3/1.3.206.217

Prue, C. S., Shannon, K. L., Khyang, J., Edwards, L. J., Ahmed, S., Ram, M., Shields, T., Hossain, M. S., Glass, G. E., Nyunt, M. M., Sack, D. A., Sullivan, D. J., & Khan, W. A. (2013). Mobile phones improve case detection and management of malaria in rural Bangladesh. *Malaria Journal*, *12*(1), 1–7. https://doi.org/10.1186/1475-2875-12-48/FIGURES/3

Quan, V., Hulth, A., Kok, G., & Blumberg, L. (2014). Timelier notification and action with mobile phones-towards malaria elimination in South Africa. *Malaria Journal*, *13*(1), 1–8. https://doi.org/10.1186/1475-2875-13-151/TABLES/2

Raab, M., Roth, E., Nguyen, V. K., & Froeschl, G. (2021). The 2021 Ebola virus outbreak in Guinea: Mistrust and the shortcomings of outbreak surveillance. *PLOS Neglected Tropical Diseases*, *15*(6), e0009487. https://doi.org/10.1371/JOURNAL.PNTD.0009487

Rahimi, B., Nadri, H., Afshar, H. L., & Timpka, T. (2018). A systematic review of the technology acceptance model in health informatics. *Applied Clinical Informatics*, *9*(3), 604–634. https://doi.org/10.1055/s-0038-1668091

Rai, R. K., Khajanchi, S., Tiwari, P. K., Venturino, E., & Misra, A. K. (2022). Impact of social media advertisements on the transmission dynamics of COVID-19 pandemic in India. *Journal of Applied Mathematics and Computing*, *68*(1), 19–44. https://doi.org/10.1007/S12190-021-01507-Y/FIGURES/9

Rajak, M., & Shaw, K. (2021). An extension of technology acceptance model for mHealth user adoption. *Technology in Society*, *67*, 101800. https://doi.org/10.1016/J.TECHSOC.2021.101800

Rajvanshi, H., Jain, Y., Kaintura, N., Soni, C., Chandramohan, R., Srinivasan, R., Telasey, V., Bharti, P. K., Jain, D., Surve, M., Saxena, S., Gangamwar, V., Anand, M. S., & Lal, A. A. (2021). A comprehensive mobile application tool for disease surveillance, workforce management and supply chain management for Malaria Elimination Demonstration Project. *Malaria Journal*, *20*(1), 1–9. https://doi.org/10.1186/S12936-021-03623-3/FIGURES/5

Raman, J., Fakudze, P., Sikaala, C. H., Chimumbwa, J., & Moonasar, D. (2021). Eliminating malaria from the margins of transmission in Southern Africa through the Elimination 8 Initiative. *Https://Doi.Org/10.1080/0035919X.2021.1915410*, *76*(2), 137–145. https://doi.org/10.1080/0035919X.2021.1915410

Ramírez-Correa, P., Mariano-Melo, A., & Alfaro-Pérez, J. (2019). Predicting and Explaining the Acceptance of Social Video Platforms for Learning: The Case of Brazilian YouTube Users. *Sustainability 2019, Vol. 11, Page 7115*, *11*(24), 7115. https://doi.org/10.3390/SU11247115

Redding, L. E., & Cole, S. D. (2019). Posters Have Limited Utility in Conveying a Message of Antimicrobial Stewardship to Pet Owners. *Frontiers in Veterinary Science*, *6*, 421. https://doi.org/10.3389/FVETS.2019.00421/BIBTEX

Reddy, P., Dukhi, N., Sewpaul, R., Ellahebokus, M. A. A., Kambaran, N. S., & Jobe, W. (2021). Mobile Health Interventions Addressing Childhood and Adolescent Obesity in Sub-Saharan Africa and Europe: Current Landscape and Potential for Future Research. *Frontiers in Public Health*, *9*, 177. https://doi.org/10.3389/FPUBH.2021.604439/BIBTEX

Robert Avis, W. (2022). *Malaria, HIV and TB in Tanzania: Epidemiology, Disease Control Challenges and Interventions*. https://doi.org/10.19088/K4D.2022.037

Robinson, R. S. (2014). Purposive Sampling. *Encyclopedia of Quality of Life and Well-Being Research*, 5243–5245. https://doi.org/10.1007/978-94-007-0753-5_2337

Rosewell, A., Makita, L., Muscatello, D., John, L. N., Bieb, S., Hutton, R., Ramamurthy, S., & Shearman, P. (2017). Health information system strengthening and malaria elimination in Papua New Guinea. *Malaria Journal*, *16*(1), 1–10. https://doi.org/10.1186/S12936-017-1910-0/FIGURES/6

Ross, J., Stevenson, F., Lau, R., & Murray, E. (2015). Exploring the challenges of implementing e-health: a protocol for an update of a systematic review of reviews. *BMJ Open*, *5*(4), e006773. https://doi.org/10.1136/BMJOPEN-2014-006773

Rouleau, G., Gagnon, M. P., Côté, J., Payne-Gagnon, J., Hudson, E., & Dubois, C. A. (2017). Impact of Information and Communication Technologies on Nursing Care: Results of an Overview of Systematic Reviews. *J Med Internet Res 2017;19(4):E122 Https://Www.Jmir.Org/2017/4/E122*, *19*(4), e6686. https://doi.org/10.2196/JMIR.6686

Roy, M., Moreau, N., Rousseau, C., Mercier, A., Wilson, A., & Atlani-Duault, L. (2020). Ebola and Localized Blame on Social Media: Analysis of Twitter and Facebook Conversations During the 2014–2015 Ebola Epidemic. *Culture, Medicine and Psychiatry*, *44*(1), 56–79. https://doi.org/10.1007/S11013-019-09635-8/FIGURES/2

Rugoho, T., & Maphosa, F. (2017). Challenges faced by women with disabilities in accessing sexual and reproductive health in Zimbabwe: The case of Chitungwiza town. *African Journal of Disability*, *6*. https://doi.org/10.4102/AJOD.V6I0.252

Ruxwana, N. L., Herselman, M. E., & Conradie, D. P. (2010). ICT applications as e-health solutions in rural healthcare in the Eastern Cape Province of South Africa. *The HIM Journal*, *39*(1), 17–26. https://doi.org/10.1177/183335831003900104

Sadoughi, F., El-Gazzar, R. F., Erfannia, L., & Sheikhtaheri, A. (2022). How the Health Information Systems Can Overcome the Challenges of Migrating to the Cloud? A Framework Based on a Mix Method Approach. *Frontiers in Health Informatics*, *11*(1), 107. https://doi.org/10.30699/FHI.V11I1.342

Sande, S., Zimba, M., Mberikunashe, J., Tangwena, A., & Chimusoro, A. (2017). Progress towards malaria elimination in Zimbabwe with special reference to the period 2003-2015. *Malaria*

Journal, *16*(1), 1–13. https://doi.org/10.1186/s12936-017-1939-0

Sande, S., Zimba, M., Nyasvisvo, D., Mukuzunga, M., Kooma, E. H., Mberikunashe, J., & Dube, B. (2019). Getting ready for integrated vector management for improved disease prevention in Zimbabwe: A focus on key policy issues to consider. In *Malaria Journal* (Vol. 18, Issue 1, p. 322). BioMed Central Ltd. https://doi.org/10.1186/s12936-019-2965-x

Sangoro, O. P., Fillinger, U., Saili, K., Nkya, T. E., Marubu, R., Masaninga, F., Trigo, S. C., Tarumbwa, C., Hamainza, B., Baltazar, C., Mberikunashe, J., Chisanga, B., Menale, K., Chanda, E., & Mutero, C. M. (2021). Evaluating the efficacy, impact, and feasibility of community-based house screening as a complementary malaria control intervention in southern Africa: a study protocol for a household randomized trial. *Trials*, *22*(1), 1–16. https://doi.org/10.1186/S13063-021-05768-7/FIGURES/4

Sarma, S., Nemser, B., Cole-Lewis, H., Kaonga, N., Negin, J., Namakula, P., Ohemeng-Dapaah, S., & Kanter, A. S. (2018). Effectiveness of SMS Technology on Timely Community Health Worker Follow-Up for Childhood Malnutrition: A Retrospective Cohort Study in sub-Saharan Africa. *Global Health: Science and Practice*, *6*(2), 345–355. https://doi.org/10.9745/GHSP-D-16-00290

Sarstedt, M., & Cheah, J. H. (2019). Partial least squares structural equation modeling using SmartPLS: a software review. *Journal of Marketing Analytics 2019 7:3*, *7*(3), 196–202. https://doi.org/10.1057/S41270-019-00058-3

Sarstedt, M., Ringle, C. M., & Hair, J. F. (2021). Partial Least Squares Structural Equation Modeling. *Handbook of Market Research*, 1–47. https://doi.org/10.1007/978-3-319-05542-8_15-2

Schamberger, T., Schuberth, F., Henseler, J., & Dijkstra, T. K. (2020). Robust partial least squares path modeling. *Behaviormetrika*, *47*(1), 307–334. https://doi.org/10.1007/S41237-019-00088-2/TABLES/4

Schlagenhauf, P., Adamcova, M., Regep, L., Schaerer, M. T., & Rhein, H. G. (2010). The position of mefloquine as a 21st century malaria chemoprophylaxis. *Malaria Journal*, *9*(1), 1–15.

https://doi.org/10.1186/1475-2875-9-357/TABLES/6

Schlagenhauf, P., & Petersen, E. (2008). Malaria chemoprophylaxis: Strategies for risk groups. *Clinical Microbiology Reviews*, *21*(3), 466–472. https://doi.org/10.1128/CMR.00059-07/ASSET/00FB1C6D-5360-443F-942E-595C15FF6C4E/ASSETS/GRAPHIC/ZCM0030822440001.JPEG

Seebregts, C., Dane, P., Parsons, A. N., Fogwill, T., Rogers, D., Bekker, M., Shaw, V., & Barron, P. (2018). Designing for scale: optimising the health information system architecture for mobile maternal health messaging in South Africa (MomConnect). *BMJ Global Health*, *3*(Suppl 2), e000563. https://doi.org/10.1136/BMJGH-2017-000563

Seliya, N., Khoshgoftaar, T. M., & Van Hulse, J. (2009). A study on the relationships of classifier performance metrics. *Proceedings - International Conference on Tools with Artificial Intelligence, ICTAI*, 59–66. https://doi.org/10.1109/ICTAI.2009.25

Seo, J. H., & Kim, Y. H. (2018). Machine-learning approach to optimize smote ratio in class imbalance dataset for intrusion detection. *Computational Intelligence and Neuroscience*, *2018*. https://doi.org/10.1155/2018/9704672

Serrano, A., Garcia-Guzman, J., Xydopoulos, G., & Tarhini, A. (2020). Analysis of Barriers to the Deployment of Health Information Systems: a Stakeholder Perspective. *Information Systems Frontiers*, *22*(2), 455–474. https://doi.org/10.1007/S10796-018-9869-0/TABLES/10

Sewe, M. O., Ahlm, C., & Rocklöv, J. (2016). Remotely Sensed Environmental Conditions and Malaria Mortality in Three Malaria Endemic Regions in Western Kenya. *PLOS ONE*, *11*(4), e0154204. https://doi.org/10.1371/JOURNAL.PONE.0154204

Shaari, F., Azuraliza, A. B., & Abdul, R. H. (2007). Discovery of non-interesting attribute in mining outliers pattern. *Proceedings - The 2007 International Conference on Computational Science and Its Applications, ICCSA 2007*, 123–130. https://doi.org/10.1109/ICCSA.2007.31

Shachak, A., Kuziemsky, C., & Petersen, C. (2019). Beyond TAM and UTAUT: Future directions for HIT implementation research. *Journal of Biomedical Informatics*, *100*, 103315.

https://doi.org/10.1016/J.JBI.2019.103315

Shi, D., Maydeu-Olivares, A., & DiStefano, C. (2018). The Relationship Between the Standardized Root Mean Square Residual and Model Misspecification in Factor Analysis Models. *Https://Doi.Org/10.1080/00273171.2018.1476221*, *53*(5), 676–694. https://doi.org/10.1080/00273171.2018.1476221

Shiferaw, K. B., & Mehari, E. A. (2019). Modeling predictors of acceptance and use of electronic medical record system in a resource limited setting: Using modified UTAUT model. *Informatics in Medicine Unlocked*, *17*, 100182. https://doi.org/10.1016/J.IMU.2019.100182

Shmueli, G., Ray, S., Velasquez Estrada, J. M., & Chatla, S. B. (2016). The elephant in the room: Predictive performance of PLS models. *Journal of Business Research*, *69*(10), 4552–4564. https://doi.org/10.1016/J.JBUSRES.2016.03.049

Shmueli, G., Sarstedt, M., Hair, J. F., Cheah, J. H., Ting, H., Vaithilingam, S., & Ringle, C. M. (2019). Predictive model assessment in PLS-SEM: guidelines for using PLSpredict. *European Journal of Marketing*, *53*(11), 2322–2347. https://doi.org/10.1108/EJM-02-2019-0189/FULL/PDF

Silva, B. M. C., Rodrigues, J. J. P. C., de la Torre Díez, I., López-Coronado, M., & Saleem, K. (2015). Mobile-health: A review of current state in 2015. *Journal of Biomedical Informatics*, *56*, 265–272. https://doi.org/10.1016/J.JBI.2015.06.003

Sinka, M. E., Zilli, D., Li, Y., Kiskin, I., Kirkham, D., Rafique, W., Wang, L., Chan, H., Gutteridge, B., Herreros-Moya, E., Portwood, H., Roberts, S., & Willis, K. J. (2021). HumBug – An Acoustic Mosquito Monitoring Tool for use on budget smartphones. *Methods in Ecology and Evolution*, *12*(10), 1848–1859. https://doi.org/10.1111/2041-210X.13663

Sitar-Tăut, D. A. (2021a). Mobile learning acceptance in social distancing during the COVID-19 outbreak: The mediation effect of hedonic motivation. *Human Behavior and Emerging Technologies*, *3*(3), 366–378. https://doi.org/10.1002/hbe2.261

Sitar-Tăut, D. A. (2021b). Mobile learning acceptance in social distancing during the COVID-19 outbreak: The mediation effect of hedonic motivation. *Human Behavior and Emerging Technologies*, *3*(3), 366–378. https://doi.org/10.1002/HBE2.261

Sitar-Taut, D. A., & Mican, D. (2021). Mobile learning acceptance and use in higher education during social distancing circumstances: an expansion and customization of UTAUT2. *Online Information Review*, *45*(5), 1000–1019. https://doi.org/10.1108/OIR-01-2021-0017/FULL/PDF

Smythe, T., Mabhena, T., Murahwi, S., Kujinga, T., Kuper, H., Rusakaniko, S., Cheshire, L., Zimbabwe, D., & Harare, Z. (2022). A path toward disability-inclusive health in Zimbabwe Part 1: A qualitative study on access to healthcare. *African Journal of Disability*, *11*(0), 8. https://doi.org/10.4102/AJOD.V11I0.990

Sobti, N. (2019). Impact of demonetization on diffusion of mobile payment service in India: Antecedents of behavioral intention and adoption using extended UTAUT model. *Journal of Advances in Management Research*, *16*(4), 472–497. https://doi.org/10.1108/JAMR-09-2018-0086/FULL/PDF

Sokolova, M., & Lapalme, G. (2009). A systematic analysis of performance measures for classification tasks. *Information Processing & Management*, *45*(4), 427–437. https://doi.org/10.1016/J.IPM.2009.03.002

Sommerville, I. (2005). Integrated requirements engineering: A tutorial. *IEEE Software*, *22*(1), 16–23. https://doi.org/10.1109/MS.2005.13

Sommerville, I. (2008). Construction by configuration: Challenges for software engineering research and practice. *Proceedings of the Australian Software Engineering Conference, ASWEC*, 3–12. https://doi.org/10.1109/ASWEC.2008.4483184

Sommerville, I., Cliff, D., Calinescu, R., Keen, J., Kelly, T., Kwiatkowska, M., McDermid, J., & Paige, R. (2012). Large-scale complex IT systems. *Communications of the ACM*, *55*(7), 71–77. https://doi.org/10.1145/2209249.2209268

Sommerville, I., & Sawyer, P. (1997). Viewpoints: principles, problems and a practical approach to requirements engineering. *Annals of Software Engineering 1997 3:1*, *3*(1), 101–130. https://doi.org/10.1023/A:1018946223345

Sornsuwit, P., & Jaiyen, S. (2019). A New Hybrid Machine Learning for Cybersecurity Threat Detection Based on Adaptive Boosting. *Https://Doi.Org/10.1080/08839514.2019.1582861*, *33*(5), 462–482. https://doi.org/10.1080/08839514.2019.1582861

Sowon, K., Maliwichi, P., & Chigona, W. (2022). The Influence of Design and Implementation Characteristics on the Use of Maternal Mobile Health Interventions in Kenya: Systematic Literature Review. *JMIR Mhealth Uhealth 2022;10(1):E22093 Https://Mhealth.Jmir.Org/2022/1/E22093*, *10*(1), e22093. https://doi.org/10.2196/22093

Sudheer, C., Sohani, S. K., Kumar, D., Malik, A., Chahar, B. R., Nema, A. K., Panigrahi, B. K., & Dhiman, R. C. (2014). A Support Vector Machine-Firefly Algorithm based forecasting model to determine malaria transmission. *Neurocomputing*, *129*, 279–288. https://doi.org/10.1016/J.NEUCOM.2013.09.030

Sunyaev, A. (2013). Evaluation of Microsoft HealthVault and Google Health personal health records. *Health and Technology*, *3*(1), 3–10. https://doi.org/10.1007/S12553-013-0049-4/FIGURES/1

Svongoro, P., & Matende, T. (2021). Covid-19 information gaps among disadvantaged communities: the case of the deaf and limited english proficiency communities in Zimbabwe. *Communitas*, *26*, 86–102. https://doi.org/10.18820/24150525/COMM.V26.6

T Alrawashdeh, M. M. S. A. (2012). Factors affecting acceptance of web-based training system: Using extended UTAUT and structural equation modeling. *International Journal of Computer Science, Engineering and Information Technology (IJCSEIT)*, *2*(2), 45–54. https://doi.org/10.5121/ijcseit.2012.2205

Tabassum, R., Froeschl, G., Cruz, J. P., Colet, P. C., Dey, S., & Islam, S. M. S. (2018). Untapped aspects of mass media campaigns for changing health behaviour towards non-communicable diseases in Bangladesh. *Globalization and Health*, *14*(1), 1–4. https://doi.org/10.1186/S12992-018-0325-1/TABLES/1

Taherdoost, H. (2018). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. *SSRN Electronic Journal*, *5*(2), 18–27. https://doi.org/10.2139/ssrn.3205035

Takarinda, K. P., Nyadundu, S., Govha, E., Gombe, N. T., Chadambuka, A., Juru, T., & Tshimanga, M. (2022a). Factors associated with a malaria outbreak at Tongogara refugee camp in Chipinge District, Zimbabwe, 2021: a case–control study. *Malaria Journal*, *21*(1), 1–12. https://doi.org/10.1186/S12936-022-04106-9/TABLES/4

Takarinda, K. P., Nyadundu, S., Govha, E., Gombe, N. T., Chadambuka, A., Juru, T., & Tshimanga, M. (2022b). Factors associated with a malaria outbreak at Tongogara refugee camp in Chipinge District, Zimbabwe, 2021: a case–control study. *Malaria Journal*, *21*(1), 1–12. https://doi.org/10.1186/S12936-022-04106-9/TABLES/4

Talukder, M. S., Chiong, R., Bao, Y., & Hayat Malik, B. (2019). Acceptance and use predictors of fitness wearable technology and intention to recommend: An empirical study. *Industrial Management and Data Systems*, *119*(1), 170–188. https://doi.org/10.1108/IMDS-01-2018-0009/FULL/PDF

Thapa, C., & Camtepe, S. (2021). Precision health data: Requirements, challenges and existing techniques for data security and privacy. *Computers in Biology and Medicine*, *129*, 104130. https://doi.org/10.1016/J.COMPBIOMED.2020.104130

Thobias, J., & Kiwanuka, A. (2018). Design and implementation of an m-health data model for improving health information access for reproductive and child health services in low resource settings using a participatory action research approach. *BMC Medical Informatics and Decision Making*, *18*(1), 1–10. https://doi.org/10.1186/S12911-018-0622-X/FIGURES/3

Ting, D. S. W., Carin, L., Dzau, V., & Wong, T. Y. (2020). Digital technology and COVID-19. *Nature Medicine 2020 26:4*, *26*(4), 459–461. https://doi.org/10.1038/s41591-020-0824-5

Tizifa, T. A., Kabaghe, A. N., McCann, R. S., van den Berg, H., Van Vugt, M., & Phiri, K. S. (2018). Prevention Efforts for Malaria. *Current Tropical Medicine Reports 2018 5:1*, *5*(1), 41–50. https://doi.org/10.1007/S40475-018-0133-Y

Tosuntaş, B., Karadaǧ, E., & Orhan, S. (2015). The factors affecting acceptance and use of interactive whiteboard within the scope of FATIH project: A structural equation model based on the Unified Theory of acceptance and use of technology. *Computers & Education*, *81*, 169–178. https://doi.org/10.1016/J.COMPEDU.2014.10.009

Toté, C., Patricio, D., Boogaard, H., van der Wijngaart, R., Tarnavsky, E., & Funk, C. (2015). Evaluation of Satellite Rainfall Estimates for Drought and Flood Monitoring in Mozambique. *Remote Sensing 2015, Vol. 7, Pages 1758-1776*, *7*(2), 1758–1776. https://doi.org/10.3390/RS70201758

Tran, V., Gwenzi, F., Marongwe, P., Rutsito, O., Chatikobo, P., Murenje, V., Hove, J., Munyaradzi, T., Rogers, Z., Tshimanga, M., Sidile-Chitimbire, V., Xaba, S., Ncube, G., Masimba, L., Makunike-Chikwinya, B., Holec, M., Barnhart, S., Weiner, B., & Feldacker, C. (2022). REDCap mobile data collection: Using implementation science to explore the potential and pitfalls of a digital health tool in routine voluntary medical male circumcision outreach settings in Zimbabwe. *Digital Health*, *8*. https://doi.org/10.1177/20552076221112163/ASSET/IMAGES/LARGE/10.1177_20552076221112163-FIG2.JPEG

Traube, D. E., Cederbaum, J. A., Taylor, A., Naish, L., & Rau, A. (2020). Telehealth Training and Provider Experience of Delivering Behavioral Health Services. *The Journal of Behavioral Health Services & Research 2020 48:1*, *48*(1), 93–102. https://doi.org/10.1007/S11414-020-09718-0

Trizano-Hermosilla, I., & Alvarado, J. M. (2016). Best alternatives to Cronbach's alpha reliability in realistic conditions: Congeneric and asymmetrical measurements. *Frontiers in Psychology*, *7*(MAY), 769. https://doi.org/10.3389/FPSYG.2016.00769/BIBTEX

Tsarwe, S. (2018). Mobile phones and a million chatter: performed inclusivity and silenced voices in Zimbabwean talk radio. *Https://Doi.Org/10.1080/13696815.2018.1551125*, *32*(2), 161–177. https://doi.org/10.1080/13696815.2018.1551125

Tsuyuoka, R., Midzi, S. M., Dziva, P., & Makunike, B. (2004). The acceptability of insecticide treated mosquito nets among community members in Zimbabwe. *Central African Journal of Medicine*, *48*(7), 87–91. https://doi.org/10.4314/cajm.v48i7.8435

Uddin, S., Khan, A., Hossain, M. E., & Moni, M. A. (2019). Comparing different supervised machine learning algorithms for disease prediction. *BMC Medical Informatics and Decision Making 2019 19:1*, *19*(1), 1–16. https://doi.org/10.1186/S12911-019-1004-8

van Deursen, A. J. A. M., van der Zeeuw, A., de Boer, P., Jansen, G., & van Rompay, T. (2019). Digital inequalities in the Internet of Things: differences in attitudes, material access, skills, and usage. *Https://Doi.Org/10.1080/1369118X.2019.1646777*, *24*(2), 258–276. https://doi.org/10.1080/1369118X.2019.1646777

Vatcheva, K. P., Lee, M., McCormick, J. B., & Rahbar, M. H. (2016). Multicollinearity in Regression Analyses Conducted in Epidemiologic Studies. *Epidemiology (Sunnyvale, Calif.)*, *6*(2). https://doi.org/10.4172/2161-1165.1000227

Venables, E., Ndlovu, Z., Munyaradzi, D., Martínez-Pérez, G., Mbofana, E., Nyika, P., Chidawanyika, H., Garone, D. B., & Bygrave, H. (2019). Patient and health-care worker experiences of an HIV viral load intervention using SMS: A qualitative study. *PLOS ONE*, *14*(4), e0215236. https://doi.org/10.1371/JOURNAL.PONE.0215236

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly: Management Information Systems*, *27*(3), 425–478. https://doi.org/10.2307/30036540

Ventola, L. (2014). Social Media and Health Care Professionals: Benefits, Risks, and Best Practices. *Pharmacy and Therapeutics*, *39*(7), 491. /pmc/articles/PMC4103576/

Vesel, L., Hipgrave, D., Dowden, J., & Kariuki, W. (2015). Application of mHealth to improve service delivery and health outcomes: Opportunities and challenges. *African Population Studies*, *29*(1), 1683–1698. https://doi.org/10.11564/29-1-718

Vidal-Alaball, J., Acosta-Roja, R., PastorHernández, N., SanchezLuque, U., Morrison, D., NarejosPérez, S., Perez-Llano, J., Salvador Vèrges, A., & López Seguí, F. (2020).

Telemedicine in the face of the COVID-19 pandemic. *Atención Primaria*, *52*(6), 418–422. https://doi.org/10.1016/J.APRIM.2020.04.003

Vijayalakshmi, A., & Rajesh, K. (2020). Deep learning approach to detect malaria from microscopic images. *Multimedia Tools and Applications*, *79*(21–22), 15297–15317. https://doi.org/10.1007/S11042-019-7162-Y/TABLES/7

Vinerean, S., Budac, C., Baltador, L. A., & Dabija, D.-C. (2022). Assessing the Effects of the COVID-19 Pandemic on M-Commerce Adoption: An Adapted UTAUT2 Approach. *Electronics 2022, Vol. 11, Page 1269*, *11*(8), 1269. https://doi.org/10.3390/ELECTRONICS11081269

Vogiatzaki, E., & Krukowski, A. (2019). Maintaining mental wellbeing of elderly at home. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 11369 LNCS*, 177–209. https://doi.org/10.1007/978-3-030-10752-9_8/FIGURES/13

Walker, K. W., & Jiang, Z. (2019). Application of adaptive boosting (AdaBoost) in demand-driven acquisition (DDA) prediction: A machine-learning approach. *The Journal of Academic Librarianship*, *45*(3), 203–212. https://doi.org/10.1016/J.ACALIB.2019.02.013

Wallis, L., Blessing, P., Dalwai, M., & Shin, S. Do. (2017). Integrating mHealth at point of care in low- and middle-income settings: the system perspective. *Https://Doi.Org/10.1080/16549716.2017.1327686*, *10*. https://doi.org/10.1080/16549716.2017.1327686

Wang, H., Tao, D., Yu, N., & Qu, X. (2020). Understanding consumer acceptance of healthcare wearable devices: An integrated model of UTAUT and TTF. *International Journal of Medical Informatics*, *139*, 104156. https://doi.org/10.1016/J.IJMEDINF.2020.104156

Wang, M., Wang, H., Wang, J., Liu, H., Lu, R., Duan, T., Gong, X., Feng, S., Liu, Y., Cui, Z., Li, C., & Ma, J. (2019). A novel model for malaria prediction based on ensemble algorithms. *PLOS ONE*, *14*(12), e0226910. https://doi.org/10.1371/JOURNAL.PONE.0226910

Wang, Xiangyu, Zhang, M., Fan, W., & Zhao, K. (2022). Understanding the spread of COVID-19 misinformation on social media: The effects of topics and a political leader's nudge. *Journal of the Association for Information Science and Technology*, *73*(5), 726–737. https://doi.org/10.1002/ASI.24576

Wang, Xiaoying, Yu, B., Ma, A., Chen, C., Liu, B., & Ma, Q. (2019). Protein–protein interaction sites prediction by ensemble random forests with synthetic minority oversampling technique. *Bioinformatics*, *35*(14), 2395–2402. https://doi.org/10.1093/BIOINFORMATICS/BTY995

Waters, K. P., Zuber, A., Simbini, T., Bangani, Z., & Krishnamurthy, R. S. (2017). Zimbabwe's Human Resources for health Information System (ZHRIS)—an assessment in the context of establishing a global standard. *International Journal of Medical Informatics*, *100*, 121–128. https://doi.org/10.1016/J.IJMEDINF.2017.01.011

Watkins, J. A., Goudge, J., Gómez-Olivé, F. X., Huxley, C., Dodd, K., & Griffiths, F. (2018). mHealth text and voice communication for monitoring people with chronic diseases in low-resource settings: a realist review. *BMJ Global Health*, *3*(2), e000543. https://doi.org/10.1136/BMJGH-2017-000543

WHO. (2021). *World malaria report 2021*. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2021

Wimberly, M. C., Nekorchuk, D. M., & Kankanala, R. R. (2022). Cloud-based applications for accessing satellite Earth observations to support malaria early warning. *Scientific Data 2022 9:1*, *9*(1), 1–11. https://doi.org/10.1038/s41597-022-01337-y

Winskill, P., Walker, P. G., Cibulskis, R. E., & Ghani, A. C. (2019). Prioritizing the scale-up of interventions for malaria control and elimination. *Malaria Journal*, *18*(1), 1–11. https://doi.org/10.1186/S12936-019-2755-5/FIGURES/5

Wouters, B., Barjis, J., Maponya, G., Maritz, J., & Mashiri, M. (2009). Supporting home based health care in South African rural communities using USSD technology. *15th Americas Conference on Information Systems 2009, AMCIS 2009*, *5*, 3357–3364.

Wu, J., Wang, J., Nicholas, S., Maitland, E., & Fan, Q. (2020). Application of Big Data Technology for COVID-19 Prevention and Control in China: Lessons and Recommendations. *J Med Internet Res 2020;22(10):E21980 Https://Www.Jmir.Org/2020/10/E21980*, *22*(10), e21980. https://doi.org/10.2196/21980

Wu, Y., & Shen, F. (2021). Exploring the impacts of media use and media trust on health behaviors during the COVID-19 pandemic in China. *Journal of Health Psychology*. https://doi.org/10.1177/1359105321995964

Yadav, S. S., Kadam, V. J., Jadhav, S. M., Jagtap, S., & Pathak, P. R. (2021a). Machine learning based malaria prediction using clinical findings. *2021 International Conference on Emerging Smart Computing and Informatics, ESCI 2021*, 216–222. https://doi.org/10.1109/ESCI50559.2021.9396850

Yadav, S. S., Kadam, V. J., Jadhav, S. M., Jagtap, S., & Pathak, P. R. (2021b). Machine learning based malaria prediction using clinical findings. *2021 International Conference on Emerging Smart Computing and Informatics, ESCI 2021*, 216–222. https://doi.org/10.1109/ESCI50559.2021.9396850

Yang, F., Poostchi, M., Yu, H., Zhou, Z., Silamut, K., Yu, J., Maude, R. J., Jaeger, S., & Antani, S. (2020). Deep Learning for Smartphone-Based Malaria Parasite Detection in Thick Blood Smears. *IEEE Journal of Biomedical and Health Informatics*, *24*(5), 1427–1438. https://doi.org/10.1109/JBHI.2019.2939121

Yaya, S., Uthman, O. A., Amouzou, A., & Bishwajit, G. (2018). Mass media exposure and its impact on malaria prevention behaviour among adult women in sub-Saharan Africa: results from malaria indicator surveys. *Global Health Research and Policy*, *3*(1), 1–9. https://doi.org/10.1186/S41256-018-0075-X/TABLES/2

Yikoniko, S. (2015, September 19). *How mosquito nets are being misused*. https://www.pressreader.com/zimbabwe/the-sunday-mail-zimbabwe/20150919/282368333444040

Yoo, J. H. (2013). The Meaning of Information Technology (IT) Mobile Devices to Me, the

Infectious Disease Physician. *Infection & Chemotherapy*, *45*(2), 244–251. https://doi.org/10.3947/IC.2013.45.2.244

Zacarias, O. P., & Bostrom, H. (2013). Comparing support vector regression and random forests for predicting malaria incidence in Mozambique. *International Conference on Advances in ICT for Emerging Regions, ICTer 2013 - Conference Proceedings*, 217–221. https://doi.org/10.1109/ICTER.2013.6761181

Zawawi, A., Alghanmi, M., Alsaady, I., Gattan, H., Zakai, H., & Couper, K. (2020). The impact of COVID-19 pandemic on malaria elimination. *Parasite Epidemiology and Control*, *11*, e00187. https://doi.org/10.1016/J.PAREPI.2020.E00187

Zayyad, M. A., & Toycan, M. (2018). Factors affecting sustainable adoption of e-health technology in developing countries: An exploratory survey of Nigerian hospitals from the perspective of healthcare professionals. *PeerJ*, *2018*(3), e4436. https://doi.org/10.7717/PEERJ.4436/SUPP-2

Zelman, B., Melgar, M., Larson, E., Phillips, A., & Shretta, R. (2016). Global fund financing to the 34 malaria-eliminating countries under the new funding model 2014-2017: An analysis of national allocations and regional grants. *Malaria Journal*, *15*(1), 1–15. https://doi.org/10.1186/S12936-016-1171-3/FIGURES/7

Zhang, H., Guo, J., Li, H., & Guan, Y. (2022). Machine learning for artemisinin resistance in malaria treatment across in vivo-in vitro platforms. *IScience*, *25*(3), 103910. https://doi.org/10.1016/J.ISCI.2022.103910

Zhou, M., Herselman, M., & Coleman, A. (2015). USSD Technology a Low Cost Asset in Complementing Public Health Workers' Work Processes. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 9044*, 57–64. https://doi.org/10.1007/978-3-319-16480-9_6

Zhu, T., Lin, Y., & Liu, Y. (2017). Synthetic minority oversampling technique for multiclass imbalance problems. *Pattern Recognition*, *72*, 327–340. https://doi.org/10.1016/J.PATCOG.2017.07.024

Zhu, X., Wang, J., Yan, H., & Wu, S. (2009). Research and application of the improved algorithm C4.5 on decision tree. *Proceedings of the International Symposium on Test and Measurement*, *2*, 184–187. https://doi.org/10.1109/ICTM.2009.5413078

Zimbabwe National Statistics Agency. (2012). *Zimbabwe National Statistics Agency*.

Zinszer, K., Kigozi, R., Charland, K., Dorsey, G., Brewer, T. F., Brownstein, J. S., Kamya, M. R., & Buckeridge, D. L. (2015). Forecasting malaria in a highly endemic country using environmental and clinical predictors. *Malaria Journal*, *14*(1), 1–9. https://doi.org/10.1186/S12936-015-0758-4/FIGURES/4

Zinszer, K., Verma, A. D., Charland, K., Brewer, T. F., Brownstein, J. S., Sun, Z., & Buckeridge, D. L. (2012). A scoping review of malaria forecasting: past work and future directions. *BMJ Open*, *2*(6), e001992. https://doi.org/10.1136/BMJOPEN-2012-001992

Zurovac, D., Sudoi, R. K., Akhwale, W. S., Ndiritu, M., Hamer, D. H., Rowe, A. K., & Snow, R. W. (2011). The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial. *The Lancet*, *378*(9793), 795–803. https://doi.org/10.1016/S0140-6736(11)60783-6

Zurovac, D., Talisuna, A. O., & Snow, R. W. (2012). Mobile Phone Text Messaging: Tool for Malaria Control in Africa. *PLOS Medicine*, *9*(2), e1001176. https://doi.org/10.1371/JOURNAL.PMED.1001176

APPENDICES

Appendix 1: DUT ethical clearance

DUT DURBAN UNIVERSITY OF TECHNOLOGY

FACULTY OF ACCOUNTING & INFORMATICS

SECRETARY FOR HEALTH & C C
PRINCIPAL DIRECTOR
PREVENTIVE SERVICES
13 NOV 2018
P.O. BOX CY 1122, CAUSEWAY
ZIMBABWE

Faculty Research Office
Durban University of Technology 9
1 November 2018

SECRETARY FOR HEALTH AND CHILD CARE
(01) SECRETARY'S OFFICE (01)
13 NOV 2018
P.O. BOX CY 1122, CAUSEWAY
ZIMBABWE

Mr E. Mbunge
Student Number: **21855551**
Degree: PhD IT
Email: mbungeelliot@gmail.com

Dear Mr E. Mbunge

ETHICAL APPROVAL: LEVEL 2

Your email correspondence in respect of the above refers.
I am pleased to inform you that the Faculty Research Committee (FRC) following its round-robin approval on 31 October 2018, has granted preliminary permission for you to conduct your research "***An investigation of an ICT-based malaria intervention system for rural communities***".

You are required to present this letter to the central DUT Research office to obtain full permission to conduct the research. You are also required to present the letter at your research site for permission to gather data at your research site. Please also note that your questionnaires and interviews must be accompanied by the letter of information and the letter of consent for each participant, as per your research proposal.

A summary of your key research findings may be submitted to the FRC on completion of your studies.

Kindest regards.
Yours sincerely

DURBAN UNIVERSITY OF TECHNOLOGY
DUT
DATE RECEIVED
01 -11- 2018
FACULTY RESEARCH OFFICE
FACULTY OF ACCOUNTING AND INFORMATICS
P O BOX 1334 DURBAN 4000

Dr Delene Heukelman
Faculty Research Coordinator (Acting)

Appendix 1b : DUT ethical clearance recertification letter

DUT
DURBAN UNIVERSITY OF TECHNOLOGY
INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

FACULTY OF ACCOUNTING & INFORMATICS

Faculty Research Office
Durban University of Technology
16 August 2021

Student: Elliot Mbunge
Student Number: 21855551
Degree: PhD in Information Technology
Email: 21855551@dut4life.ac.za
Supervisor: Richard C Millham, PhD
Supervisor email: richardm1@dut.ac.za

Dear Mr Mbunge

An investigation of ICT-based malaria intervention framework for rural communities

The Faculty Research Ethics Committee acknowledges receipt of your Safety Monitoring and Annual Recertification report.

I am pleased to inform you that the study has been approved to continue.

Please note that ethical approval has been extended till **27 July 2022.** If the research is not complete within this time, you will be required to apply for recertification three months before the expiry date.

Yours Sincerely

Kindest regards.

Yours sincerely

Dr Mogiveny Rajkoomar
FREC Chair
Faculty of Accounting and Informatics
Durban University of Technology
Ritson Campus
Durban, South Africa
4001

Appendix 2a : Letter of request for permission to conduct study

SECRETARY FOR HEALTH & C/C
(PRINCIPAL DIRECTOR)
PREVENTIVE SERVICES
13 NOV 2018
P.O. BOX CY 1122, CAUSEWAY
ZIMBABWE

SECRETARY FOR HEALTH AND C/C
SECRETARY OFFICE (01)
09 NOV 2018
P.O. BOX CY 1122, CAUSEWAY
ZIMBABWE

Request approval subject to MRCZ clearance. PMD. to support.

University of Swaziland
Private Bag 4 Kwaluseni, Matsapha
Manzini, Swaziland

05 November 2018

The Permanent Secretary
Ministry of Health and Child Care
Postal Address Box CY 1122
Causeway
Harare
Zimbabwe

Dear Sir/ Madam

Re: <u>REQUEST FOR PERMISSION TO CONDUCT ACADEMIC RESEARCH IN MANICALAND DISTRICT HOSPITALS AND CLINICS IN ZIMBABWE</u>

I am a Zimbabwean currently working at University of Swaziland, studying Doctoral studies (PhD) in the Department of Information Technology at Durban University of Technology. I am conducting a research on investigation and impact of malaria Information and Communication Technology (ICT) intervention system for Buhera rural communities to dissemination information. The development and implementation of the intervention framework will incorporate computers, mobile phones and educational animations. My research seeks to use mobile phones and health educational animations as information diffusion method to help health promotion and digital awareness using indigenous and English language to manage malaria in rural healthcare centres. In addition to that, the research will engage stakeholders including healthcare experts, rural communities, software developers and animation experts to contribute in the requirements elicitation, specifications, development and evaluation process. The aim of this research is to investigate an ICT-based malaria intervention system to create digital awareness in rural communities. Therefore, this research seeks to achieve the following objectives:

- To explore and analyse current strategies and information diffusion methods to help health promotion to manage malaria.
- To identify and implement the most feasible ICT strategy of information dissemination, based on the previous investigation, to reduce malaria incidences.
- To develop a secure ICT intervention system to enhance secure transmission of health information in resource-constrained rural areas.

- To investigate opportunities, challenges, success/failure factors and implications of ICT intervention system in health policy formulation in Zimbabwe.
- To assess the impact of the ICT intervention system to reduce malaria in rural communities.
- To explore the views, attitudes and perceptions of health workers and communities towards the use of ICTs to communicate and disseminate health information.

In this regard, I am asking your permission to conduct a research in Buhera rural communities including hospitals and clinics in Zimbabwe while engaging provincial health executives, district health executives, medical doctors and nurses as participants in this research. Please note that this is not an evaluation of participants. Participants will be asked to respond to a questionnaire comprising of at most ten questions as well as semi-structured interview questions relating to their perceptions, views, attitudes and practices. The questionnaire will take approximately 20 minutes to complete while follow-up interviews will take approximately 15 minutes. There will be no additional cost to your institutions. Identities of all participants in this study will be protected in accordance with the code of ethics as stipulated by the Durban University of Technology. I undertake to uphold the autonomy of all participants and such participants will be free to withdraw from the research at any time without negative or undesirable consequences to them. The names of participants will not appear in my research report, or in any papers or presentations that I make after the study without permission to do so from the Department of Information Technology.

You may contact my supervisors, should you have any queries or questions you would like answers regarding the contents of this letter. My supervisors are:

1. Professor Richard Millham – Department of Information, email: - richardm1@dut.ac.za , office number – 0027 313735542.
2. Professor Nokuthula Sibiya – Dean of Health Science, email - nokuthulas@dut.ac.za , office number – 0027 031373 2704.

Yours faithfully

Mr Elliot Mbunge
Department of Computer Science
University of Swaziland, Swaziland
Cell: +26878246653
Email: mbungeelliot@gmail.com , embunge@uniswa.sz

Appendix 2b: Letter of request for permission to conduct study: MRCZ

University of Swaziland
Private Bag 4 Kwaluseni, Matsapha
Manzini
Swaziland

25 September 2019

Ethical Clearance Office
Medical Research Council of Zimbabwe
207 Josiah Tongogara Cnr 9th Ave,
Avenues, Harare
Zimbabwe

Dear Sir/ Madam

Re: REQUEST FOR PERMISSION TO SUBMIT CORRECTIONS FOR PhD ETHICAL CLEARANCE APPLICATION TO CONDUCT ACADEMIC RESEARCH IN BUHERA DISTRICT

I am writing to inform you that I have made some corrections addressing reviewers' comments pertaining to the Ethical Clearance application submitted on the 30th of July 2019. I received Ethical Clearance from the Ministry of Primary and Secondary Education to conduct in secondary schools in Buhera district. I am kindly requesting the Medical Research Council of Zimbabwe (MRCZ) to consider my ethical clearance application. I am anticipating collecting data as soon as I receive the ethical clearance from MRCZ.

You may contact my supervisors, should you have any queries or questions you would like answers regarding the contents of this letter. My supervisors are:

1. Professor Richard Millham – Department of Information, email:- richardm1@dut.ac.za , office number – 0027 313735542.
2. Professor Nokuthula Sibiya – Dean of Health Science, email - nokuthulas@dut.ac.za , office number – 0027 031373 2704.
3. Dr Sam Takavarasha Jr - stakavarasha@wua.ac.zw, Office numbers: (263)-4-2934551 / (263) 4 459 601/647, Mobile number / Cell: +263774727548

Thank you,

Yours Faithfully,

Elliot Mbunge (PhD Candidate)

Appendix 2c : MRCZ Approval letter for permission to conduct the study

Telephone: 791792/791193
Telefax: (263) - 4 - 790715
E-mail: mrcz@mrcz.org.zw
Website: http://www.mrcz.org.zw

Medical Research Council of Zimbabwe
Josiah Tongogara / Mazoe Street
P. O. Box CY 573
Causeway
Harare

APPROVAL

MRCZ/A/2507

11 October, 2019

Elliot Mbunge
9 Devon Drive Fitchlea
Kwekwe

RE: - An investigation of ICT-Based Malaria Intervention Framework for Rural Communities

Thank you for the application for review of Research Activity that you submitted to the Medical Research Council of Zimbabwe (MRCZ). Please be advised that the Medical Research Council of Zimbabwe has **reviewed** and **approved** your application to conduct the above titled study.

This approval is based on the review and approval of the following documents that were submitted to MRCZ for review:-

a) Study Proposal
b) Informed Consent Forms (English and Shona)
c) Assent Forms (English and Shona)
d) Data collection Tools

APPROVAL NUMBER : **MRCZ/A/2507**

This number should be used on all correspondence, consent forms and documents as appropriate.

- **TYPE OF MEETING** : **FULL BOARD**
- **MEETING DATE** : **29 August 2019**
- **APPROVAL DATE** : **11 October, 2019**
- **EXPIRATION DATE** : **10 October, 2020**

After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the MRCZ Offices should be submitted three months before the expiration date for continuing review.

- **SERIOUS ADVERSE EVENT REPORTING**: All serious problems having to do with subject safety must be reported to the Institutional Ethical Review Committee (IERC) as well as the MRCZ within 3 working days using standard forms obtainable from the MRCZ Offices or website.
- **MODIFICATIONS**: Prior MRCZ and IERC approval using standard forms obtainable from the MRCZ Offices is required before implementing any changes in the Protocol (including changes in the consent documents).
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the MRCZ using standard forms obtainable from the MRCZ Offices or website.
- **QUESTIONS**: Please contact the MRCZ on Telephone No. (04) 791792, 791193 or by e-mail on mrcz@mrcz.org.zw

Other

- Please be reminded to send in copies of your research results for our records as well as for Health Research Database.
- You're also encouraged to submit electronic copies of your publications in peer-reviewed journals that may emanate from this study.
- In addition to this approval, all clinical trials involving drugs, devices and biologics (including other studies focusing on registered drugs) require approval of Medicines Control Authority of Zimbabwe (MCAZ) before commencement.

MEDICAL RESEARCH COUNCIL OF ZIMBABWE
2019 -10- 11
APPROVED
P.O. BOX CY 573 CAUSEWAY, HARARE

MRCZ SECRETARIAT
FOR CHAIRPERSON
MEDICAL RESEARCH COUNCIL OF ZIMBABWE

PROMOTING THE ETHICAL CONDUCT OF HEALTH RESEARCH

Appendix 2d : Approval letter for permission to conduct the study from the Ministry of Primary and Secondary Education

All communications should be addressed to "The Secretary for Primary & Secondary Education
Telephone: 794895
Telegraphic address : "EDUCATION"

ZIMBABWE

REF: C/426/3/Man
Ministry of Primary and Secondary Education
P.O Box CY 121
Causeway
HARARE

26 July 2019

Mbunge Elliot
University of Swaziland
P. B 4 Kwaluseni
Matsapha, Manzini M201
Swaziland

Re: **PERMISSION TO VISIT MANICALAND PROVINCE FOR RESEARCH: BUHERA DISTRICT SCHOOLS**

Reference is made to your application to visit schools to collect data for research purposes at the mentioned schools in Manicaland Province on the research title:

"AN INVESTIGATION OF AN INFORMATION AND COMMUNICATION TECHNOLOGY-BASED MALARIA INTERVENTION SYSTEM FOR RURAL COMMUNITIES."

Permission is hereby granted. However, you are required to liaise with the Provincial Education Director Manicaland who is responsible for the schools which you want to involve in your research. You should ensure that your research work does not disrupt the normal operations of the schools. Where students are involved, parental consent is required.

You are also required to provide a copy of your final report to the Secretary for Primary and Secondary Education by December 2019.

MIN OF PRY & SEC EDUCATION
POLICY PLANNING RESEARCH
AND D
02 AUG 2019
P.O. BOX CY 121 CAUSEWAY

T. Thabela (Mrs)
SECRETARY FOR PRIMARY AND SECONDARY EDUCATION
Cc: P.E.D - - Manicaland Province

MINISTRY OF EDUCATION
(PROFESSIONAL ADMINISTRATION
22/1/20
MANICALAND
P.O. BOX 144, MUTARE

DSI – BUHERA
Please assist
Member accordingly
22/1/20

Heads listed below please Assist

MIN. OF PRY & SEC. EDUCATION
BUHERA DISTRICT
DISTRICT SCHOOLS INSPECTOR
22 JAN 202
P.O. BOX 200, MUR
TEL: 021-2277/CELL: 0717

LISTS OF SCHOOLS

DISTRICT	NAME OF SCHOOL
Buhera	Bangure Secondary Betera Secondary Bhegedhe Secondary Bika Secondary Chabata High Chapanduka Secondary Chapwanya High Chawatama Secondary Chiteshe Secondary Dune Secondary Gotora Secondary Gunde Secondary Hande Secondary Holy Family Secondary Mabvuregudo Secondary Makumbe Mission ✓ Mamunyadza Secondary Masocha Secondary Muchuva Secondary Mukodza Secondary Murambinda High Murambinda B Secondary Murambinda Gvt Secondary Murove Secondary Mutasa Secondary Mutepfe Seconday Mutiusinazita High Muzokomba Secondary Nechikova Secondary Nechavava Secondary Nedziva Secondary Neshava Secondary Nerutanga Secondary Ndongwe Secondary Nyadi Secondary Nyashanu Mission St Alban's Secondary St. Augustin's Chapwanya High St. Benard's Secondary St. John's Chifamba Secondary St. Michael's Mambo Secondary Svinurai Secondary

Appendix 3a : Letter of information for participating in the study (parental concern)

IRB No. ___________

INFORMED CONSENT FORM
FOR PARENTAL CONSENT

An investigation of ICT-based malaria intervention framework for rural communities

Principal Investigator_**ELLIOT MBUNGE_**, [*Ph.D. Candidate)*]
Co-Investigator(s) _**Richard Millham (Prof), SamTakavarasha Jr (Dr), Nokuthula Sibiya (Prof)** ________________
Phone number(s): +26878246653, 002731 373 5542, +263774727548, 0027 031373 2704

ADD THE FOLLOWING PARAGRAPH TO ALL CONSENT FORMS
MORE THAN TWO (2) PAGES LONG (BEFORE ADDITION OF THIS PARAGRAPH)

What you should know about this research study:

- We give you this consent so that you may read about the purpose, risks, and benefits of this research study.
- The main goal of research studies is to gain knowledge that may help future patients.
- We cannot promise that this research will benefit your child. Just like regular care, this research can have side effects that can be serious or minor.
- You have the right to refuse to allow your child to take part, or agree for your child to take part now and change your mind later.
- Whatever you decide, it will not affect your child’s regular care.

- Please review this consent form carefully. Ask any questions before you make a decision.
- Your choice to allow your child to participate is voluntary.

PURPOSE

You are being asked to allow your child to participate in a research study titled, **An investigation of ICT-based malaria intervention framework for rural communities**. The purpose of the study is to develop a malaria intervention framework to enhance health promotion in rural communities through mobile technology. This is because malaria is a life-threatening disease responsible for killing people but it is preventable and treatable. In addition to that, people living in rural areas are faced with medical challenges such as drug shortages, shortage of medical staff members, lack of access to health information through affordable, feasible and sustainable ICT-based information dissemination tools, poorly equipped clinics and access to healthcare. Malaria morbidity and cases are high in Zimbabwe especially in rural areas and resource-constrained areas where there are few or no access to ICT-based malaria monitoring, surveillance and information dissemination tools. Currently, hospitals and clinics use awareness campaigns, community meetings, posters and dramas to convey malaria information in rural communities**.** Therefore, your child is selected as a possible participant in this study because he/she is a potential user of the proposed ICT-based malaria intervention framework. The study is targeting learners at secondary level (adolescents) learning or living in Buhera rural districts and with access to mobile phones. The total number of the participants expected to participate in this study is 384 including secondary school learners, teachers and healthcare professionals.

PROCEDURES AND DURATION

If you decide to allow your child/children to participate, the researcher will invite you and your child/children to explain the purpose, aim, benefits and your child's/ childrens' roles and rights in participating in the study using the language that you are comfortable with between English or Shona. After that, the researcher will give your child/children a questionnaire to respond to. If your child/children need some clarification or help, he/she is free to ask the researcher at no costs. Your child/children will participate to this research by responding to a survey questionnaire to get his/her views, opinions and experiences concerning malaria and the use of mobile phones to disseminate malaria information. Responding to the questionnaire will take approximately less than 20 minutes and the identity of your child/children will not be captured. Your child/children have the right to withdraw at any time and no adverse reaction will be encountered for withdrawal. If misconduct happens between your child/children and the researcher, you are encouraged to report to the Medical research Council of Zimbabwe, nearest police station on +263 79 17 92/ 79 11 93, 08644073772, Cell: +263 784 956 128 and Durban University of Technology (Prof Millham) on 002731 373 5542, Prof Sibiya on 002731373 2704 or the Institutional Research Ethics Administrator on 002731 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support, Prof C. Napier on 031 373 2577 or carinn@dut.ac.za

RISKS AND DISCOMFORTS

There are no reasonably foreseeable risks, discomforts or inconveniences to the child - including health, legal, economic and psychological risks, financial standing or social standing or employability involved in participating in the research.

RISKS TO PREGNANT WOMEN

This research represents a non-significant risk to unborn children and pregnant women. Therefore, there are no reasonably foreseeable risks, discomforts or inconveniences to the unborn children and pregnant women.

BENEFITS AND/OR COMPENSATION

The research will potentially develop an affordable, feasible and adaptive ICT-based malaria intervention framework to create malaria digital awareness, disseminate malaria health information, monitoring, reporting and surveillance of malaria using local language in resource-constrained communities. The proposed system will potentially benefit the community and healthcare professionals to communicate malaria information and monitoring, reporting and surveillance of malaria at district level with the potential of scaling it up to the provincial level and nationally with the ultimate goal of reducing malaria. However, the researcher cannot and do not guarantee or promise that your child will receive any benefits of any form from this study.

ALTERNATIVE PROCEDURES OR TREATMENTS

The research is not anticipating to use any medical treatment.

CONFIDENTIALITY

If you indicate your willingness for your child/children to participate in this study by signing this document, the researcher guarantees confidentiality of your child/children by assigning a pseudo number to the questionnaire. Any information that is obtained in connection with this study that can be identified with your child/children will remain confidential. Confidentiality will be enhanced by using codes instead of participants' names. Research materials will be stored under lock and key. Research documents will be kept for 5 years thereafter they will be destroyed by shredding. Electronic documents of the study will be kept in a password-protected computer and will be deleted after 5 years. Kindly note that, there will be no medical records or information of your child /children will be taken in this study.

ADDITIONAL COSTS

You and your child/children will not pay anything or incur any costs for participating in the study. Your Child's participation is completely free of charge.

IN THE EVENT OF INJURY

In the event of injury resulting from your child's participation in this study, treatment will be offered by the study. You should understand that the costs of such treatment will be the study's responsibility.

In the event of injury, contact the following co-investigators who are available 24 hours a day :

4. Professor Richard Millham – Department of Information, email: richardm1@dut.ac.za, office number – 0027 313735542.
5. Professor Nokuthula Sibiya – Executive Dean of Health Science, email: nokuthulas@dut.ac.za, office number – 0027 031373 2704.
6. Dr Sam Takavarasha Jr - Email - stakavarasha@wua.ac.zw, Office numbers: (263)-4- 2934551 / (263) 4 459 601/647, Mobile number / Cell: +263774727548

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. If you decide not to allow your child to participate in this study, your decision will not affect you or your child's future relations with this institution- Durban University of Technology, its student - Elliot Mbunge and its personnel- Prof Richard Millham , Prof Nokuthula Sibiya, Dr Sam Takavarasha Jr. If you decide to allow your child to participate, you and your child are free to withdraw your consent and assent and discontinue participation at any time without penalty.

ADDITIONAL ELEMENTS

The findings of the research will be accessed in the library of Durban University of Technology and a copy will be sent to Medical Research Council of Zimbabwe for future use of reference.

OFFER TO ANSWER QUESTIONS

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over.

AUTHORIZATION

YOU ARE MAKING A DECISION WHETHER OR NOT TO ALLOW YOUR CHILD TO PARTICIPATE IN THIS STUDY. YOUR SIGNATURE INDICATES THAT YOU HAVE READ AND UNDERSTOOD THE INFORMATION PROVIDED ABOVE, HAVE HAD ALL YOUR QUESTIONS ANSWERED, AND HAVE DECIDED TO ALLOW YOUR CHILD TO PARTICIPATE.

____________________ ____________________

Name of Child *(please print)* Date & time

Name of Parent *(please print)* Date& time

Signature of Parent/Legally Authorized Representative Date& time

Relationship to the Child

Signature of Witness *(if required)* Date & time

Signature of Research Staff Date & time

YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.
If you have any questions concerning this study or consent form beyond those answered by the investigator, including questions about the research, your rights as a research participant or research-related injuries; or if you feel that you have been treated unfairly and would like to talk to someone other than a member of the research team, please feel free to contact the Medical Research Council of Zimbabwe on telephone 791792/791193 and 0784956128 or the following address:

Medical Research Council of Zimbabwe
Cnr. J. Tongogara & Mazowe Street
P.O. Box CY 573
Causeway
Harare

Appendix 3b : Tsam ba yeruzivo kune vachatora chikamu mutsvakurudzo (Bvumirano yemubereki)

CHIBVUMIRANO CHEMUBEREKI KUMWANA

Kudzivirira marariya kupfurikidza nekukurudzirwa kwehutano mumagariro emumaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko

Mukuru Wetsvakurudzo: **Elliot Mbunge**, mudzidzi wePhD reInformation Technology.

Vadzidzisi Vetsvakurudzo _**Richard Millham**(Prof), **SamTakavarasha Jr**(Dr), **Nokuthula Sibiya**(Prof)

Nhare dzetsvakurudzo: +26878246653, 002731 373 5542, +263774727548, 0027 031373 2704

Zvamunotarisirwa kuziva pamusoro petsvakurudzo iyi:

- Tinokupai chibvumirano iyi kuti muverenge muve neruzivo nezve chinangwa, zvimhingamupini, uye zvakanakira tsvakurudzo iyi.
- Chinangwa chikuru chetsvakurudzo iyi ndechekuti pave nedenhe reruzivo kuitira varwere vamangwana
- Hativimbise kuti tsvakurudzo iyi ichabetsera mwana kana vana venyu Sedzimwe tsvakurudzo, inogona kuva nezvimhingamupini.
- Mune kodzero yekuramba kuti mwana wenyu atore chikamu mutsvakurudzo iyi kana kuti kubvuma parezvino mozochinja mafungiro pamberi.
- Sarudzo ipi zvayo yamuchatora haina zvimhingamupini mukuwana rubatsiro kumwana wenyu
- Ndapota munokurudzirwa kuverenga chibvumirano ichi uye munokwanisa kubvunza mibvunzo pamunoda kujekeserwa musati maita sarudzo
- Isarudzo yenyu yekutendedza mwana wenyu kutora chikamu mutsvakurudzo iyi.

CHINANGWA

Murikukumbirwa kutendera mwana wenyu kutora chikamu mutsvakurudzo yekudzivirira marariya kupfurikidza nekukurudzirwa kwehutano mumagariro emumaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko. Marariya chirwere chakonzera kufa kwevanhu vakawanda asi chinodzivisirika uye chinorapika. Vanhu vanogara kumaruwa vanotarisana nezvinetso sezvakadai sekushayikwa kwemapiritsi, kushayikwa kwevashandi vezvehutano, kusakwanisa kuwana ruzivo, makiriniki asina midziyo yakakwana uye kushaya rubatsiro rweutano. Chirwera chemarariya uye ndufu dzakawanda kwazvo muZimbabwe kunyanya munzvimbo yeManicaland nekuda kwekusakwanisa kuwana ruzivo rwemarariya kunyanya kumaruwa uko kune zvigadzirwa zvishoma zvekuparadzira mashoko uye hurongwa hwehutano hwakanaka. Pari zvino, zvipatara nemakiriniki zvinoshandisa mishandirapamwe yekuziva, misangano yemagariro, mapepa nemadhirama kuparidzira mashoko emarariya munharaunda dzemaruwa. Saka, chetsvakurudzo iyi ndechekusimbisa nekudzivirira mararariya kupfurikidza nekukurudzirwa kwehutano mumagariro emaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko. Saka, mwana wenyu asarudzwa kuti atore chikamu mutsvakurudzo iyi. Tsvakurudzo iyi irikutarisira vadzidzi vekusekondari (vechidiki) varikudzidza kana kugara mumatunhu emaruwa eBuhera uye vane mukana wekuwana mbozhanhare. Huwandu hwevatori vechikamu vanotarisirwa kutora chikamu tsvakurudzo iyi mazana matatu nemakumi masere nemana vanosanganisira vadzidzi vechikoro chekusekondari, vadzidzisi pamwe nevashandi vezvehutano.

MUTSARA WEZVIREVO UYE NGUVA YECHIDZIDZO

Kana mukatendedza mwana wenyu kutora chikamu, muongorori achakukokai imi nemwana/vana otsanangura chinangwa, zvimhingamupini, zvakanakira tsvakurudzo uye kodzero dzemwana/ vana venyu mutsvakurudzo iyi uchishandira rurimi rwamunoda pakati peChirungu kana chiShona. Kana izvi zvapera, muongorori achapa mwana wenyu bepa rine mibvunzo yaanotarisirwa kupindura uchinyora mhinduro pabepa ipapo. Kana mwana asina kunzwisisa mibvunzo akasungunuka kubvunza muongorori pasina mubhadharo. Mwana/Vana venyu vachatora chikamu mutsvakurudzo iyi nekupindura bepa remibvunzo rinosanganisira maonere uye mafungiro emwana mayererano nehutachinona wemarariya uyezve kushandiswa kushandiswa kwemushina yezvekufambiswa kwemashoko ezvehutano. Nguva inotarisirwa kutorwa pakupindura mibvunzo iyi inova maminitsi asingadariki makumi maviri uyezve zita remwana kana chitaridzo chemwana hachinge chiri pabepa remibvunzo. Mwana/vana venyu vanekodzero yekurega kutora chikamu mutsvakurudzo iyi.Kana pakava nekupokana pakati pemuongorori nemwana wenyu munokuridzirwa kuchaya runhare ku Medical Research Council of Zimbabwe pabhozharunhare dzinoti +263 79 17 92/ 79 11 93, 08644073772, Cell: +263 784 956 128, , kana kuti zivisai mapurisa aripedyo nemi ueyezve chayai runhare kuDurban University of Technology (Prof Millham) pa002731 373 5542, Prof Sibiya pa002731373 2704 kana kuti Institutional Research Ethics Administrator pa 002731 373 2375 kana kuti veResearch and Postgraduate Support, Prof C. Napier pa 031 373 2577 kana kuti carinn@dut.ac.za

NJODZI UYE NEKUSAGADZIKANA

Hapana njodzi dzati dzaonekwa mukutora chikamu mutsvakurudzo iyi.

NJODZI KUNE VAKAZVITAKURA

Hapana njodzi dzati dzaonekwa kune vakazvitakura mukutora chikamu mutsvakurudzo iyi.

ZVIWANIKWA KANA MURIPO

Tsvakurudzo iyi inokwanisa kudzivirira marariya kupfurikidza nekukurudzirwa kwehutano mumagariro emumaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko mukudzivirira marariya mu kuparadzira ruzivo rwechirwere cheMarariya, kuongorora, kumhan’ara nekutarisa marariya uchishandisa mitauro yemunharaunda. Urongwa hwakatsanangurwa hunogona kubatsira nharaunda pamwe nevanochengetedza hutano kuti vashambadze ruzivo rwemarariya uye kuongorora nekutarisisa, kuudza nekutarisa marariya. Nekudaro, muongorori haakwanise uye haavimbise kuti mwana wenyu achapiwa mubairo chero upi zvawo kubva mutsvakurudzo iyi

.

ZVIMWE ZVIKAMU ZVEMISHONGA

Hapana mishonga inotarisirwa kushandiswa kutsvakurudzo iyi.

IRB No. ____________

KUVIMBIKA

Kana mukabvuma kuti mwana wenyu atore chikamu mutsvakurudzo iyi, munokuridzirwa kuisa chiratidzo nekusaina uyezve muongorori anobvimbisa kuchengetedza zita remwana. Zita remwana haribudi pabepa remubvunzo asi kuti anopiwa namba isina anoziva. Zvichabuda mutsvakurudzo iyi zvichengetedzwa kwemakore mashanu zvozoparadzwa zvazvo. Munoziviswa kuti hapana mibvunzo kana kuti zvinyorwa kana kutorwa kwemashoto ehutano hwenyu mutsvakurudzo iyi.

MUTENGO KANA ZVIBHADHARWA

Imi nemwana/vana munoziviswa kuti hapana chamunotairiswa kubhadhara mukutora chikamu mutsvakurudzo iyi.

MUCHIITIKO CHENJODZI

Kana pakaitika tsaona patsvakurudzo iyi , mitengo uye kurapiswa kwemwana kuchange kuchitwa netsvakurudzo iyi. Mishonga yose ichange ichibhadharwa neChikoro cheDurban University of Technology.

Kana pakaitika tsaona, fonerai vamwe vaongorori vanotevera chero nguva :

7. Professor Richard Millham – Department of Information, email: richardm1@dut.ac.za, office number – 0027 313735542.
8. Professor Nokuthula Sibiya – Executive Dean of Health Science, email: nokuthulas@dut.ac.za, office number – 0027 031373 2704.
9. Dr Sam Takavarasha Jr - Email - stakavarasha@wua.ac.zw, Office numbers: (263)-4- 2934551 / (263) 4 459 601/647, Mobile number / Cell: +263774727548

KUTORA CHIKAMU

Kutora chikamu mutsvakurudzo iyi hakumanikidzwi. Kana mukarambidza mwana kutora chikamu mutsvakurudzo iyi hakuna zvakaipa zvakamuchasangana nazvo mutsvakurudzo kana hukama hwemwana nechikoro cheDurban University of Technology, uye nemudzidzi - Elliot Mbunge and uye vashandil- Prof Richard Millham, Prof Nokuthula Sibiya, Dr Sam Takavarasha Jr. Kana mafunga kubvumira mwana wenyu kutora chikamu, imi nemwana wenyu makasununguka kubvisa mvumo yenyu uye kubvuma uye kurega kutora chikamu chero nguva musina kurangwa.

ZVIMWEWO

Bhuku rezvichabuda mutsvakurudzo iyi rinowanikwa kuDurban University of Technology uye rimwe bhuku richatumirwa kuMedical Research Council of Zimbabwe kuitira tsvakurudzo dzamangwana.

RB No. ____________

KUZVIPIRA KUPINDURA MIBVUNZO

Musati masaina chibvumirano ichi, munokumbirwawo kuti mubvunze chero mibvunzo pane chero chikamu ichi chisina kujeka kwamuri. Uye munogona kutora nguva yekudzeya nezvazvo.

MVUMO

MURI KUTI MUITE SARUDZO KUTI MURI KUTENDA KANA KUSATENDA MWANA WENYU KUTI ATORE CHIKAMU MUCHIDZIDZO. KUSAINA KWENYU ZVINOREVA KUTI MAVERENGA MAKANZWISISA ZVESE ZVIRIPA MUSORO APA MABVUMIRA MWANA KUTI ATORE CHIKAMU MUTSVAKURUDZO IYI.

____________________ ____________________

ZITA REMWANA ZUVA NENGUVA

____________________ ____________________

ZITA REMUBEREKI ZUVA NENGUVA

____ ____________________

SIGINECHA YEMUBEREKI ZUVA NENGUVA

____

HUKAMA KUMWANA

________________________________ __________________

SIGINECHA YEMUCHAPUPU*)* ZUVA NENGUVA

________________________________ ____________________

SIGINECHA YEMUOGORORI ZUVA NENGUVA

MUCHAPIWA CHIBVUMIRANO CHATANYORERANA KUTI MUGARE NACHO

Kana muine mibvunzo nezve tsvakurudzo iyi, kana chibvumirano chataita,kana zvingava zvimwe zvamusina kugutsikana nazvo, kana kukuvara, kana kusabatwa zvakanaka uye muchida kutaurira mumwe mumhu anga asiri mutsvakurudzo makasununguka kutaurira veMedical Research Council of Zimbabwe panamba dzinoti 791792/791193 nepa 0784956128 kana kunyorera kana kuenda ku:

Medical Research Council of Zimbabwe
Cnr. J. Tongogara & Mazowe Street
P.O. Box CY 573
Causeway
Harare

Appendix 3c: ADULT CONSENT FORM

MRCZ No. ____________

ADULT CONSENT FORM

An investigation of ICT-Based Malaria Intervention Framework for Rural Communities

Principal Investigator: _**ELLIOT MBUNGE**__, [*Ph.D. Candidate.)*]
Phone number(s)_ **+26878246653, 002731 373 5542, +263774727548, 0027 031373 2704**

ADD THE FOLLOWING PARAGRAPH TO ALL CONSENT FORMS
MORE THAN TWO (2) PAGES LONG (BEFORE ADDITION OF OTHER PARAGRAPHS)

What you should know about this research study:

- We give you this consent so that you may read about the purpose, risks, and benefits of this research study.
- Routine care is based upon the best-known treatment and is provided with the main goal of helping the individual patient. The main goal of research studies is to gain knowledge that may help future patients.
- We cannot promise that this research will benefit you. Just like regular care, this research can have side effects that can be serious or minor.
- You have the right to refuse to take part, or agree to take part now and change your mind later.
- Whatever you decide, it will not affect your regular care.
- Please review this consent form carefully. Ask any questions before you make a decision.

- Your participation is voluntary.

PURPOSE

You are being asked to participate in a research study of ***an investigation of ICT-based malaria intervention framework for rural communities.*** The purpose of the study is to develop a malaria intervention framework to enhance health promotion in rural communities through mobile technology. This is because malaria is a life-threatening disease responsible for killing people but it is preventable and treatable. In addition to that, people living in rural areas are faced with medical challenges such as drug shortages, shortage of medical staff members, lack of access to health information through affordable, feasible and sustainable ICT-based information dissemination tools, poorly equipped clinics and access to healthcare. Malaria morbidity and cases are high in Zimbabwe especially in rural areas and resource-constrained areas where there are few or no access to ICT-based malaria monitoring, surveillance and information dissemination tools. Currently, hospitals and clinics use awareness campaigns, community meetings, posters and dramas to convey malaria information in rural communities**.** Therefore, you are selected as a possible participant in this study because he/she is a potential user of the proposed ICT-based malaria intervention framework. The study is targeting learners at secondary level (adolescents) learning or living in Buhera rural districts and with access to mobile phones. The total number of the participants expected to participate in this study is 384 including secondary school learners, teachers and healthcare professionals.

PROCEDURES AND DURATION

If you decide to participate, the researcher will invite you and explain the purpose, aim, benefits and your roles and rights in participating in the study using the language that you are comfortable with between English or Shona. After that, the researcher will give you a questionnaire to respond to. If you need some clarification or help, he/she is free to ask the researcher at no costs. You will participate to this research by responding to a survey questionnaire to get his/her views, opinions and experiences concerning malaria and the use of mobile phones to disseminate malaria information. Responding to the questionnaire will take approximately less than 20 minutes and the identity of you will not be captured. You have the right to withdraw at any time and no adverse reaction will be encountered for withdrawal. If misconduct happens between you and the researcher, you are encouraged to report to the Medical research Council of Zimbabwe, nearest police station on +263 79 17 92/ 79 11 93, 08644073772, Cell: +263 784 956 128 and Durban University of Technology (Prof Millham) on 002731 373 5542, Prof Sibiya on 002731373 2704 or the Institutional Research Ethics Administrator on 002731 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support, Prof C. Napier on 031 373 2577 or carinn@dut.ac.za

RISKS AND DISCOMFORTS

There are no reasonably foreseeable risks, discomforts or inconveniences to the child - including health, legal, economic and psychological risks, financial standing or social standing or employability involved in participating in the research

BENEFITS AND/OR COMPENSATION

The research will potentially develop an affordable, feasible and adaptive ICT-based malaria intervention framework to create malaria digital awareness, disseminate malaria health information, monitoring, reporting and surveillance of malaria using local language in resource-constrained communities. The proposed system will potentially benefit the community and healthcare professionals to communicate malaria information and monitoring, reporting and surveillance of malaria at district level with the potential of scaling it up to the provincial level and nationally with the ultimate goal of reducing malaria. However, the researcher cannot and do not guarantee or promise that you will receive any benefits of any form from this study

ALTERNATIVE PROCEDURES OR TREATMENTS

The research is not anticipating to use any medical treatment.

IRB No. ____________

CONFIDENTIALITY

If you indicate your willingness to participate in this study by signing this document, the researcher guarantees confidentiality by assigning a pseudo number to the questionnaire. Any information that is obtained in connection with this study that can be identified will remain confidential. Confidentiality will be enhanced by using codes instead of participants' names. Research materials will be stored under lock and key. Research documents will be kept for 5 years thereafter they will be destroyed by shredding. Electronic documents of the study will be kept in a password-protected computer and will be deleted after 5 years. Kindly note that, there will be no medical records or your information will be taken in this study

ADDITIONAL COSTS

You will not pay anything or incur any costs for participating in the study. Your participation is completely free of charge.

IN THE EVENT OF INJURY

In the event of injury resulting from your participation in this study, treatment will be offered by the study. You should understand that the costs of such treatment will be the study's responsibility.

In the event of injury, contact the following co-investigators who are available 24 hours a day :

10. Professor Richard Millham – Department of Information, email: richardm1@dut.ac.za, office number – 0027 313735542.
11. Professor Nokuthula Sibiya – Executive Dean of Health Science, email: nokuthulas@dut.ac.za, office number – 0027 031373 2704.

Dr Sam Takavarasha Jr - Email - stakavarasha@wua.ac.zw, Office numbers: (263)-4-2934551 / (263) 4 459 601/647, Mobile number / Cell: +263774727548

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. If you decide not to participate in this study, your decision will not affect your future relations with this institution- Durban University of Technology, its student - Elliot Mbunge and its personnel- Prof Richard Millham , Prof Nokuthula Sibiya, Dr Sam Takavarasha Jr. If you decide to participate, you are free to withdraw your consent and assent and discontinue participation at any time without penalty.

ADDITIONAL ELEMENTS

The findings of the research will be accessed in the library of Durban University of Technology and a copy will be sent to Medical Research Council of Zimbabwe for future use of reference.

OFFER TO ANSWER QUESTIONS

Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over.

AUTHORIZATION

You are making a decision whether or not to participate in this study. Your signature indicates that you have read and understood the information provided above, have had all your questions answered, and have decided to participate.

____ ____________

Name of Research Participant (please print) Date

____ ____________

Signature of Participant or legally authorized representative Time

____

Relationship to the Participant

______________________________ ________________ ______________

Name of Staff Obtaining Consent Signature Date

______________________________ ________________ ______________

Name of Witness (*if required)* Signature Date

YOU WILL BE OFFERED A COPY OF THIS CONSENT FORM TO KEEP.

If you have any questions concerning this study or consent form beyond those answered by the investigator, including questions about the research, your rights as a research participant or research-related injuries; or if you feel that you have been treated unfairly and would like to talk to someone other than a member of the research team, please feel free to contact the Medical Research Council of Zimbabwe (MRCZ) on telephone (04)791792 or (04) 791193 and cell phone lines 0784 956 128. The MRCZ Offices are located at the National Institute of Health Research premises at Corner Josiah Tongogara and Mazowe Avenue in Harare.

Audio Recording

In an interview session, the researcher uses the semi-structured interview guide to get overall understanding of how healthcare professional disseminates health information, their views towards the ICTs to disseminate health information and the difficulties they face with the current strategies being used to create awareness and prevent malaria in rural communities. Therefore, the researcher is asking to audio record the interview session using an audio recorder. The recorded audio will be used for academic work in this study only. You have the right to refuse to be audio recorded and fill in the space provided in the interview guide. You are informed that the recorded audio would be kept safe for the period of five years and securely destroyed later by the university. Before you sign this form, please ask any questions concerning audio recording or on any aspect of this study that is unclear to you.

Statement of Consent to be Audiotaped.

I understand that audio recordings will be taken during the study. *(For each statement, please choose YES or NO by inserting your initials in the relevant box)*

- I agree to **being audio recorded** **Yes** ☐ **No** ☐

Name of Participant (please print) Signature Date

Appendix 3d : CHIBVUMIRANO NEMUBEREKI

IRB No. ___________

CHIBVUMIRANO NEMUBEREKI

Kudzivirira marariya kupfurikidza nekukurudzirwa kwehutano mumagariro emumaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko

Mukuru Wetsvakurudzo: **Elliot Mbunge**, mudzidzi wePhD reInformation Technology.
Vadzidzisi Vetsvakurudzo _**Richard Millham**(Prof), SamTakavarasha Jr(Dr), Nokuthula Sibiya(Prof)
Nhare dzetsvakurudzo : +26878246653, 002731 373 5542, +263774727548, 0027 031373 2704

Zvaunotarisirwa kuziva pamusoro petsvakurudzo iyi:

- Tinokupai chibvumirano ichi kuti muverenge muve neruzivo nezve chinangwa, zvimhingamupini, uye zvakanakira tsvakurudzo iyi.
- Chinangwa chikuru chetsvakurudzo iyi ndechekuti pave nedenhe reruzivo kuitira varwere vamangwana
- Hativimbise kuti tsvakurudzo iyi ichakubetsera .Sedzimwe tsvakurudzo, inogona kuva nezvimhingamupini.
- Une kodzero yekuramba kutora chikamu mutsvakurudzo iyi, kana kuti kubvuma parezvino wozochinja mafungiro pamberi.
- Sarudzo ipi zvayo yauchatora haina zvimhingamupini mukuwana rubatsiro
- Ndapota unokurudzirwa kuverenga chibvumirano ichi uye unokwanisa kubvunza mibvunzo paunoda kujekeserwa usati waita sarudzo
- Isarudzo yako kutora chikamu mutsvakurudzo iyi.

CHINANGWA

Urikukumbirwa kutora chikamu mutsvakurudzo yekudzivirira marariya kupfurikidza nekukurudzirwa kwehutano mumagariro emumaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko. Marariya chirwere chakonzera kufa kwevanhu vakawanda asi chinodziviririka uye chinorapika. Vanhu vanogara kumaruwa vanotarisana nezvinetso sezvakadai sekushayikwa kwemapiritsi, kushayikwa kwevashandi vezvehutano, kusakwanisa kuwana ruzivo, makiriniki asina midziyo yakakwana uye kushaya rubatsiro rweutano. Chirwera chemarariya uye ndufu dzakawanda kwazvo muZimbabwe kunyanya munzvimbo yeManicaland nekuda kwekusakwanisa kuwana ruzivo rwemarariya kunyanya kumaruwa uko kune zvigadzirwa zvishoma zvekuparadzira mashoko uye hurongwa hwehutano hwakanaka. Pari zvino, zvipatara nemakiriniki zvinoshandisa mishandirapamwe yekuziva, misangano yemagariro, mapepa nemadhirama kuparidzira mashoko emarariya munharaunda dzemaruwa. Saka, chetsvakurudzo iyi ndechekusimbisa nekudzivirira marararariya kupfurikidza nekukurudzirwa kwehutano mumagariro emaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko. Wasarudzwa kuti utore chikamu mutsvakurudzo iyi. Tsvakurudzo iyi irikutarisira vadzidzi vekusekondari (vechidiki) varikudzidza kana kugara mumatunhu emaruwa eBuhera uye vane mukana wekuwana mbozhanhare. Huwandu hwevatori vechikamu vanotarisirwa kutora chikamu tsvakurudzo iyi mazana matatu nemakumi masere nemana vanosanganisira vadzidzi vechikoro chekusekondari, vadzidzisi pamwe nevashandi vezvehutano.

MUTSARA WEZVIREVO UYE NGUVA YECHIDZIDZO

Kana ukatenda kutora chikamu, muongorori achakukoka otsanangura chinangwa, zvimhingamupini, zvakanakira tsvakurudzo uye kodzero yako mutsvakurudzo iyi uchishandira rurimi rwaunoda pakati peChirungu kana chiShona. Kana izvi zvapera, mudzidzi achakupa bepa rine mibvunzo yaunotarisirwa kupindura uchinyora mhinduro pabepa ipapo. Kana usina kunzwisisa mibvunzo wakasungunuka kubvunza muongorori pasina mubhadharo. Bepa remibvunzo rinosanganisira maonere ako mafungiro mayererano nehutachinona wemarariya uyezve kushandiswa kwemushina yezvekufambiswa kwemashoko ezvehutano. Nguva inotarisirwa kutorwa pakupindura mibvunzo iyi inova maminitsi asingadariki makumi maviri uyezve zita rako kana chitaridzo chako hachinge chiri pabepa remibvunzo. Munekodzero yekurega kutora chikamu mutsvakurudzo iyi. Kana pakava nekupokana pakati pemuongorori nemi unokuridzirwa kuchaya runhare ku Medical Research Council of Zimbabwe pabhozharunhare dzinoti +263 79 17 92/ 79 11 93, 08644073772, Cell: +263 784 956 128, , kana kuti zivisai mapurisa aripedyo nemi ueyezve chayai runhare kuDurban University of Technology (Prof Millham) pa002731 373 5542, Prof Sibiya pa002731373 2704 kana kuti Institutional Research Ethics Administrator pa 002731 373 2375 kana kuti veResearch and Postgraduate Support, Prof C. Napier pa 031 373 2577 kana kuti carinn@dut.ac.za

NJODZI UYE NEKUSAGADZIKANA

Hapana njodzi dzati dzaonekwa mukutora chikamu mutsvakurudzo iyi .

NJODZI KUNE VAKAZVITAKURA

Hapana njodzi dzati dzaonekwa kune vakazvitakura mukutora chikamu mutsvakurudzo iyi.

ZVIWAKIKWA KANA MURIPO

Tsvakurudzo iyi inokwanisa kudzivirira marariya kupfurikidza nekukurudzirwa kwehutano mumagariro emumaruwa kuburikidza nekushandisa mushina yezvekufambiswa kwemashoko mukudzivirira marariya mu kuparadzira ruzivo rwechirwere cheMarariya, kuongorora, kumhan'ara nekutarisa marariya uchishandisa mitauro yemunharaunda. Urongwa hwakatsanangurwa hunogona kubatsira nharaunda pamwe nevanochengetedza hutano kuti vashambadze ruzivo rwemarariya uye kuongorora nekutarisisa, kuudza nekutarisa marariya. Nekudaro, muongorori haakwanise uye haavimbise kuti muchapiwa mubairo chero upi zvawo kubva mutsvakurudzo iyi.

.

ZVIMWE ZVIKAMU ZVEMISHONGA

Hapana mishonga inotarisirwa kushandiswa mutsvakurudzo iyi.

KUVIMBIKA

Kana ukabvuma kutora chikamu mutsvakurudzo iyi, unokuridzirwa kuisa chiratidzo nekusaina uyezve muongorori anobvimbisa kuchengetedza zita rako. Zita rako haribudi pabepa remubvunzo asi kuti anopiwa namba isina anoziva. Zvichabuda mutsvakurudzo iyi zvichengetedzwa kwemakore mashanu zvozoparadzwa zvazvo. Unoziviswa kuti hapana mibvunzo kana kuti zvinyorwa kana kutorwa kwemashoto ehutano hwenyu mutsvakurudzo iyi.

MUTENGO KANA ZVIBHADHARWA

Unoziviswa kuti hapana chaunotairiswa kubhadhara mukutora chikamu mutsvakurudzo iyi.

MUCHIITIKO CHENJODZI

Kana pakaitika tsaona patsvakurudzo iyi , mitengo uye kurapiswa kwako kuchange kuchitwa netsvakurudzo iyi. Mishonga yose ichange ichibhadharwa nechikoro cheDurban University of Technology.

Kana pakaitika tsaona, fonerai vamwe vaongorori vanotevera chero nguva :

12. Professor Richard Millham – Department of Information, email: richardm1@dut.ac.za, office number – 0027 313735542.
13. Professor Nokuthula Sibiya – Executive Dean of Health Science, email: nokuthulas@dut.ac.za, office number – 0027 031373 2704.
14. Dr Sam Takavarasha Jr - Email - stakavarasha@wua.ac.zw, Office numbers: (263)-4- 2934551 / (263) 4 459 601/647, Mobile number / Cell: +263774727548

KUTORA CHIKAMU

Kutora chikamu mutsvakurudzo iyi hakumanikidzwi. Ukarega kutora chikamu mutsvakurudzo iyi hakuna zvakaipa zvauchasangana nazvo kubva kuchikoro cheDurban University of Technology, uye nemudzidzi - Elliot Mbunge uye vashandi- Prof Richard Millham, Prof Nokuthula Sibiya, Dr Sam Takavarasha Jr. Kana wabvuma kutora chikamu mutsvakurudzi iyi, wakasununguka zvakare kurega kutora chikamu chero nguva pasina kurangwa.

ZVIMWEWO

Bhuku rezvichabuda mutsvakurudzo iyi rinowanikwa kuDurban University of Technology uye rimwe bhuku richatumirwa kuMedical Research Council of Zimbabwe kuitira tsvakurudzo dzamangwana.

KUZVIPIRA KUPINDURA MIBVUNZO

Musati masaina chibvumirano ichi, munokumbirwawo kuti mubvunze chero mibvunzo pane chero chikamu ichi chisina kujeka kwamuri. Uye munogona kutora nguva yekudzeya nezvazvo.

IRB No. ____________

MVUMO
URIKUNZI UITE SARUDZO KUTI URI KUTENDA KANA KUSATENDA KUTORA CHIKAMU MUCHIDZIDZO. KUSAINA KWAKO KUNOREVA KUTI WAVERENGA UKANZWISISA ZVESE ZVIRIPA MUSORO APA UYEZVE WABVUMA KUTORA CHIKAMU MUTSVAKURUDZO IYI.

____________________ ____________________
ZITA REMWANA ZUVA NENGUVA

____________________ ____________________
ZITA REMUBEREKI ZUVA NENGUVA

____ ____________________
SIGINECHA YEMUBEREKI ZUVA NENGUVA

____
HUKAMA KUMWANA

________________________________ ____________________
SIGINECHA YEMUCHAPUPU) ZUVA NENGUVA

________________________________ ____________________
SIGINECHA YEMUOGORORI ZUVA NENGUVA

MUCHAPIWA CHIBVUMIRANO CHATANYORERANA KUTI MUGARE NACHO
Kana muine mibvunzo nezve tsvakurudzo iyi, kana chibvumirano chataita,kana zvingava zvimwe zvamusina kugutsikana nazvo, kana kukuvara, kana kusabatwa zvakanaka uye muchida kutaurira mumwe mumhu anga asiri mutsvakurudzo makasununguka kutaurira veMedical Research Council of Zimbabwe panamba dzinoti 791792/791193 nepa 0784956128 kana kunyorera kana kuenda ku:

Medical Research Council of Zimbabwe
Cnr. J. Tongogara & Mazowe Street
P.O. Box CY 573
Causeway
Harare

<u>Kurekodha Mazwi</u>

Muchirongwa chebvunzurudzo, muongorori anoshandisa nhungamiro yekubvunzurudza kuwana kunzwisisa kuti vezveutano vanoshandisa chii kuparadzira ruzivo rwehutano, maonero avo mayererano nekushandisa mushina yechizvinozvino kuparadzira ruzivo rwehutano, uye nematambudziko avanosangana nawo mukupa ruzivo, kudzidzisa uye kudzivivira marariya kumaruwa. Naizvozvo, muongorori ari kukumbira kurekodha chikamu chebvunzurudzo achishandisa kaseti rekodha. Iyo kaseti rekodha ichashandiswa basa redzidzo retsvakurudzo ino chete. Une kodzero yekuramba kurekodhwa, wongopindura mibvunzo pazasi pemibvunzo yakapihwa mugwaro rekubvunzurudza. Unoziviswa kuti kaseti rekodha ichachengetedzwa kwemakore mashanu uye yozoparadzwa nechikoro. Usati wasaina fomu iri, unokumbirwa kubvunza chero mibvunzo nezvekurekodha mazwi kana chero chikamu chetsvakurudzo iyi chisina kujeka kwauri.

Chirevo cheChibvumirano Kurekodha Mazwi

Ini ndinonzwisisa kuti kurekodha mazwi kuchaitika mutsvakurudzo ino *(Pamashoko ega ega, ndapota sarudza Hongu kana Kwete nekuisa ruvara rumwe rwezita rako mubhokisi rakakodzera)*

- Ini ndinobvuma kurekodhwa mazwi — **Hongu** ☐ **Kwete** ☐

Zita remutori muchikamu chetsvakurudzo (ndapota nyorai)	Siginecha	Zuva

Appendix 4a: Quantitative survey questionnaire

DURBAN UNIVERSITY OF TECHNOLOGY
INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

The purpose of this study is to investigate ICT-based malaria intervention framework for rural communities in Buhera rural district. Therefore, you are kindly requested to participate in this study by completing the questionnaire. Please do not write your name on this questionnaire. The questionnaire can take less than 25 minutes to fill. After completing the questionnaire, the researcher will personally take the questionnaire. Your participation in this study is highly appreciated. Answer the questions by ticking in one box only where applicable. Make sure all questions have been answered before you move to the next page. For more information kindly contact Mr Elliot Mbunge telephonically on +263777666385, or via email mbungeelliot@gmail.com

Section A: Demographic data

1. Select your gender
   Male
   Female
   Other, Specify____________________________________
2. Write the name of your community

   ____
3. Marital Status
   Single
   Married
   Divorced
   Widowed

Other (specify)____

4. Select your age group
   Below (<) 21 years

   21- 30 years

   31- 40 years

   Above (>) 40 years

5. What is your highest level of schooling that you have completed?
   Primary School

   Secondary school

   Higher and Tertiary (College and University)

   Other, specify____

Section B: Malaria symptoms and prevention methods

6. Do you have a mosquito net at home?
   Yes

   No

7. Was your house sprayed with Intermittent Residual Spraying in 2019?
   Yes

   No

8. Did you use Antimalarial treatment drug in 2019?
   Yes

   No

9. Do you think the following are symptoms of malaria?

	Yes	No	Don't know
Shivering			
High Temperature			
Vomiting			
Headache			
Loss of appetite			
Body Weakness			

10. Do you agree to the following ways of preventing mosquito breeding area?

	Yes	No	Don't know
Avoid keeping stagnant water			
Clearing of bushes around the house			
Use of treated mosquito nets			
Indoor Residual Spraying			

Section C: Information and Communications Technology (ICT) information dissemination methods in Buhera rural district

11. To what extent do you agree to use the following ICT methods to disseminate malaria information? Please respond by providing X once under your preferred answer between Strongly Agree, Agree, Disagree and Strongly Disagree

	Strongly Agree	Agree	Disagree	Strongly Disagree
Television				
Radio				
Community Networks- Murambinda Works				
Mobile phone				
WhatsApp				
Facebook				
Email				
Computers				

12. Indicate the extent to which you have used the following ICTs to send or receive health information. Please respond by providing X once under your preferred answer between Never, Rarely, Occasionally, Frequently and Always.

	Never	Rarely	Occasionally	Frequently	Always
Television					
Radio					
Digital Billboards					
Mobile phone					
WhatsApp					
Facebook					
Email					

Section D: Information and Communications Technology (ICT) accessibility and usage

13. Indicate the extent you have accessed the following ICT platforms. Please respond by providing X once under your preferred answer between Never, Rarely, Occasionally, Frequently and Always.

	Never	Rarely	Occasionally	Frequently	Always
Television					
Radio					
Digital Billboards					
Mobile phone					
WhatsApp					
Facebook					
Email					
Computers					

Community Networks- Murambinda Works					

14. Rate yourself on how you have used the following ICTs for communication purposes. Please respond by providing X once under your preferred answer between Never, Rarely, Occasionally, Frequently and Always

	Never	Rarely	Occasionally	Frequently	Always
Television					
Radio					
Digital Billboards					
Mobile phone					
WhatsApp					
Facebook					
Email					

15. Which mobile line do you use for voice calling and messaging?

Econet Zimbabwe

NetOne Zimbabwe

Telecel Zimbabwe

Other, Specify____

16. Do you have internet access?

Yes

No

If No, give the

reason(s)____

____

____

__

Section E: Information and Communications Technology (ICT) challenges

17. Indicate the extent to which the following challenges can hinder you to use ICTs to disseminate health information? Please respond by providing X once under your preferred answer between Strongly Agree, Agree, Disagree and Strongly Disagree

	Strongly Agree	Agree	Disagree	Strongly Disagree
Network problem(s)				
Poor access to electricity				
High cost of ICT devices				
Unavailability of ICT devices				
Poor access to ICT devices				
Digital literacy				
Lack of health information written in my vernacular language				
Cultural issue(s)				
Religious issue(s)				
Use of technical language				
Poor health data security				
Lack of patient data privacy				
Poor ICT policy in the health sector				

Software incompatibility				

Others, Specify-

____

____

____

____

____

18. Do you have any comment(s) concerning the study or questionnaire? Write in the space provided below.

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

Before submitting the questionnaire make sure all the questions have been answered.

The End. Thank you for your time!

Appendix 4b : Mibvunzo yetsvakurudzo

DURBAN UNIVERSITY OF TECHNOLOGY
INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

Chinangwa chetsvakurudzo iyi ndechekudzivirira marariya kupfurikidza nekushandisa mushina yezvekufambiswa kwemashoko mudunhu reBuhera. Naizvozvo, unokumbirwa kutora chikamu mutsvakurudzo iyi nekupindura mibvunzo yauchabvunzwa yakanangana netsvakurudzo iyi. Wakasununguka kusanyora zita rako. Kupindura mibvunzo inotevera kunogona kutora maminitsi ari pasi pemakumi maviri nemashanu kupindura. Kana wapedza kupindura mibvunzo, mudzidzi wetsvakurudzo iyi achatora bhuku remibvunzo. Kutora kwako chikamu mutsvakurudzo iyi kunotendwa zvikuru. Pindura mibvunzo nekuisa tsvunha(✓) muchibhokisi chimwe nemafungiro ako pamubvunzo mumwe nemumwe. Iva nechokwadi kuti mibvunzo yese yapindurwa usati waenda kune peji inotevera. Kana paine zvamungada kubvunza nezve tsvakurudzo iyi, taurai nemudzidzi wetsvakurudzo anonzi Elliot Mbunge muchishandisa runhare pa+263777666385 kana kumunyorera pa mbungeelliot@gmail.com

Chikamu Chekutanga: Mibvunzo pamusoro pako

19. Sarudza kuti uri murume here kana kuti mukadzi?

Murume

Mukadzi

Zvimwe, (tsanangura)__________________________________

20. Nyora zita redunhu rako

____

21. Sarudza chikamu chimwe chete chinoratidza zvauri panezvinotevera.
    Uri mhandara kana jaya

    Wakaroorwa kana kuti wakaroora

    Wakarambana nemurume kana kuti nemukadzi

    Uri chirikadzi kana kuti tsvimborume(Pfunda)

    Zvimwe,

    (tsanangura)____

22. Sarudza boka remakore ako ekuberekwa
    Pasi makore makumi maviri nerimwe(<21)

    Makumi maviri nerimwe kusvika makore makumi matatu (21- 30)

    Makumi matatu nerimwe kusvika makumi mana (31- 40)

    Pamusoro pemakumi mana (>40)

23. Ndeipi dzidzo yako yepamusoro yawakapedza?
    Puraimari

    Sekondari

    Koreji kana Yunivhesiti

    Zvimwe, (tsanangura)____

Chikamu chepiri: Zviratidzo zveMarariya uye nzira dzekudzivirira

24. Une mambure ehumhutu/ nhunga here?
    Hongu

    Kwete

25. Imba yenyu yakapfapfaidzwa nemushonga wekudzinga umhutu / nhunga here mugore ra2019?

Hongu

Kwete

26. Wakamboshandisa mushonga wekudzivirira marariya here mugore ra2019?

Hongu

Kwete

27. Unofunga kuti zvinotevera zviratidzo zvemarariya here?

	Hongu	Kwete	Handizivi
Kubvunda			
Kupisa kwemuviri			
Kurutsa			
Kutema kwemusoro			
Kusanzwa kuda kudya chikafu			
Kuneta Kwemuviri			

28. Unobvuma here kuti nzira dzinotevera dzingashandiswa kudzivirira kuberekana kweumhutu /nhunga?

	Hongu	Kwete	Handizivi
Kudzivirira kuchengeta mvura yakajenga			
Kubviswa kwemakwenzi akatenderedza dzimba			
Kushandisa mambure enhunga /umhutu			
Kupfapfaidza mushonga weumhutu /nhunga			

Chikamu Chetatu: Kurudziro yehutano hweMarariya uye nzira dzekuparadzira ruzivo

29. Unobvumirana kusvika pamwero wakadii kuti wakashandisa nzira dzinotevera dzinoparadzira ruzivo rweMarariya? Ndinokumbirawo upindure nekunyora X kamwe muchibhokisi pasi pemhinduro yako yaunofarira pakati pendinobvuma zvakanyanyisa, ndinobvuma, handibvumi, handibvumi zvachose

	Ndinobvuma Zvakanyanyisa	Ndinobvuma	Handibvumi	Handibvumi zvachose
Terevhizheni / Chivhitivhiti				
Dzangaradzimu				
Netiweki yemunharaunda – Murambinda Works				
Nharembozha				
WhatsApp				
Facebook				
Tsamba yepahindateni				
Makombuyuta				

30. Ratidza mwero wako wekushandisa muchina yechizvinozvino inotevera yeICT mukutumira kana kugamuchira ruzivo rwezvehutano. Ndinokumbirawo upindure nekunyora X kamwe chete pasi pemhinduro yako yaunofarira pakati pehandina zvachose , kashoma, apo neapo , kazhinj uye nguva dzose

	Handina zvachose	Kashoma	Apo neapo	Kazhinji	Nguva dzose
Terevhizheni / Chivhitivhiti					
Dzangaradzimu					
Dhijitari Bhodhi					
Nharembozha					
WhatsApp					
Facebook					
Tsamba yepahindateni					

Chikamu Chechina: Kuwanikwa uye kushandiswa kwemuchina yechizvinozvino yeInformation and Communications Technology (ICT)

31. Ndeipi muchina yechizvinzvino yeICT pane inotevera yaunowana mukana wekushandisa? Ndinokumbirawo upindure nekunyora X kamwe chete pasi pemhinduro yako yaunofarira pakati pehandina zvachose , kashoma, apo neapo , kazhinj uye nguva dzose

	Han dina zvac hose	Kasho ma	Apo neapo	Kazhin ji	Ng uv a dzo se
Terevhizheni / Chivhitivhiti					
Dzangaradzimu					
Dhijitari Bhodhi					
Nharembozha					
WhatsApp					
Facebook					
Tsamba yepahindateni					
Makombuyuta					
Netiweki yemunharaunda – Murambinda Works					

32. Ratidza mwero wako wekushandisa muchina yechizvinozvino inotevera yeICT mukufambisa mashoko kana kutaurirana nevamwe uye nemhuri. Ndinokumbirawo upindure nekunyora X kamwe chete pasi pemhinduro yako yaunofarira pakati pehandina zvachose , kashoma, apo neapo , kazhinj uye nguva dzose.

	Handina zvachose	Kashoma	Apo neapo	Kazhinji	Nguva dzose
Terevhizheni / Chivhitivhiti					
Dzangaradzimu					
Nharembozha					
WhatsApp					
Facebook					
Tsamba yepahindateni					

33. Unoshandisa mutsetse wekambani ipi pakufona kana kutumira mameseji?
Econet Zimbabwe
NetOne Zimbabwe
Telecel Zimbabwe
Zvimwe
(tsanangura)____

34. Une mukana wekuwana hindaneti here?

Hongu

Kwete

Chikamu chechishanu: Zvimhingamupuni zvingawanikwa mukushandisa muchina yekufambiswa kwemashoko [Information and Communications Technology (ICT)]

35. Ratidza kuti matambudziko anotevera anogona kukukanganisa sei kushandisa muchina yechizvinozvino yeICT kutumira kana kugamuchira ruzivo rwezvehutano. Ndinokumbirawo upindure nekunyora X kamwe chete pasi pemhinduro yaunofarira pakati pendinobvuma zvakanyanyisa, ndinobvuma, handibvumi, handibvumi zvachose.

	Ndinobvuma Zvakanyanyisa	Ndinobvuma	Handibvumi	Handibvumi zvachose
Dambudziko rekushaya netiweki				
Kushaikwa kwemagetsi				
Kudhura kwemichina yeICT				
Kushaikwa kwemichina yeICT				
Mushaya mukana wekushandisa michina yeICT				
Kusagona kushandisa michina yeICT				
Kushaikwa kweruzivo rwezveutano				

rwakanyorwa nerurimi rwamai				
Tsika nemagariro edu hazvitenderi				
Chitendero changu hachibvumi				
Kushandiswa kwemitauro yehunyanzvi yepamusorosoro (Technical language)				
Kusachengetedzeka kweruzivo rwezvinoitika mubazi rezvehutano				
Kusavanzika kweruzivo rwezvehutano rwevarwere				
Kushaikwa kwemitemo yekushandiswa kwemichina yeICT kubazi rezvehutano				
Kusapindirana kwemichina yechizvinozvino yekufambiswa kwemashoko				

Zvimwe,(tsanangura)____

36. Pane zvaungada kutaura here pamusoro petsvakurudzo iyi? Ndinombirawo unyore panzvimbo yakapihwa pazasi

Usati waendesa mhinduro dzemibvunzo iva nechokwadi kuti mibvunzo yese yapindurwa.

Magumo. Ndinotenda nekundipa nguva yenyu!

Appendix 5a : Interview guide

The purpose of this study is to investigate the ICT-based malaria intervention framework to disseminate malaria information in Buhera rural communities. Therefore, you are kindly requested to complete the questionnaire. Please do not write your name on this qualitative questionnaire. Make sure each question have been fully answered before you move to the next question. For more information kindly contact Mr Elliot Mbunge telephonically on +263777666385, or via email mbungeelliot@gmail.com

Date: ______________________________

Age: ______________________________

Gender: ______________________________

Occupation: ______________________________

1. What are your views regarding to the use of clinic posters, community gathering, schools outreach events and dramas as malaria information dissemination strategies?

2. What are the challenges that the Buhera Rural District face when preventing the spread of Malaria?

3. What are the challenges associated with clinic posters, community gathering, schools outreach events and dramas to disseminate health information in Buhera rural district?

4. Do you think mobile phones can be used as a feasible method to enhance malaria awareness in Buhera rural district?

5. What are your views on the use of mobile phones to disseminate malaria information in Buhera rural communities?

6. Which other Information and Communication Technologies(ICTs) can be used to disseminate malaria information in Buhera rural district?

7. What are challenges would be faced with ICTs to disseminate malaria information in Buhera rural district?

8. What are the implications of integrating ICTs in health sector to disseminate health information in Buhera rural district?

9. Do you have anything you would like to add towards the adoption and use of ICTs to disseminate malaria information in rural communities?

Closing remarks

I appreciate your time and willingness to respond to the questions. Thank you.

Appendix 5b: Mibvunzo yetsvakurudzo

DURBAN UNIVERSITY OF TECHNOLOGY
INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE

Chinangwa chetsvakurudzo iyi ndechekudzivirira marariya kupfurikidza nekushandisa mushina yezvekufambiswa kwemashoko mudunhu reBuhera. Naizvozvo, unokumbirwa kutora chikamu mutsvakurudzo iyi nekupindura mibvunzo inotevera yakanangana netsvakurudzo iyi. Wakasununguka kusanyora zita rako. Iva nechokwadi kuti mibvunzo yese yapindurwa usati waenda kune mimwe mibvunzo inotevera. Kana paine zvamungada kubvunza nezve tsvakurudzo iyi, taurai nemudzidzi wetsvakurudzo anonzi Elliot Mbunge muchishandisa runhare pa+263777666385 kana kumunyorera pa mbungeelliot@gmail.com

Zuva ranhasi: ____

Une makore mangani ekuzvarwa:____________________________

Sarudza kuti uri murume kana kuti mukadzi: Murume Mukadzi

Basa raunoita: ____

10. Unofungei mayererano nekushandiswa kwenzira dzinotevera dzekushambadza nadzo ruzivo rweMarariya dzinoti mifananidzo yemarariya yakanamirwa mumakiriniki, ungano dzemunharaunda, zvikoro uye madhirama?

11. Ndezvipi zvimhingamupini zvinosangana nevagari vemuBuhera mukudzivirira kuparira kweMarariya?

12. Ndezvipi zvimhingamupini zvinowanikwa nekushandisa mifananidzo yemarariya yakanamirwa mumakiriniki, ungano dzemunharaunda, zvikoro uye kushandisa madhirama senzira dzekushambadza ruzivo rwezveMarariya?

13. Iwe unofunga here kuti mbozharunhare inogona kushandiswa senzira yekushambadza ruzivo rwezveMarariya munzvimbo yeBuhera?

14. Ndeapi mafungiro uye maonero ako mayererano nekushandisa mbozharunhare mukuparadzira ruzivo rwemarariya munzvimbo yeBuhera?

15. Ndeipi imwe michina yezvekufambiswa kwemashoko (ICT) ingashandiswa kuparadzira ruzivo rweMarariya munharaunda yeBuhera?

16. Ndeapi matambudziko awunofunga kuti angasanganikwa nawo mukushandisa muchina yezvekufambiswa kwemashoko (ICT) mukushambadza ruzivo rweMarariya munzvimbo yeBuhera?

17. Ndezvipi zvimhingamupini zvingasanganikwa nazvo mukushandisa michina yezvekufambiswa kwemashoko (ICT) munyaya dzezvehutano mudunhu reBuhera?

18. Pane chaungada kuwedzera here mayererano nekushandiswa kwemichina yezvekufambiswa kwemashoko(ICT) mukuparadzira ruzivo rweMarariya munzvimbo dzekumaruwa.

Mashoko ekuvhara

Ndinotenda nekundipa nguva yenyu uye mukana wekuti tikurukure nezveMarariya. Ndatenda

Appendix 8: Editors' Certificate

Sarah Frost

B.A. (Hons in English Literature) (UCT), Masters in English Literature (UKZN)

Editing Services

Cell: 074 384 2772

Email: sfrost@juta.co.za

---

19 October 2022

Re: Editing services rendered

Please be advised that I edited a thesis written by Elliot Mbunge (Student number 21855551), written as part of his PhD degree: Information Technology in the Faculty of Accounting and Informatics at the Durban University of Technology.

Regards

Sarah Frost

Editor