IMPROVING INFORMATION USE THROUGH PUBLIC HEALTH INFORMATICS SYSTEMS & HUMAN RESOURCE CAPACITY BUILDING

A for Dissertation Presented

to the faculty of the University of Missouri.

In partial fulfillment of the requirements for the degree

Philosophical Doctor in Informatics- Health Informatics

MU Institute of Data Science and Informatics

University of Missouri- Columbia

By

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December, 2020

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APPROVAL

The undersigned, appointed by the dean of the Graduate School, have examined the entitled IMPROVING INFORMATION USE THROUGH PUBLIC HEALTH INFORMATICS SYSTEMS & HUMAN RESOURCE CAPACITY BUILDING presented by Zeyana A. Hamid, a candidate for the degree of Doctor of Philosophy, and hereby certify that, in their opinion, it is worthy of acceptance.

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DEDICATION

To My Mom, who is truly my superhero.

I dedicate my dissertation work to her, Madam Fatma Ali Mohammed for years' long fight, and supporting throughout to ensure I stay motivated, pushing me to believe in myself and pull this through, falling and rising together, even when there was no hope to be seen.

To my Dear Husband, Rajab Mohammed Ramia who sacrificed so much to let me achieve this dream together with my Children Biubwa, Abdallah, Ramia, Fatma and Halima for their love and patience through several days of absence, and sleepless nights they have witnessed.

To my siblings Selwa, Rabia and Hamid, also to Biubwa for every little and huge help sought necessary to share the sweat with me and helped me retain the positive energy needed to keep going.

A special Thanks to Brother Abdul Aziz Raudha for his tireless day and night support, Feisal Ali for his technical support, Mwana Suleiman for Always being by my side, the Mgambo Shaaban and Alban Ali Families for being my Family away from home.

Last but not the least to my Late Dad, who determined to raise his girls with so much wisdom and necessary education, to help them face the world solve its challenges with confidence.

Acknowledgements

I would like to thank the following people, without whom I would not have been able to complete this research. To Dr. Kalyan Pasupathy who taught me so much and motivated me to join the Ph.D Program; To Dr Eduardo Simoes who picked this work from infancy and nourished it to what it is seen today, his vision and support from the beginning of this work to the end; will never be forgotten; To Dr. Popescu who found it in the middle of diversions and challenges, needing to re-emerge into one piece of work and for striving to help me focus into what I wanted to present eventually; Dr Fulcher for his dedicated support and introducing me to so much of what he does for the community and how this research is applicable not just in developing nations, but also in this country as far as rural health is concerned. I deeply acknowledge support from Dr John Snyder who has been a great mentor and hoping to learn so much from even after completion of this research and lastly but not the least to Dr. Lincoln Sheet for his unlimited attention and support to this work.

I would love to extend my sincere appreciation to the District Health Management Teams (DHMTs) in Zanzibar for owning this work and believing that supporting it will open doors for Informatics to happen even at community level. The Ministry of Health Zanzibar for allowing this work to take place in the isles and supporting it administratively and believing in my contribution to the sector.

Special thanks to the Zanzibar Presidents Office for its support to ensure Zanzibar does continue work in Health Informatics and that its DHMT's are continuously supported with capacity building.

I would like to extend my deepest gratitude to the Tanzania Commission of Science and Technology (COSTECH) through its previous Director Hassan Mshinda, who wanted to have this research conducted in Tanzania, and blessed it with institutional and financial support and ensured its successful completion. This dissertation year has been fully supported by the Association of American University Women (AAUW) who has believed in its output and has chosen it to be supported as one of its recognized research. Also, to all the librarians at University of Missouri, the MUII community, for their contributions towards the completion of my dissertation.

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List of Abbreviations

CHW	Community Health Workers
DANIDA	Danish International Development Agency
DHIS	District Health Information System/Also District Health Information System 2
DHMT	District Health Management Team
GIS	Geographical Information System/Science
HIS	Health Information System
HISP	Health Information System Program
HF	Health Facilities
HMIS	Health Management Information Systems
hMIS	Hospital Management Information System
IS	Information System
MOH	Ministry of Health
M&E	Monitoring and Evaluation
PH	Public Health
PHI	Public Health Informatics
WHO	World Health Organizations
ZCHIS	Zanzibar Community Health Information System

Abstract

The District Health Information System (DHIS) has been installed to a number of Low and Middle Income Countries (LMIC) to collect health records at a district level and share the data nationally [1, 2]. While data collection coverage is very high in most countries, [3, 4] information use is still reported to be very low [4, 5]. Annual data use workshops [6] have been designed to improve the rate of information use for surveillance in Zanzibar, Tanzania. However, in order to increase data and information use, in addition to the annual workshops, real-time tools are needed to support surveillance at district and national levels and continuous data use in public health sectors. [7-9]. The DHIS dataset is aggregated at the district level, lacking information on location within the district and social demographic information on patients utilizing health services at the ward (shehia) level. This insufficiency, limits use in epidemiology, even if it was intended for national and district administrative purposes. There are three tiers of governance on Zanzibar: 1) regional administration (five regions); 2) district administration (10 districts per region); and 3) wards (236 shehias – smallest division of administrative regions – in all districts). The Health Management Information Systems unit (HMIS) manages the DHIS, and through the hard work of District Health Management Teams (DHMTs) has been continuously collecting quality information. It is unfortunate that collected data ends up in databases for showcasing and trivially used for decision making [10]. HMIS acknowledges minimal data use as one of the challenges in the sector and demonstrated that data could be used for secondary data analysis [11]. While the immediate outcome of this work is a system that analyzes real-time HMIS data on pneumonia, all upper respiratory tract infection (URTI), and diarrhea with added value data for surveillance, the long-term goal of this work is developing a Health Information System (HIS) that supports evidence-based management of Zanzibar's entire public health, using epidemiologic-embedded analysis and a well-built workforce. The other important objective of this research is to strengthen the capacity of officers' district surveillance of public health informatics practices through improved data quality, training of health surveillance officials, and development of software tools that analyze, disseminate, and facilitate information use.

Chapter 1 Introduction

Developing countries are facing disease burdens attributed merely to poverty and illiteracy. Apparently, the most frequent mortalities and morbidities are in countries with high childhood mortality (Figure 1.1) In poverty-stricken countries, children are highly diagnosed with preventable diseases such as pneumonia and diarrhea (Figure 1.2), These preventable cases are strongly linked to socioeconomic status like educational status, [12] poverty, and access to care [13]. The United Nations Children's Fund (UNICEF) and the World Health Organization (WHO) jointly published *Diarrhea: why children are still dying and what can be done*, a report that raises awareness and lays out a comprehensive plan of action for reducing the incidences and mortality [12]. The Global Action Plan for Pneumonia and Diarrhea (GAPPD) proposed a multi sectorial, integrated approach to reduce the incidence and deaths of pneumonia and diarrhea, using an integrated framework of key interventions proven to protect and effectively prevent and treat childhood pneumonia and diarrhea in a coordinated manner by 2025.

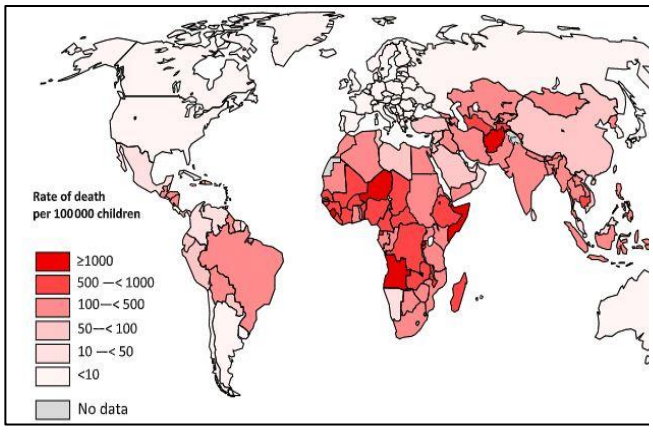


Figure 1.1 Global distribution of deaths among children [13]

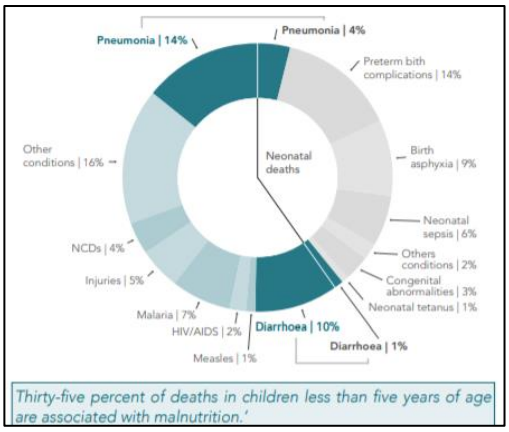


Figure 1.2 Child mortality 2000-2012

Preventable cause of death	Type of Estimate	Calculations	Estimated number of lives saved
Diarrhoea	Mean	0.751 million × 0.48	360 000
	Low	0.751 million × 0.24	180 000
	High	0.751 million × 0.63	473 000
Pneumonia	Mean	1.071 million × 0.23	246 000
	Low	1.071 million × 0.11	118 000
	High	1.071 million × 0.33	353 000
Total	Mean	0.360 million + 0.246 million	607 000

Figure 1.3 Global Lives saved by hand washing with soap, children 1–59 month (Source: [15])

Simple interventions like oral rehydration salts (ORS) provision [12] and hand washing [14] have not seen sustainability, and for a decade, these morbidities and mortalities are still prevalent (Table 1.1).

It is about time to address diarrhea and pneumonia by properly targeting the vulnerable populations. Additionally, although poverty has been known to be a major risk factor for these diseases, most developing countries fail to evidently incorporate the variation of socioeconomic status of the population, specific neighborhoods and geographical areas to these diseases burden, and the design of their sustainable interventions.

National data itself is aggregated, missing the opportunity to identify the location of incidence cases and hence localized prevention actions. Tracking disease occurrence in a manner that fails to fully identify the affected populations in terms of person, place, and time, preclude the chance of studying Socio Economic Status (SES).

On Zanzibar, for the last decade, pneumonia, URTI, and diarrheal disease have been in the leading in morbidity and mortality rates [14]. Since preventions depend on awareness and education [15, 16], target populations per each disease have to be identified within the routine reporting and used to shape and evaluate interventions periodically. Evaluating the association of socioeconomic factors for the first time on Zanzibar should help the public health actors in their effort to minimize the burden of these three diseases.

Public Health Informatics (PHI) is a relatively new discipline where informatics approaches can support diseases surveillance and evidence can be applied to population health to prevent morbidity and mortality [17-19]. One such example was carried out in Tanzania and South Africa with spatial variability of HIV epidemics using routine facility data [17]. Other Tanzanian initiatives involved the spatial and space-time clustering to study mortality due to malaria [20] and pattern/spatial distribution of the plague [21]. The main difference to the mentioned projects with this research is the total shifting of access to analysis, from researchers and academicians to the low level, district, and community surveillance officers to answer the same questions as frequent as surveillance needs

be, and within the scope of their work requirements. With the existence of free software, informatics can design software tools that identify target populations, analyze its socioeconomic impact to disease rates, and can appropriately report for evidence based public health action.

For Zanzibar, the introduction of District Health Information System (DHIS) in 2005 marks the beginning of the PHI, but unfortunately, due to the well-intended data aggregations (explained in subsequent sections), the country fails to closely target the population at high risk for disease occurrence and fully understands the socioeconomic disparities of morbidity and mortality on Zanzibar. The University of Oslo, Norway; developed DHIS 2 (https://www.dhis2.org/), as a free and open source health management information system used to manage, analyze, and report health facility-level aggregated data.. It is being deployed in more than 67 countries on four continents representing 30% of the world's population. A review by Measure Evaluation[22] was conducted to assess the feasibility of integrating the DHIS critical health indicators with health social service and community health. This review argues that the public health systems are not being linked to the social data systems (where people are), and that this insufficiency leads to an inability to offer "holistic information for decision making" on services.

Developing countries are left behind with the overall benefits in Public Health Informatics (PHI) due to minimal capacities on personnel and consequently the supporting systems required being in place. The investment made on Zanzibar to deploy DHIS and later to migrating to DHIS2 is close to one million dollars [23] for deployment only. In addition, there are other systems in place that are strengthening costs, yet the workforce has not matured into full data use capacity [5, 24]. This dissertation studies the usability of HMIS data (deposited in the DHIS) for decision making, gaps, and paces in DHIS uptake in different countries, and showcases an Action Research (AR) approach to develop a PHI intervention for supporting an improved public health analytic environment for the District Health Management Teams (DHMTS) and other national users.

1.1 Background

Data use in decision making in developing countries is vital (Nutley, 2012). Strengthening health data use is fundamental and failure to use the information we collect is a waste of investment in collecting the data in the first place. The main reason we collect data, and heavily invest in data collection systems (hardware, software, and protocols), training, and quality assurance, is to maximize use of the data collected and see a return on investments. The public health informatics capacity building in developing countries has become the main goal of Centers for Disease Control's (CDC) Global Health Informatics initiative [25].

1.2 Proposed Study

This research presented in this work will evaluate the impact of a strategy to make health surveillance data more available and useful for decision making, planning and evaluation of public health strategies to promote health and prevent diseases on Zanzibar. The strategy is three-pronged: 1) improve data quality, 2) use statistical software and web-based information, and 3) train health professionals to use these new tools. This research is significant by addressing weaknesses of the public health surveillance systems on Zanzibar, such as unavailability of shehia estimated rates for common diseases and conditions, and lack of capacity for evidence decision making and planning.

1.3 Specific Aims

Specific Aim 1: Evaluate the availability, usage and application in practice by health officials of health surveillance data on the most frequent health events on Zanzibar before, during, and after the implementation of the three-pronged approach to improve health surveillance systems on Zanzibar.

Rationale: Public health decision making, planning and evaluation activities are affected by poor quality of local data on health outcomes. Data is aggregated and lacks information about both locations of outcome and the socio-demographic of patients. Additionally, HMIS data lacks time stamp for the healthcare visit and unique patient identifier (ID) which impedes tracking patients who return for the same conditions, or use multiple facilities which are in different shehias and districts.

Improving upon the quality of public health data and facilitating analysis of this data at low cost are critical for improving population health on Zanzibar.

1.4 1.4 Hypothesis to be Tested

Hypothesis: The availability, use, and application of surveillance data in public health practice will increase with improvement of data quality, user-friendly statistical analysis software, and results sharing tools. Assessment for this improvement is presented in the results section.

Activities for Aim 1:

1) To design and implement a quasi-experimental design to evaluate impact of a three-prong intervention in public health surveillance;

2.a) To calculate disease frequency by facility and shehia from health facility utilization data, and analyze this data with shehia-based socioeconomic characteristics;

2.b) To design and program statistical analysis software for analysis automation, and make it available as a portal for health officials;

2.c) To train public health information system staff on use/application of newly-developed statistical software and portal (2.b) using disease dataset (2.a) . Assessment for the training effectiveness will be presented in results section.

Specific Aim 2: Dissemination of study results to health surveillance officials, planners and managers of the public health services in Zanzibar, especially shehias involved in the study.

Rationale: Dissemination of study results should increase the chance for sustainable efforts to improve public health surveillance and practice on Zanzibar.

Activities for Aim 2:

1) Identify the best channels and targets for dissemination;

2) Develop policy/issue briefs (white papers or reports) and one scientific manuscript with findings from the evaluations. (Manuscripts are being prepared for publication, after which will follow the policy briefs for Information Use Advocacy). Evidence based policy formulation and briefs have not been found in Zanzibar literature, and hence this will provide opportunity of also assessing it as a dissemination channel that will shape policy and/or decision making.

1.5 Research Implications

1.5.1 Significance

Developing countries recently introduced to electronic health data have minimum data use and no data use indicators. The purpose of investing in data collection lies in its use. The unused repository of information is a huge waste of such investments. This research will help to establish indicators of information-use-capacity, design systems that will boost the use of existing and incoming data, and then train surveillance officers on key informatics practices that will improve knowledge generation to the communities. Measuring information-use-capacity[1] will change the culture of District and Community Health Workers (CHW)/shehia Information System personnel in using the information they collect on a daily basis, and eventually improve the collection process as they will appreciate the value of each data component collected. Bi-annual Performance Assessment using the Open Performance Review and Appraisal System (OPRAS) was introduced by the Tanzania government in 2004 as a new innovation for managing individual's performance in the Tanzania public service. OPRAS assesses performance, challenges, and root causes in health sector, lacking information use indicators which are part and parcel of performance. Responses are compared to targets, identifying areas that need to be addressed for improvement. [26, 27] Having systems and personnel able to follow disease trends electronically, perform statistical analysis routinely, disseminate results using

[1] [I will need you help rephrasing what is meant here]. After realizing it takes time to measure information use in the lifespan of this research—we propose to measure information-use-capacity, and that is what was measured using the four main Indicators "the outcome Indicators: chapter 4." The previous statement is introducing the idea

web tools, and encourage online discussion is very important in public health informatics and disease management, especially in low resource settings [28]. This contribution is significant since it allows for close follow-up on cases at the facility and community levels [29], bringing awareness of data representation. It raises evidence-based decision making and information utilization to the national and the district levels, and adds to the information use culture back into the communities. DHMTs dissemination of results will maximize their capacities in modern techniques of managing diseases. Team work from national level to the district level for using public health using informatics should encourage shared ideas and resources to investigate and tackle community-based problems. By bringing public health information for decision making to sub-district level, DHMTs will and gain corresponding acknowledgement from the communities on assessment and evaluation findings, co-designing of intervention, plan and prioritization activities based on mutual understanding of evidenced problems. This will put experts from research, epidemiologists, communities and HMIS personnel "on the same page." This professional community will help solve problems and design interventions that help reduce morbidity and mortality, allocate resources more efficiently and effectively and collaborate for research. The results of this research will be shared among LMICs that use the DHIS database for collecting district health information, and improve the health of their communities.

1.6 Publications produced by this research

1) Introducing ZCHIS: A Web-Based Analytical Tool for Health Management Information Systems' Routine Data using Census SES, Journal of Health Informatics in Developing Countries (JHIDC), under review.
2) Public Health Informatics for Decentralized Health Systems in Developing Countries. Literature Review, Journal of Health Informatics in Developing Countries (JHIDC) manuscript in preparation, to be submitted April 2020
3) District Health Management Teams' Capacity Building Using Public Health Informatics Interventions and Periodic Assessments. Manuscript in preparation, to be submitted, May 2020.
4) Utilization Health Management Information System Routine data for Socioeconomic Determinants of Health Analysis, manuscript in preparation, to be submitted May 2020.

Chapter 2. Literature Review

This chapter presents findings from the literature targeted to the DHMTs which collects the national data through the DHIS System. Tanzania and other developing countries have interventions that strengthen health system performance, improve information use, build DHMTs capacity, and present the challenges and opportunities for this integration. Specifically, the literature review main categories are:

1. DHIS Development in Tanzania and across LMIC
2. Usability of HMIS/DHIS Data
3. Zanzibar DHIS Gaps and Opportunities for a Better HMIS
4. Role of DHMTs and entitlement to Informatics Capacity building
5. Community Extension and Role of Tacit Knowledge.

2.1 DHIS Development in Tanzania and across LMIC

DHIS software was developed by the University of Oslo as a routine Health Information System for global use [4, 22, 30]. South Africa initiated national DHIS rollout in 2000 where apart from the technical framework, an important demand was organizational change in human resource development and technical support to use locally generated information to improve coverage and quality of primary health care services [31, 32].

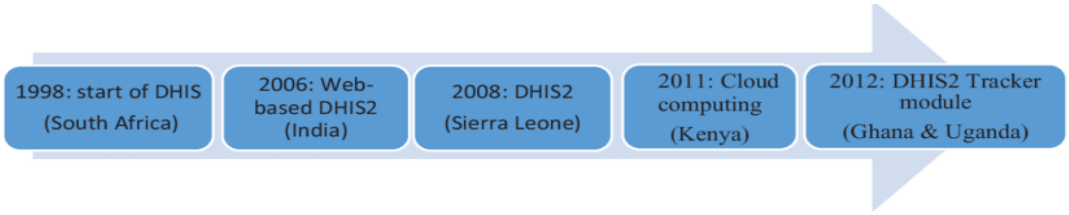


Figure 2.1 DHIS Developments across counties

Five year later, Zanzibar adopted the system after realizing that using open source for health information systems for LMIC is appropriate given the advantages including low entry costs, proprietary freedom, and flexibility of localization [33, 34]. The DHIS was customized into Zanzibar essential datasets, computer database used for data storage, summaries and reporting, [1, 35-37] by the support from Health Information System Programme (HISP) using participatory design and Action Research (AR) to build local capacities [38].

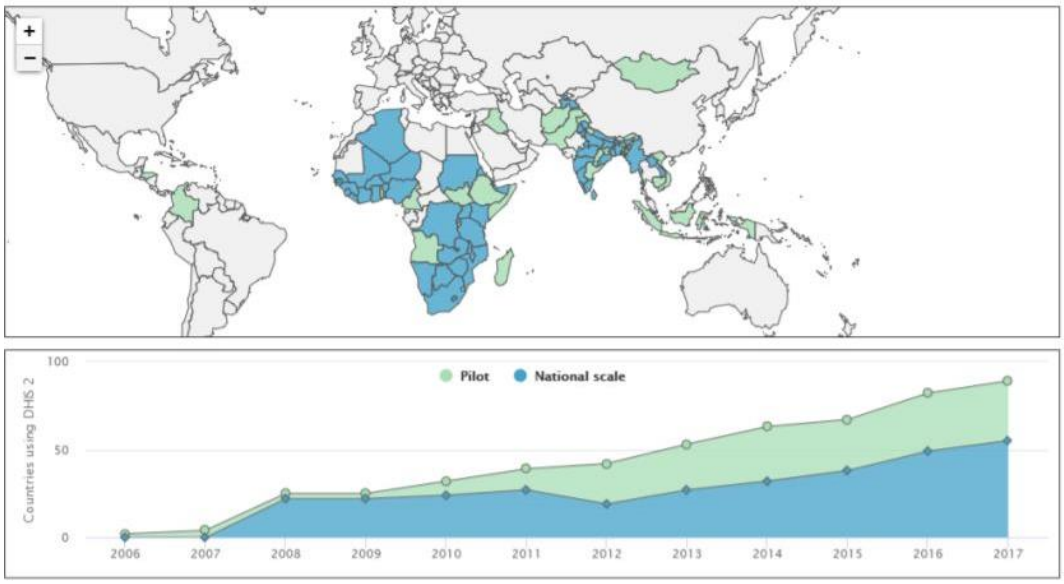


Figure 2.2 Global Adoptions of DHIS 2005-2017

As seen in South Africa (above) [32], apart from the technical and careful planning on rolling out, successful achievement in Zanzibar deployment was the use of local, culturally-embed and integrated leaders to lead the implementation between the local primary actor's and stakeholders interest [1].

In development of DHIS hospital-Management Information System (hMIS) in Zanzibar, an incremental approach was used where a small set of daily used dataset was initiated also involving users and leaders; gradually training and testing the system, more diagnosis and other parameters were being added to its completion [35].

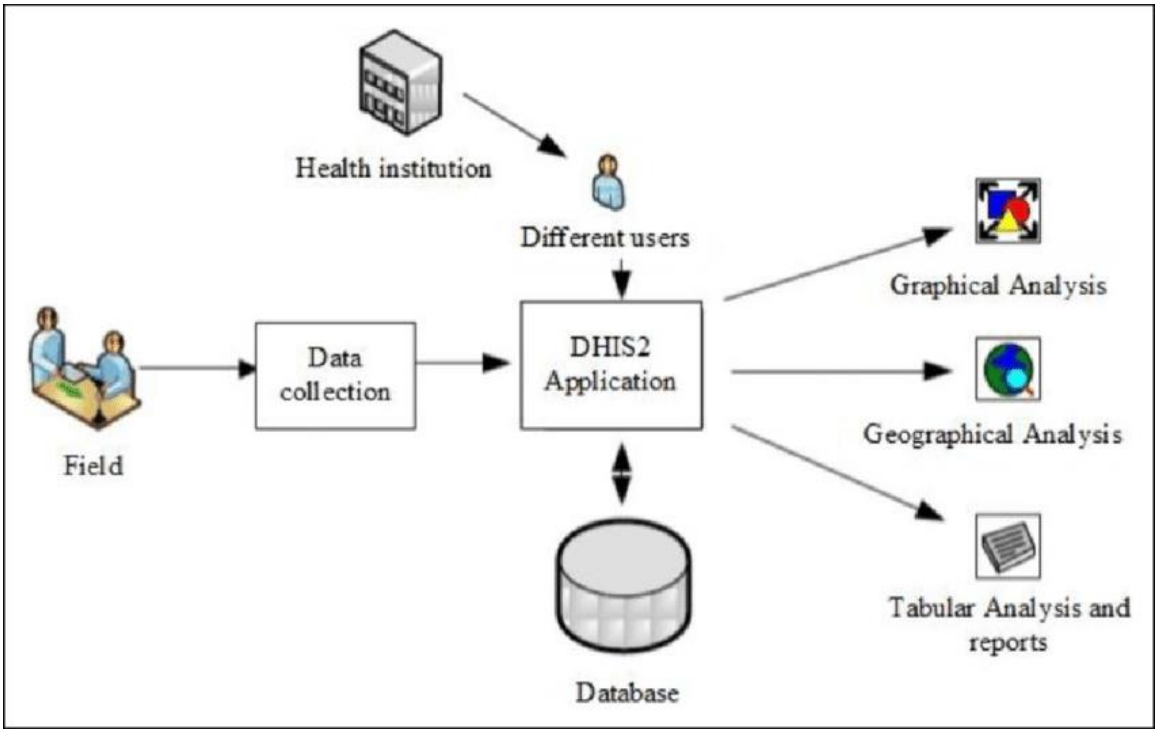


Figure 2.3 District Health Information System

Figure 2.4 DHIS Sample Dashboard of National and District Level Indicators

In spite of improving information use to a more granular level (this work), the question is: How do we sustain these efforts amidst limited resources Sustainability has become the main agenda for

information systems developed in LMIC given the limited human resource capacity to fully utilize the benefits of these systems, and limited resources [5, 39-43].

This literature has found two main pillars around health systems strengthening:

(i) Human resource capacity building: through action research, on-the-job training and technical support.

(ii) PH Systems capacity building: through integrations, data captures, analysis and use.

In regards to human resource, technical capacity building remains the most important strategy for most of developing countries [44, 45]. In Tanzania, health information systems human resource capacity building remains a matter of urgent concern for the sustainability of public health [40].

From the health system standpoint, integrating DHIS with Vertical Health Programs (VHPs) can pool the shared resources and use [46]. In a comparison of Mozambique and Tanzania, we learn that important factors for sustainability are system integration along with flexibility to user changes and adaptability to users culture [47]. Taking a closer look DHIS Integrations it is one of the two major factor to sustainability of PHI ecosystem [48]. It has been stressed that this is not just the hardware and software connectivity that has to take place, but the administrative, management, sociological and cultural aspects aligned to the HIS has to be well integrated [49]. PHI integration uptake and hence sustainability, will as well build the informatics maturity of the nations, leaders and local experts. In spite of heavy investments in Tanzania to achieve HIS integration, adoption of what Smith termed it as "narrow, managerial perspective of integration" instead of Sociological, epidemiological administrative and management integration may have resulted into minimal impact to provide adequate inputs for healthcare use in Tanzania[49]. The narrow perspectives and minimal capacities among most managers in developing countries poses integration barriers with what was analyzed as power tensions [50], which can be minimized by building and communicating shared perspective of integration process, decentralize the powers within integrated HIS and distributing the shared resources. Vertical Health Programs (VHPs) acceptance has been a tangible

integration hurdle in Tanzania and Zanzibar amongst other places it is becoming an opportunity after realizing their information needs can be captured by DHIS and on the other hand they can offer support through interoperation of DHIS with VHPs; by sharing resources for HIS agenda in capacity building and operation[46]. Zanzibar has studied integration for its opportunities and challenges and proved it to be the solution to technical and administrative capacity challenges that faces the health sector in spite of being counter-effected by it [51].

Apart from the administrative and capacity challenges in developing countries, integration is also challenged by absence of guidelines, tools, information incompleteness [52] and standards [53-55]. Mahundi's [53] analysis argues that while standards aim at unifying ways we integrate across multiple systems, it is unrealistic not to appreciate and build upon the local variations while making these standards. Hence, the different types of health facilities can utilize different clusters of standards be it dispensaries, heath facilities and hospitals [53]. Standards has posed great challenges in integrating TB/HIV Services in Tanzania, where strategies are to establish formal control of information system standards across stakeholders, reviewing existing national policy guidelines, establishing a functional regulatory authority and implementing data quality assurance mechanisms [56]. Additionally integration has to account for the dynamics in ICT ecosystems (or rather Informatics ecosystems) with wider Sociocultural and political aspects catered for the desired sustainability of linking the health sector [48]. This is the extent reached in just a decade by Bangladesh journey of DHIS known as the quiet revolution, into a national data warehouse ranging from EHR to vital statistics, strengthening health systems that support outcomes and interventions [57].

Other initiatives of integration have focused in extending DHIS with public data sets like the rabies-specific disease surveillance with a web based, open access HIS for interventions to utilize [58]. In dealing with low capacity and poor data quality, data capturing systems have been integrated with the DHIS as in the case of the Palestinian eRegQual which is electronic health registry that supports interactive checklists and clinical decision support for quality antenatal care among other things[59].

The DekiReader use in Nigeria for Malaria data has facilitated malaria diagnosis, treatment, and real-time quality improvement and data management [60]. In other countries, integration has taken great use of mHealth developments for electronic capture of HMIS [61] in South Africa the Open Data Kit (ODK) collects and aggregates data from the electronic health records and inputs into the DHIS; eliminating the need for the laborious data collation and entry [62]. In an intervention for an outbreak response sub-system in Uganda, mobile data entry facilitated reports suspected cases of priority pathogens illnesses on text message to DHIS-2 and expansion of the specimen-transport and laboratory-reporting system [63]. It has been recommended that surveillance of outbreak systems could make good use of DHIS once integrated. Zanzibar's GIS project integrated DHIS data with an open source visualization software which could also help in surveillance, but outdated spatial data also with key user reluctance affected its sustainability. According to the system design, there was no effort to capture shehia that has been lost due to aggregation. It is a typical case of surveillance at a higher level of geographical clustering, that this work aims at unveiling. Integration to DHIS has also focused at the District level software applications. Mera proposed for Colombia to have an intelligent system that supports analysis automation, prediction of future scenarios and that identifies patterns, based on Case Based Reasoning methodology, and integrated with DHIS2. Further, the system is intended to enabling public health decision-making through user-friendly web-based dashboards for performance improvement and resource management [7]. Similarly in Zambia, a district level system integration has been developed in such a way the DHIS, and the financial MIS data streams of expenditure are analyzed and output data useful for service-specific unit expenditures and individualized facility performance [64]. Zambia has a robust and practical community based health system, their integration benefited community health workers by utilizing the Community-HMIS mobile platform to provide integrated community case management services and send data into the DHIS [65]. Another community intervention in rural Kenya used a structured HMIS community-participatory intervention and reported to have improved uptake of family planning services and facility-based deliveries.

DHIS has also integrated with the M&E systems. In the event where there were no indicators supported in the DHIS, especially to the vertical health programs like the case of HIV/AIDS in South Africa [66], and in Nigeria [67], maternal health DHIS integration has supported outcomes in various places. A more success story of integration is reported in Bangladesh with maternal health which managed to have real time data-use which helped in saving maternal and perinatal death [68]. In Uganda, data from public and private facilities through the national and district HMIS facilitated web-based software that integrated reporting using software which supported reporting and automated performance reviews. This was also supported by training staff; supportive supervision; and quarterly performance review meetings among other behavioral facilitators, and among briers like limited computing devices and technical capacities [69]. The difference between Wandera's [69]work and ours is that it focuses on administration and service delivery in maternal health management, while we propose a framework that can translate every routine incidence of the DHIS back into the communities for vertical health programs, for surveillance of the most frequent morbidities and mortalities and for knowledge management and research interventions.

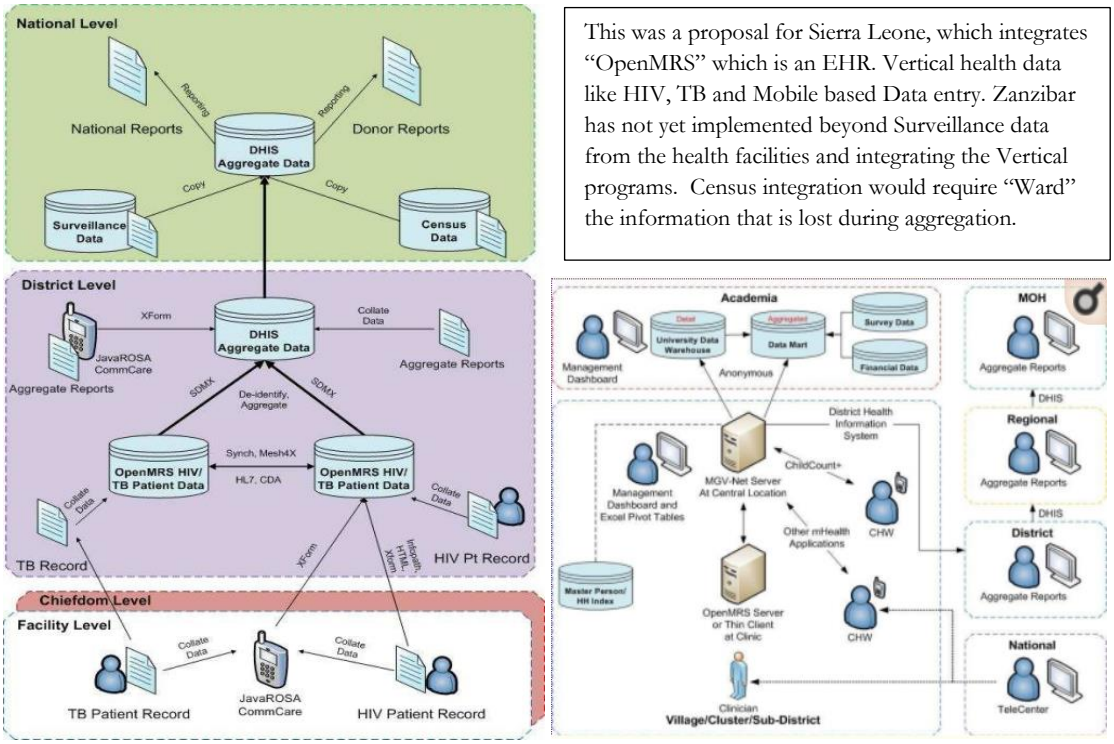


Figure 2.5 Proposed Enterprise Architecture[70]

The most recent, and the very important category of integration, is in the electronic health records and DHMS. Developing countries are just stepping the foot into national EHRs. Most countries are opting into the open source EMR despite the technical requirements needed to support deployment which is a challenge they are opting to face implementing the Open Medical Record System (OpenMRS) [71-74] which is a community developed free application that offers flexible interoperability with the DHIS making it a key building block in HIS [70]. While this proposal was based in Sierra Leone, Kenya successfully implemented the architecture with the indicator data sent from OpenMRS at a health facility to DHIS2. This step alone, resolves many existing challenges in DHIS counties like data coverage, validity issues like transcription errors, reporting timeliness, and reduces the reporting burden on human resources. This increased availability of quality indicator data using available resources to facilitate monitoring service delivery and measuring progress towards set goals Kariuki [72]. In Tanzania, there are 46 hospitals using ten different e-health systems, ranging from the openMRS, MTUHA- The Tanzanian based EHR, and many other, and still lacking interoperable standards and policies to support integrated HIS [24]. Tanzania has been struggling to integrate the "very extensive HIS" as Wilms [75] calls it and recommends only collection of core business indicators for routine services from MTUHA that will support performance assessment and use [75]. Specifically, it was found MTUHA is posing challenges to HIS Integration as much as to the users who report tedious data collection responsibilities and the researcher found limited training, low mathematical capabilities, and poor MTUHA knowledge dissemination within the hospital, and lacking awareness of the HIS's full capabilities. Whilst data collection for routine services functioned reasonably well, filling of the secondary data tools was unsatisfactory. Internal inconsistencies between the different types of data tools were found. These included duplications, and the collection of data that was not further used. In more advanced nations like Afghanistan, the ALMANACH project implemented a decision support system that synchronizes real time data from EHR in clinical setting, and the system is integrated with DHIS for conducting epidemiological evaluations and

decision making [76]. Further integration is seen with the newly implemented mHealth4Africa which through HL7 FHIR interoperable data exchanges are supported between the EMR and DHIS [77].

2.2 Usability of HMIS Data

Usability of HMIS data is a matter that needs a rigorous analysis and reform commitment to gain stakeholders' support for HIS to invest in integration and continuous systems strengthening. The term *usefulness* can be addressed in terms of dataset structures, completeness of indicators and quality of data input into the DHIS (completeness, timeliness and validity). A number of studies have found poor quality of HMIS data in their work and presented their recommendations.

2.2.1 Data Quality and Improvement efforts

One major obstacle is information use that is facing the HMIS utilizing DHIS systems is the quality of its data, which has advocated more data quality improvement interventions in the last decade. The literature on quality of HMIS data is divided into two. One is coming from research that are intended to tackle the data quality. In a maternal health study cutting across Bangladesh, Nepal and Tanzania, for the first time internationally, the research team is validating facility based routine data from the DHIS to compare with direct observation in order to inform core list of indicators for inclusion in the national system [78]. In South Africa, an initiative recommended analysis of hospital data quality using the DHIS proves to be inconsistent and incomplete, and calls upon other countries to replicate the study in a more cost effective manner to support realization of data driven hospitals [79].

Other countries in eastern and southern Africa have been studies on the entire aspect of generating statistics from health facility data and calls upon systematic examinations and reporting quality issues, feedback to caregivers ad managers and transparent corrections and adjustments, to be critical to improve quality of data [80]. Data quality is presenting challenges for routine health system data in Prevention of Mother to Child Transmission (PMTCT) and a South African research that audited 316 heath facilities reported accuracy of 50% where 5.3% of clinics met the definition of accuracy in

DHIS data entry. These findings are complemented in another PMTCT study in the same settings and diagnose that the quality is lost during collation process [81, 82].

In Tanzania, 11 health facilities were involved in a cross sectional descriptive study to bridge the gaps seen in HMIS data quality observed unfilled booklets by half, and is linked to "lack of training, inactive supervision, staff workload, pressure and lengthy and laborious nature of the system". There is a lack of standardization as seen in Kenya with daily addition of datasets but no review or revision of the existing ones [83]. Nigerian study on Malaria data sets reviewed and identified missing indicators like active case detection and entomological data needed for surveillance towards malaria elimination [84]) The second category is secondary result of research focused on other aspects of health research using the data. An example is an effort to build a research registry for birth complication in Palestine a case record form using e-health was presented which consequently improved DHIS data completeness and reliability [3]. A take home for quality improvement interventions is spotted from Rwanda [85] where it is recommended that "future data-driven QI interventions begin with data quality assessments to promote that rapid health system improvement is possible, ensure confidence in available data, serve as the first step in data-driven targeted improvements, and improve staff data analysis and visualization skills. Explicit Ministry of Health collaborative engagement can ensure performance review is collaborative and internally driven rather than viewed as an "external audit."

2.2.2 Application of HMIS data across different countries

Despite its quality limitation, research has continuously relied on HMIS data, indicating a desperate demand for secondary data in LMIC, where there are no adequate resources for collecting data from scratch whenever a research needs to be conducted. With the completeness limitation observed in DHIS data, Kenya has managed to model a spatio-temporal discrepancies and statistically interpolated data incompleteness for use for decision making [86]. Recently, Kenya also utilized an interrupted time series analysis of free maternity services and using DHIS monthly data the research

informed the policy makers of the worsening of institutional maternal mortality ratio [87]. The Zanzibar Malaria Program (ZMP) also recently utilized the interrupted time series analysis on HMIS data to study impact of malaria control interventions in Zanzibar, from 2000 to 2015 [88]. Information use is a catalyst in HIS strengthening as seen in India, the malaria elimination program is heading towards real time DHIS data capture to enable integrated and rapid case management [89]. In South Africa, DHIS was used to expand the data set to include trauma, a research which led to a finding that intentional and unintentional trauma cases are in the ratio of nearly 1:1 [90]. Uganda is among the successful countries in efficiently adopting DHIS. One study has utilized under-5 malaria cases from DHIS before, during and after an indoor spraying intervention and revealed a strong relationship of increased malaria cases geospatially [91]. In a similar setting, another study utilized DHIS data to portray the perceived relationship of rainfall and malaria cases. This can support the malaria program's preparedness to prevent new malaria cases in the population [92]. Additionally, Ugandan malaria program showed the decline in malaria incidence from DHIS to analyze the effectiveness of vector-control, community interventions and case management with artemisinin-based combination therapy (ACT) which advocates sustaining interventions to curb reverses in malaria observed decline. The same methods and conclusion were presented earlier on Zanzibar [93].

In evaluating DHIS in rural South Africa, the data quality, utilization for facility management, work burden, and usefulness of the system to clinic staff were assessed. It was found that workers had a high perceived work burden associated with DHIS data collection and aggregation; some tools were not correctly used. Although there was good understanding of the data collection process there was little analysis, interpretation or utilization of data with no routine feedback to clinics [94]. Data use intervention has to be deliberately conducted to improve data quality and coverage, rationalization, local and routine use of indicators and informing national policy [4].

2.3 Zanzibar DHIS Gaps and Opportunities for a Better HMIS

Zanzibar has had her first scoop of Public Health Informatics (PHI) through the establishment of Health Management Information Systems (HMIS) in 2004 where important transformation like developing standard data collection forms, reporting and computerizing discrete data sets, and analysis [35, 95] occurred. This led to the District Health Information System (DHIS) deployment in 2005 [34] which has been defined as: *"a software tool for collection, validation, analysis and presentation of aggregate statistical data managed in multiple data sets and tailored to support integrated health information management activities"* [4]

Deployment worked on design and testing of data collection forms, customization and testing of DHIS software, data forms revision, analysis, reporting, and eventually the DHIS roll out on Zanzibar [35, 95]. With the upgrade of DHIS2 in 2008, the sector matured into web-based data collection storage, and analytics which resulted to more demand for data, analysis and use [5]; but hence the sudden need for systems' integrations [49, 96].

Since its establishment with Danish International Development Agency (DANIDA) , Zanzibar HMIS has been fully engaged through routine indicator revision meetings, improving data quality through feedback meetings, and data use workshops, while ensuring quality and coverage of data [4]. Although this rich database now has over 500 health indicators, extractable as pivot tables (by facilities, districts, month years, gender and age), usability of the data has been a critical agenda to date. Without a clearly defined data usage strategy and informatics tools that can advance it, the return of Zanzibar DHIS investment of over $500,000 can hardly be met [23]. In analyzing Zanzibar's malaria decline using HMIS data, Ashton (2017) stated, "*Considering the substantial investments already made in HMIS systems, the underutilization of routine HMIS data has been described as an unacceptable inefficiency in resource constrained countries*"

While other countries continuously advance DHIS extensibility and usability [97], Zanzibar, due to administrative and workforce capacity challenges analyzed, [96] has faced a diminished growth to

DHIS usability as intended and sustainability as described by [5]. In general, Zanzibar lacks full participation to PHI and health systems strengthening interventions [55]. Using the HMIS data is also challenged by a scarcity of statisticians in Zanzibar's' health sector among other skilled workers [96]. Routine statistical analysis of the extracted data are becoming increasingly infeasible as more data is being generated, while production of the informatics and/or statistics capacity is minimal (worldbank.org). The HMIS analysis are based on district and facility level, visual summaries for management/administrative purposes as is the intention for DHIS on first place [4, 70].

The current data analysis are less of health outcomes, statistical inferences on disease trends, and secondary datasets utilization like census and demographic surveys. Portions of the datasets do get used in analysis on occasional funded research or vertical programs (VP) like the Malaria Program [93], while several local interventions and decision-making is conducted based on simplified charts summaries, with no statistical significance. The multi-year repository of DHIS2 data is big enough to be coupled with data science tools to allow knowledge mining. When merged with other national surveys, the desired secondary analysis can be achieved and possibly support a more meaningful HIS Integration [96]. Zanzibar lacks, on top of its limited workforce, an agenda to automate information generation, improve its Informatics/ICT ecosystems [48], and develop an evidence-based culture [55] at all levels of the health sector.

DHIS was designed for administrative management of the health facilities. However, one research termed it: "*the de-facto standard by regulations as well as by experiences"* [48]. Rather than acting like national repository of health data, DHIS database is potentially more than that [10]. It remains the most populated, program integrated, and sustainable system to support health indicator outcome analysis.

The Health Metrics Network (HMN) architecture analysis the missing link PHI informatics to guiding National development [98] using Integrated Health Information systems where the Institutional records (Individual records, service records and Service Records) are to be integrated

with population data, (census, civil registration, and population surveys) to produce useful evidence-based decision making.

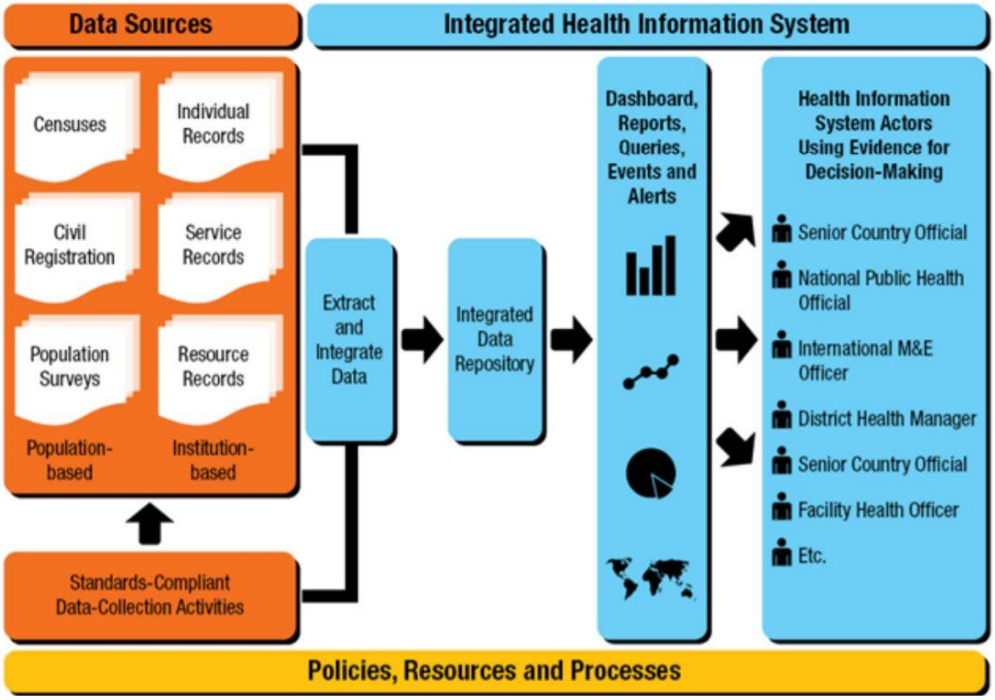


Figure 2.6 HMN Architecture National Data-warehouse [98]

Statistical analyses being conducted thus far are mainly coming from donor-funded projects, particularly from the malaria, HIV monitoring, and maternal health areas. Meanwhile, data left behind in the DHIS repository tells a larger picture of what is going on in individual communities had population datasets been incorporated into analysis, something that now can be high level at district level without reusing the shehia that has been aggregated.

DHIS data analysis must be automated into well defined, routine structured outcome reports that support feedback to the health facilities and surrounding communities, districts, the MOH since it is the largest repository of health records in spite the presence of OpenMRS [96]. The development of Free and Open Source GIS in Zanzibar [99] heads in the same direction as the purpose of this research with three fundamental improvements; a) level of analysis drops from District level to shehia level; b) in addition to GIS design that analysis HMIS data, we are adding a link to

socioeconomic analysis through Census, and c) inferential statistics using R Statistical tests and analysis has been made possible on real time queries. Online analytics that provide visualization of indicators and modeling of risk factors to inform public health are now inevitable as data is produced dramatically ([100-104] with time and technology advancement.

Several systems in the last decade have been developed for epidemiologic purposes using R statistics and web interfaces to minimize standalone practices of reproducing routine analysis that are needed for daily operation and interventions [105-109]. Socio-demographic risk factors for population health outcomes have also been largely documented [108, 110-112], like multi-group risk factor online analysis to serves cross-national comparability to inform disparities [103].

Visualization and analytical system are also common in decision support systems that utilize health records to support delivery of care [113] and many other PHI systems focus on visualization of online geospatial information systems (GIS) for public health research with socioeconomic (SES) or environmental factors [114-116]. Analytical visualization has a growing research concentrated around genomics [117], social network data [118-120] and research that informs policy, like the tobacco control effectiveness research [121] across EU countries. While these countries utilizes individualized data, developing nations due to lack of data collection funding, rely on aggregated data and in worst case as an example [122], had to analyze Ebola from thematic analysis of critiques and rebuttals in digital news. Informatics systems designed for settings with no EMR are scarce, which indicates a gap in Public Health Informatics uptake between the high-income and low-to-middle income countries (LMIC).

2.4 Role of DHMTs and entitlement to Informatics Capacity building

While the DHMTs are the center of Public health Management in any decentralized health system Zanzibar, compared to most countries has the least team composition as per WHO definition with just basic positions. These six are prescribed with high technical responsibilities as per policy but in reality they are entrusted with very minimal tasks.

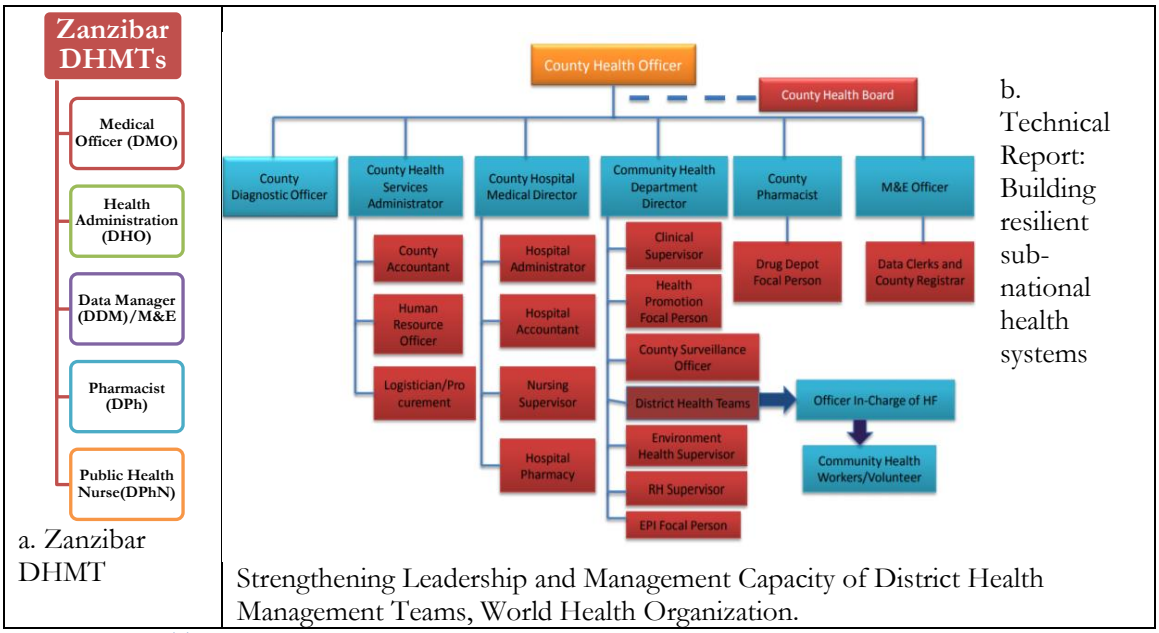


Figure 2.7 DHMTs Composition compared to WHO recommendations

The HIS benefit to community is impossible without fully utilizing the District Health Management Teams (DHMTs). It is nearly 30 years since the journey of decentralization started and several countries have had their experiences in establishing the DHMTs. In Tanzania like many other developing countries the decentralization process was initiated in 1982- 1984 through the Local Government Legislation Act of 1982 [123, 124], followed by Kenya in 1983 [125], and India during early 1990s. The DHMTs have roles official to their appointment but the challenges to release power from the national level to the districts have led them to be underutilized strive in the field with limited skills, funds and resources. Developing countries are depending on these district teams to manage health in the communities, while public health at national level is looking down at these teams only for data collection, answer population health queries and lead way in emergency and routine health.

The District Health management teams were introduced following the need to decentralize health care delivery from the national level to the districts in the early 1980s. After the Harare Declaration in 1987, it was decided that Public Health Management will be managed by decentralization models through the District Management Teams (DHMTS) Many developing countries joined the initiatives

and DHMTs were formed with almost similar titles and positions (Fig 1). There has been variation in growth, transference, delivery capacities, and countries' maturity in how this decentralization deems successful. There is a need to assess DHMTs capacities and compare the role and responsibilities assigned to them versus the resources allocated for assignment at hand. The following is a literature review to determine the pertinence of delegating the DHMTs the role for leading the integrated HIS and public health informatics in developing countries according to different researches on DHMTs capacity to carry out their responsibilities and their role in using information for health delivery.

Country	Tanzania	**[126-129] [130] [131]**
	Ghana	[128, 131-135]
	Uganda	[128, 131, 136, 137]
	Kenya	[138-140]
	Morocco	[38]
	Ethiopia, India	[141]
	Nigeria	[142]
	Malawi	[127]
	Zambia	[143], [45] [144]
	Niger	[44]
	Sierra Leone	[145]
	Pakistan	[146]
	Gambia	[147],
Study type	Situational Analysis	[44, 45, 126, 131]
	Evaluation	[19, 132]
	Comparative study	[136]
	Cross-sectional Study	[138, 139]
	Literature Review	[38, 148]
	Survey	[127, 133, 135, 141, 142, 144, 146, 149, 150]
	Critical analysis	[39, 151]
	Participatory solving	[147]
	Action Research	[128, 152]
Themes	Administration/Management	[126, 133-135, 144, 146, 147]
	Health Delivery	[126, 132, 150]
	Health Management	[19, 143, 144, 152, 153]
	Supervision	[127, 132]
	Decision Making	[136, 141]

	Capacity Building	[128, 131, 138]
	Financing	[142, 148]
	Communication	[129]
	Information use	[141]
Roles	Community Health Delivery	[132, 134, 138]
	Supportive Supervision	[132, 137, 143]
	Decision Makers	[18, 136, 152, 154]
	Key Informants	[131, 133, 139, 141, 144, 146, 148-150],
	Subjects	[128, 131] [135]
	Planners	[142]

Table 2.1 DHMTs Studies conducted in Developing Countries

Findings:

The findings for this analysis were categorized in the different themes. These include Administration and Management, Interventions Involvement and Research, Financing, Decision Making, Health Delivery, Information Use, Informatics and Innovation, and Capacity Building.

Administration /Management	Facilitative Supervision is crucial in managing PHC officers esp. in rural areas **[132]**
	Strengthening teams with personnel, skills, funds and delegating authority can lead into efficient management practices and stronger health system performance. [133]
	Shortages of staff, conflicting responsibilities and lack of finances impede supervision [127]
	Greater devolution of project management to the district level, and better management of resources would have resulted in more effective and efficient implementation [39, 125, 146, 155-157]
	IDSR implementation structure, with clearly defined goals and measurable indicators. Dedicated disease surveillance positions, epidemic preparedness committees, and rapid response teams; national to district levels, Challenge include inadequately trained human resources, lack of optimal technical support to the DHMTs and health facilities, poor infrastructure and coordination challenges [143, 158-163]
	Surveillance package built for communities developed to be used by DHMTs as an operational tool [161, 164]
	EmOC requires multiple partners approach where roles and responsibilities well stipulated in a framework within the district health system, there was improved delivery outcomes: Number of facility deliveries, Number ambulance trips and training to providers [150]
	The district is considered the key level of managing public health [134]
	Decentralization is derailed by inadequate funds, lack of qualified personnel, inadequate logistics and equipment, poor interpersonal relationships, lack of

	transparency and a good operational system, lack of incentives to motivate the staff, political interference, poor infrastructure and high rate of illiteracy. [135]
	Sectorial collaboration, creation of new posts at sub-district level for close monitoring and supervision, and greater financial autonomy to prioritize according to needs. The reported weaknesses included lack of team work, limited autonomy, and lack of capacity, nepotism and poor accountability [146].
	The tool was deployed to improves the timeliness and ease of using data for DHMT decisions making [152]
Capacity Building	implementation of policy guidelines for integrating community-based health workers in the health system may not automatically guarantee successful integration at the local or district level, at least at the start of the process [144]
	Low immunization Coverage may be linked to inadequate staff at DHMTS with poor data management
	Health Outcomes is a direct result of managerial and leadership functions (Belrhiti, 2016)
	There are differences in Formal and Informal institutions and financing practices that emerged as the outcome of the 'bargaining' process between the local health actors [148]
	inadequately trained human resources, lack of provision of optimal technical support to the DHMTs and health facilities, poor infrastructure and coordination challenges [143]
	Competing reporting requirements; Lack of standards for data entry; Lack of structure and security for data sharing; Siloed data; Timeliness and quality of data for making decisions; Skills in the health management workforce; [165]
	the system aided decision making for operational tasks, and reduced the time taken to analyze and report surveillance data [19]
Financing	There are differences in Formal and Informal institutions and financing practices that emerged as the outcome of the 'bargaining' process between the local health actors [148]
	DHMTs were able to produce more robust annual work plans with systematic approach of using district-specific evidence. Prioritized activities in the annual work plans were evidence based: Procurement and logistics, training, and support supervision activities [166]. Between 4% and 5.5% of the total planned expenditure was for child survival, while 47% to 94% of the budget was from donor and other partner contributions
Decision Making	DHMTs need power, authority and control over resources [136]
Health Delivery	
	DHMTS use district action research and education with no extra resources. The process strengthened the capacities of the DHMTs with positive problem-solving attitudes [126].
	roles and responsibilities well stipulated in a framework within the district health system, there was improved delivery outcomes: #facility deliveries, # ambulance trips and training to providers [150]
	DHMTs have insufficient management skills or resources to effectively implement the health programs. Training and coaching, integrated district planning processes, and decentralized allocation of resources are essential, implementation research and district-to-district learning will facilitate strategies and enable local solutions [167].

Information Use	due to the availability of more data at the district level than at regional, state and national levels in both countries, existing district health data has the potential to shape national policies [141]
	There is lack of adequate knowledge and information exchange capacities among the health providers and the ability to share that information with the targeted community [129, 149]
	Districts lack autonomy, and funding to prioritize based on evidence based needs [166]
Capacity Building	DHMT are under trained and ill-equipped to manage the complicated programs needed to maximize delivery of services [138]
	Action Research can build DHMTs capacities [128]
	Through action research DHMTs can integrate the project tasks within their routine work and duties and determine which outcomes can be measured [131]

Table 2.2 Themes around DHMTs research.

2.4.1 Administration and Management as the Basic Role DHMTs

The district is considered the key level in health management where functions allocated for the teams among others include, serving as the basic unit for planning, budgeting, evaluating health work, training and supervising health workers within the district [134] administration, and management issues are vital to DHMT since "management" is their primary role in the district health especially in planning and coordination [147]. They cannot be the "District Health Management Teams" if they are lacking management and administrative skills; undermining the whole point for decentralization. [135] assessed the challenges to decentralization in Ghana which is a comprehensive list cross cutting to most DHMTs as; high rate of illiteracy and lack of qualified personnel, inadequate funds, equipment logistics, and incentives to motivate the staff, lack of transparency and/or a good operational system, political interference, poor interpersonal skills and infrastructure [135].

The core message in this literature is that decentralization alone and allocating the functional responsibility is not yet sufficient if DHMTs are not strengthened with management capacity from personnel, tools and systems' perspective and methodological packages localized for DHMTs' tools for operations [137]. For efficiency and effectiveness of these district managers, it has been found in Ghana that the DHMTs have to be equipped with the appropriate personnel, adequate skills, available funds and delegating authority which lead into efficient management practices and stronger health system performance [133].

Another Ghanaian study evaluated specifically the supervisory visits conducted to the Primary Health Care Units (PHCUs) and reported having facilitative supervision and creating strong management linkages with PHCUs is crucial in DHMTs Performance especially in rural areas [132]. However, due to staff shortages, conflicting responsibilities and lack of finances, quality and extent of this supervision are impeded as seen in Malawi and Tanzania [127].

One innovative strategy to tackle shortage of workforce was carried out in Zambia [144] where Community Health Assistants (CHAs) were integrated into the health system at district level, which is a start even it may not automatically guarantee successful integration.

2.4.2 Informatics and Management tools support to DHMTs

In implementing the integrated Disease Surveillance and Response (IDSR) strategy in Zambia, the research team managed to develop operationalized response and epidemic preparedness from National to district levels, even with the reported challenges like inadequate trained human resources, poor infrastructure and coordination limitations [143]. In Uganda, a surveillance package was developed for DHMTs as an operational tool to facilitate rapid surveys in support of district health information systems [137], whereas in Tanzanian DHMTs have been introduced to the Emergency Obstetric Care (EmOC) tool served as a tool for rural district health managers utilizing multiple partners in a framework administered at district level [150].

Consequently, sustaining these systems is going to face the challenges facing the DHMTs in LMIC including inadequate funds, lack of qualified personnel, inadequate logistics and equipment, poor interpersonal relationships, lack of transparency and a good operational system, lack of incentives to motivate the staff, political interference, poor infrastructure and high rate of illiteracy. Most recommendations cross cuttingly urge national organs to grant autonomy to the DHMTs in management and resource utilization (especially funding and power to utilize them).

2.4.3 Power devolution to DHMTs

In studying "devolution in district health system" a needed reform in Pakistan highlighted the importance of sectorial collaboration, creation of new posts at sub-district level for close monitoring and supervision, and greater financial autonomy to prioritize according to corresponding needs [146]. Devolution is needed to ensure good governance and sustainability at National and District level, to result into effective and efficient project implementation. The autonomy hereby anticipated can still be derailed by lack of team-work within the DHMTs, lack of capacity, nepotism in this case of Pakistan, and poor accountability [39, 146]

2.4.4 Decision Making autonomy and Capacity

Health reforms and decentralization have shifted responsibility for health delivery and service management to districts, mostly without commendable authority nor resources [167] Lack of autonomy in decision making is putting the DHMTs in a difficult operational position since the management responsibilities assigned to them require a significant level of decision-making power to effectively, systems to utilize information and customize its use to their districts, prioritize options, pick decisions and efficiently execute them [166, 168]. DHMTs need to have power and authority necessary to exercise control over their situations and resources [136]. With adequate decision-making, districts are more able to conduct evidence-based planning which into more robust district annual health work plans, with evident prioritization of activities and planned expenditure [154].

The information we learn as seen in Pakistan with devolution is that, before we actually attain the desired autonomy to make these decisions, there has to be not only financial autonomy to prioritize the needs but decision-making capacity among the DHMT staff. To fill this gap, decision support tools [18, 152], have to be adopted throughout the limited resource settings for DHMTs operation which not only build capacity but alleviate the other resource challenges that almost all DHMTs face.

Similarly, before countries engage to develop a decision-making application, decision making environment has to be conducive especially with the issues of timeliness and quality of data for

making decisions; standards, structures and skills in the health management workforce [152]. With information system we propose to adopt in Tanzania, it is very unfortunate, to date, there are no decision making guidelines to guide these informatics designs and standardized the operations and procedures as per countries policies, benchmarks and policies, and there is no regulatory authority to guide these implementations [24, 48]

Accountability is researched to help DHMTs make effective prioritization on decision making. In Tanzania all stakeholders involved in Accountability for Reasonableness (A4R) intervention reported it as an important and feasible approach for improving priority-setting and health service delivery in their context [169]. At the same time in Ghana, public accountability was found to be totally missing through lack of communication channels and participation of the public in priorities setting and assessment of their performance [170].

2.4.5 Financial provision and utilization

Lack of autonomy not only suffocates DHMTs in operational decision making, but also in financial decision making. DHMTs have limited power on allocation and prioritization of activities, but also utilization from disbursement to actual expenditures, which is a needed reform for devolution [146]. This is stunting decentralization since with limited finances there comes inadequate funds to activities, lack of qualified personnel, inadequate logistics and equipment, and even lack of incentives to motivate the staff [135] and according to Tarimo the whole idea of decentralization will become impossible [123]. Shortages of funds will impact especially activities that involve logistics aligned to the health officers like supportive supervision [127], and it is recommended that strengthening DHMTs with funds and delegating authority can result in efficient management practices and hence stronger health systems' performance [133].

Districts have ended up shaping the incentives received from working with NGOs like in the case three districts in Sierra Leone [148], notable differences have been seen. It has been studied in this instance, that the emerging formal and informal institutions' financing practices is the outcome of the

'bargaining' process between the districts' health actors and NGOs which resulted in discrepancies from one district to another in shaping health worker incentives.

One methodology that has linked performance to financial provisions and in this case incentives are the financed based performance, where apart from the traditional remuneration, officers were incentivized based on their individual performances. It has been applied in Rwanda after successes in low-income Asian countries showing it can improve health service and redistribute roles within the health district in a more transparent and efficient manner. However, this comes with a precondition for the success that authorities grant autonomy on health facilities competing for subsidies [171].

The challenge to financial autonomy, the case for most DHMTs, is lack of planning and budgeting capacity among the DHMTs. For instance Nnaji finds that in Nigeria, constraining financial decision making capacity is not just through their skills, but also the inadequate Health Management Information System (HMIS), a non-functional financial Management System (FIMS) and an unreliable Human Resources Management System (HRMS) [142]

2.4.6 Health Delivery

DHMTs are responsible for management of primary health care. The districts' insufficient skills or resources eventually affect delivery [167]. This is an area that seems less of the challenge compared to administrative and management challenges due the will of the DHMTs to perform even in the limited resource setting [44]. Nations need to determine to tackle capacity issues, at the same time DHMTs need to integrate the project tasks within their routine work and duties [39, 131].

It is hoped that best outputs at district level are best achieved when they are well integrated within their communities through the health workers in the district [143]. While that holds a promise of evidence-based management, implementation of policy guidelines that direct community-based integration with the health workers in the health system may not directly guarantee required integration at district level [172].

2.4.7 Information Use in Health Delivery

Information use is directly an issue of capacity not just of the respective DHMTs but maturity of the country in Information to shape national policy. This has been found in Tanzania where there is a lack of knowledge and information exchange capacities among the health providers and lack in ability to share with the community [149]. On the other hand, due to the availability and creation of more data where more than 60% of the data is collected at district health, the already existing district health data has the potential to guide district decision-making enforce them directly to health delivery in each corresponding district, and help shape national policies [141].

Only when workforce capacity, systems enhanced and available quality data is used to make community, district and national level decisions, is when we can be in a matured position to better utilize what called an adequate use in HMIS, financial management and human resources [142]. Uganda has demonstrated good decision making with health planning intervention where half of the prioritized activities in the annual work plans were evidence based, for instance procurement, training, and support supervision activities were the most prioritized activities, ironically, found 5% of the total planned expenditure was for child survival, which carried 47% to 94% from donor contributions [170].

In Sierra Leone, while designing a web-based decision support tool for disease surveillance at the district level, barriers for information use found were lack of skills in the health management workforce; lack of structure and security for data sharing, lack of data entry standards, competing reporting requirements, silo data and issues tied to timeliness and quality of data for making decisions [19, 145]. With all these challenges however the system still managed to be implemented [19] which resulted into system-aided decision making used for operational tasks, and more importantly improved the time taken to analyze and report surveillance data. Findings from Kenya, [139] shows District Health systems are suffering from numerous designs constituting operational, resources and

managerial problems, a kind of situation which call upon an urgent need to computerize existing manual systems and use microcomputers for the DHIMTs.

2.4.8 DHMTs Capacities and Impact on Health Management

Most DHMTs are found with gaps for capacity. In an immunization intervention to improve coverage in Kenya, the project embedded an objective of studying the capacities of the DHMTs administering the immunization coverage. It was found that low immunization coverage may be linked to limited capacities of the DHMTs which are under trained and ill-equipped to manage complicated programmed needed to maximize services delivery [138].

Zambia efforts for implementing an IDSR

was challenged by capacity with inadequately trained workforce and lack of optimized technical support to the DHMTs [143]. So far it is clear need design specific management trainings in district settings and coaching [167], for instance the integrated district planning intervention conducted in Uganda and the AR [154] were found to be essential for effective management. In effort to build capacity a management strengthening intervention (MSI) conducted in Tanzania, Uganda and Ghana using an action research approach [167] tested in nine districts, it was found to be an adequate methodology of management strengthening for DHMTs and performance improvement [128, 131].

2.5 Community Extension and Role of Tacit Knowledge

Lastly, in this literature review, we look at the role of tacit knowledge and the contribution extensions offer to foster linkages between research findings, application and outputs delivery into the communities. Tacit knowledge has been described as the knowledge acquired through practice and experience rather than through language, and difficult to communicate, related to individual skills while embedded in context, inseparable from explicit knowledge. It carries the same meaning as "*skills, intuition, know-how, procedural knowledge, implicit knowledge, unarticulated knowledge, and practical or experiential knowledge"* Whereas Explicit knowledge is knowledge that can be easily documented, shaped, created, written down, transferred and followed [173]. Tacit knowledge is common is Public

health due to dependence of working with the community like prioritizing implementation challenges in existing maternal health programs [174]. It has been used to plan public health programs and working them out in partnering and funding[173]. Extension as a concept, roots from the context that a community is more than just a socio-political entity, but a deeper common identity and culture binding people together. Specifically, it is a "*rich interplay of the collective/social history of a place, the geographic or natural history of a place, the values that people share, and the ways that people live, work, and play together*" [175]. Extension may be a new concept being introduced to Zanzibar, Tanzania that this work gets to transfer its benefits, but in the United States for the last century, communities have been implementing findings from research and academic institutions to the general population where application is intended to. With the emerge of Cooperative Extensions (CE) in 1914 as agriculturists and farmers built relationships with governments and universities, and fostered innovations transfer between experts and communities [176]. It is found in Ethiopia where evidence is seen from the effect on thinking but also practices of rural people on disease prevention, family health, hygiene and environmental sanitation. it is reported that due to this community engagement Ethiopia increased primary health care coverage from 76.9% in 2005 to 90% in 2010 [177].

It is when deliberate cooperative extension or programs have built strong partnerships, shape outreach, health promotion and research to shape community needs since "community members are cultural experts – they know what will work and what will not in their own communities" in the entire spectrum of the activity from the problem, designing and implementing the intervention to impact [176]. This is the tacit knowledge we are looking to complement in achieving the desired outcomes. There is knowledge created when working with the communities in what Bowling and Brahm assumed to be indeterminate systems capable of becoming more that what capacities they portray at the moment of engagement and may guide how they evolve, and how they shape what is possible of their communities through their (Tacit) knowledge about themselves, their history, community, and the world around them; for example, discovering what is best for them, dreaming about what might be, designing an Ideal future and delivering actions [175].

Chapter 3. Research Methodology

The methodology for this research is built around two overarching needs for the current status of the Zanzibar HIS and growth of Informatics in general.

1. The need for quality health data for decision making and planning, and
2. The need for web-based analytical software for middle level use and feedback.

The current situation that this research is trying to address is summarized in Figure 3.1.

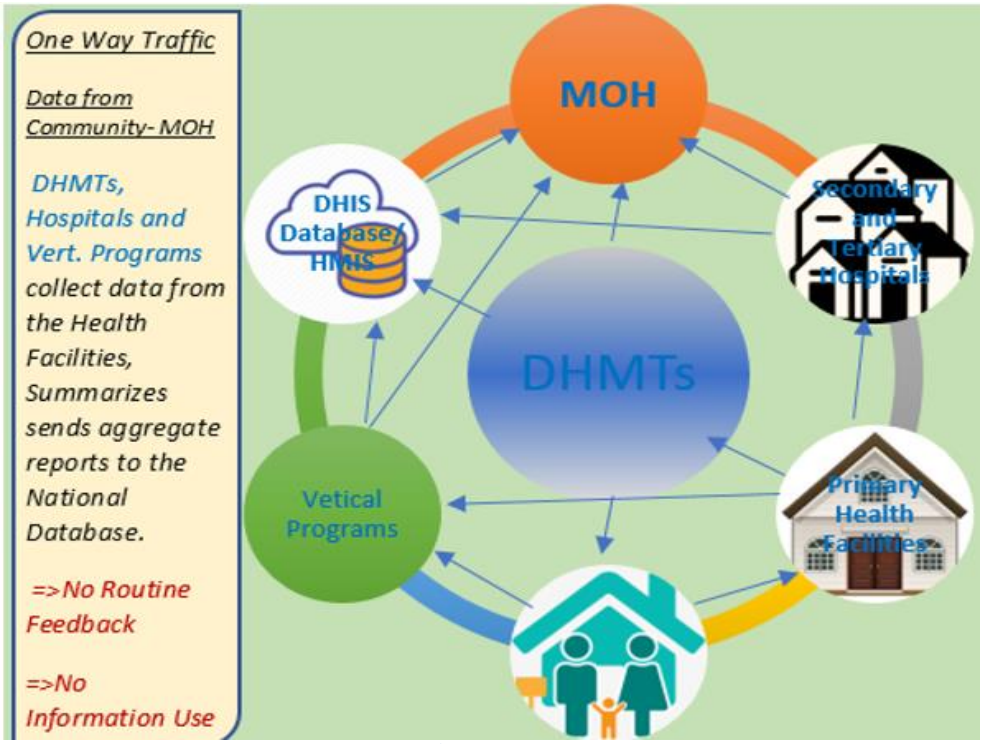


Figure 3.1 Current Information Flow in the Zanzibar Decentralized Health System

The faded blue in the DHMT reflect the underutilized DHMTs within the health systems, where for a long time the perception was to use the teams as mere administrative support of the Ministry and vertical programs at district level; rather than co-exist in varied and dependable core responsibilities in the ecosystem. The Ministry of health recent decentralization reform needs to be supported with health informatics research and projects like in this research to equip the teams to manage the populations adequately.

3.1 Interventions

This research designed a PHI Intervention using a three-pronged approach.

- Intervention 1: Improving Quality Data Availability for Use
- Intervention 2: Statistical Software Development
- Intervention 3: Informatics Capacity Building for DHMTs

3.1.1 Intervention 1: Improving Quality Data Availability for Use

Improving quality-data availability for use, by restoring "morbidity location" in the HMIS data before from the facility registers. The importance of this first intervention is generation of disease indicators by shehia and SES which cannot be currently performed without shehia being in the dataset. The method utilized was scanning the HMIS registers in health facilities and performing a manual data entry into an MS Access Database written for this phase. The objective of this intervention is generation of epidemiological measures by shehia and SES to use with the DHMTs in training them evidence based planning and decision making. To obtain that we designed the following activities:

1) Survey HMIS registers to obtain incidence and residence information by Shehia.

2) Concatenate/link information from HMIS registers with Census.

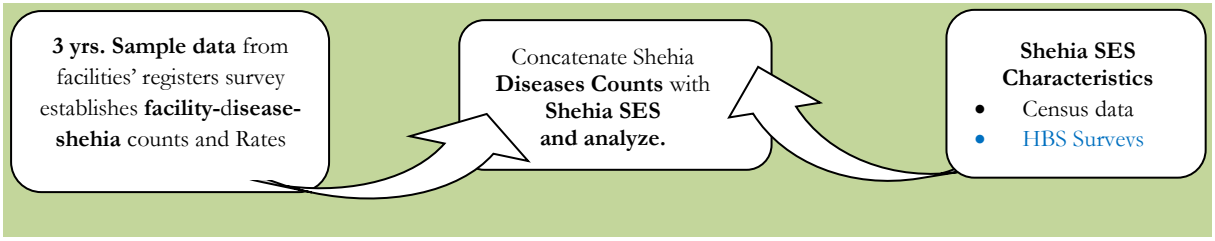


Figure 3.2 Concatenating HMIS Data with Census 2012

The rationale is that linking morbidities to origins will enable Zanzibar to have community-based estimates of diseases for the 236 shehia units; which will help Zanzibar overcome its big challenge of Community Health Information system (CHIS), hence the proposed name Z-CHIS. Current efforts seen in the literature review are directed towards programming new applications to collect information from the community, which is useful but threats quality and expensive to implement and sustain. SES characteristics are analyzed along area based mean rates and counts for each

corresponding shehia which is the unit of analysis. Concatenation combines diseases and SES datasets (see Figure 3), making it possible to generate shehia-specific counts and rates of diseases.

HMIS Register from the Health Facility

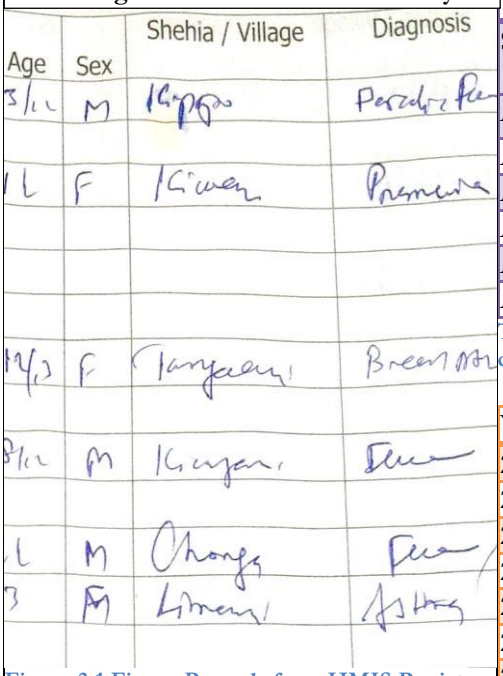


Figure 3.1 Figure Records from HMIS Registers

	Diarrhea				Pneumonia				URTI					
Shehia	**Adult**		**Child**		**Adult**		**Child**		**Adult**		**Child**		**MM**	**YY**
	B	**G**	**F**	**M**	**B**	**G**	**F**	**M**	**B**	**G**	**F**	**M**		
Amani	2	4		1	5	7			28	54			Jan	2011
Amani	5	3	3		3	6	1		27	19	2		Feb	2012
Amani	3	4			4	5			20	24	2		Mar	2013
Amani	2	2			5	3			43	31	1	4	Apr	2011
Amani	3	7			4	2			14	13	2	1	May	2012
Amani	2	1			0	1			45	35		1	June	2013

Table 3.2 Data Entry from Health Facility to Access Database to capture "Shehia", keeping Health Facility

Yr.	**Month**	**Shehia**	**Tot**	**Male**	**Fem**	**SES1**	**PriM**
2011	Oct	Amani	5548	2579	2969	2158	1068
2013	Dec	Amani	5548	2579	2969	2158	1068
2013	Febr	Amani	5548	2579	2969	2158	1068
2013	Jan	Amani	5548	2579	2969	2158	1068
2013	July	Amani	5548	2579	2969	2158	1068
2013	June	Amani	5548	2579	2969	2158	1068
2013	March	Amani	5548	2579	2969	2158	1068

Table 3.3 Data Joining from Access Data Base to MySQL with Census SES Indicators using "Shehia"

Data Entry from Scanned documents to Access database using digitized HMIS Forms which according to the register Includes: Date, Name, Age, Sex Shehia, Diagnosis, Test, Treatment, Tel. We Captured: Month, Year, Facility Name, Diagnosis, Age(Adult/Child<5), Sex (M/F) Shehia

Facility visits were conducted to three districts out of ten to scan the patient registers (patients age <5) for the three most recent years, 2011, 2012, and 2013. These districts are in urban settings, hence having a network of two or more facilities per shehia unit. Due to urban infrastructure (Annex 1), estimating community-based incidence from the current DHIS data with no shehia information become impossible since patients coming from multiple shehias or changing providers from time to time tend to visit multiple facilities and could be counted twice. This research enables tracking each case from the shehia it originated from. In absence of Electronic Health records, the only information available to capture the morbidity location lies in the paper registers. This requires a

registers' survey of the multiple facilities to record patients encounters and their respective communities. Unfortunately, the HMIS Zanzibar has not established Patient Identification Number (PIN) to cater for tracking patients moving from one health facilities to another.

The total disease counts from each health facility by shehia per month were divided by the shehia population to estimate shehias' morbidity counts and rates (Table 3.1). Summing the counts across shehias allows for calculations of counts and rates across district. Presentation of shehia-specific disease morbidity rates by SES provides a better understanding of the burden of disease in a shehia or district and informs intervention. Currently HMIS Data aggregates the disease counts by facility which is still useful in planning for facilities, personnel but not in disease prevention interventions where origin of the morbidity is key. The scanning of HMIS paper registers used apple smart phones and the scanned documents were archived and later on each record was entered into access database. Three diseases were captured, pneumonia, URTI and diarrheal diseases with the shehia from which they came. This dataset led to a table which estimates facilities' proportion of a specific disease population from a specific shehia. While data entry was done by entering records from each health facility capturing shehia per record, a new table was produced with summation of all incidence counts across all health facilities per each shehia. Hence each record is a Shehia morbidity count (or rate after deviding by shehia population), aggregated by Type (Pneumonia, Diarhea and URTI), age category (adult/child), Sex (Male/ Female) and aggregated by month year. The table produced represents facility's population distribution by shehia that report diseases (i.e., if 15 cases of diarrhea are reported at facility X, two can be traced from shehia A, and seven from shehia B, and so on, and i month and year reported). In this way, facility-based data has been transformed into shehia-based as originated, thus into rates of total cases of each disease from specific shehia. This task should serve as a "wake-up call" to the Ministry of health to the need for electronic medical records, or other patient tracking mechanism which will finely collect disease and population information simultaneously, which currently we have no record of apart from the HMIS paper registers.

3.1.2 Intervention 2: Statistical Software Development

Improve *access* and *comfort-ability* of analysis through statistical software and a web portal for data access. The importance of this intervention phase to engage in analyzing information rather than depending on descriptive excel-based summary reports. This enables them to use evidence directly to manage health populations with statistical confidence. The objective is to build the public health informatics capacity for Zanzibar's public health system and personnel through basic statistical and software design. Action Research methodology was used to co-design an online analytical system.. The challenge that leads to this intervention is the scarcity of statisticians and the skills among the vast majority of Zanzibar public health personnel. We broke the intervention into the following:

- Prototype Design
- User requirements collection
- Data Preparation
- System Design and Implementation
- System Usability and Assessment

3.1.2.1 Prototype Design

Providing an online software tool that addresses this need (Annex 2) can simplify statistical analysis for novice users and obtain nearly the same results as manual and repetitive analysis. This tool will primarily use the data obtained from the HMIS registers' surveys. Zanzibar's DHMTs will now have analysis systems and skills that will improve data use. Sharing the analysis reports will increase public health knowledge and awareness, promote a sharing culture, and develop informatics skills. Projects using R in graphic user interface (GUI) are currently being criticized due to a potential drawback oft R command line interface. These projects range from the earlier projects like SNetscape, Rserve, Webbased and R Commander, SciViews-R, (intuitive GUI) [178] to the more recent like R-GIS and R-PHP which was a project for teaching purposes [179] that uses PHP scripting to represent R. This

work inspired this research, since we indeed need it for teaching purpose and capacity building to the Zanzibar Public health workforce.

Statistical package R with PHP programming language was used to design the online statistical software. Emphasis was given to simplicity, user-friendliness and accessibility so as to minimize potential negative perceptions of the new users in limited resource settings.

Using adequate data collection methods identified in the literature, University Statistical lectures consultations and statistical officers from the Office of Chief Government Statisticians (OCGS), seven types of statistical analysis were chosen: (Annex 2).

Descriptive statistics:

Statistical tests: Two sample T test, Chi Square test,

Statistical analyses: Poisson Regression and ANOVA

Simulations were conducted with select DHMTs to understand what they need to know to plan intervention and how HMIS data can be used for it. This also helped to balance level of complexity of the tasks to be performed by the user on the computer. The same commands that users and researcher jointly simulated to get to a statistical report; statistical analysis using PHP scripting was coded in the software. Users can see the whole list of variables and types of analysis from which to select (Annex 3). Users shall select datasets to analysis varying in space, time and the outcomes of the recorded incidences, Also users can filter the dataset to gender and age groups categories. Results are available to print or save on the desktop for reuse purposes. The system records user logs which can be analyzed by the nature of user activity, the outputs and length of activity operation in minutes.

Programming the software: Integrating R and PHP aims at arriving at the same basic functionalities that a SAS or SPSS user needs without having to conduct statistical programming (Fig 3.4). These include being able to input data, use the data available in the libraries, perform multiple tests, create and print output reports, and draw conclusions with a measure of statistical significance and

confidence level. The difference between such packages is that, first, this tool is free, and second, it is customized to the underlying datasets based on the nature of HMIS data and the needs of the DHMTs, making it easy to simply 'click' and get the variables needed for their routine analysis. The first step was for the researcher to document the R codes required to run the statistical analysis. A detailed specification of operations was designed depicting from the descriptive analysis, statistical tests, statistical analysis, GIS, sharing reports, groups discussions and exportation of reports. After simulation of manual analysis with the DHMTS, the R Codes were then handed over to the programmers for interface design using PHP to communicate R commands and different users. The interface captures the input and executes back-end R pre-programmed functions. PHP works to capture plots that R produces and will then be temporarily available for the current users' session.

```
<?php // PHP code
 echo "<form action='poorman.php' method='get'>";
echo "Number values to generate: <input type='text' name='N' />";
echo "<input type='submit' />";
echo "</form>";
 if(isset($_GET['N']))
$N = $_GET['N'];
   // execute R script from shell
// this will save a plot at temp.png to the filesystem
  exec("Rscript my_rscript.R $N");
// return image tag
  $nocache = rand();
  echo("<img src='temp.png?$nocache' />");
?>
 //R script… You can input any R code here and it will give you the
result.
# my_rscript.R
args<- commandArgs(TRUE)
N <- args[1]   x <- rnorm(N,0,1)
png(filename="temp.png", width=500, height=500)
hist(x, col="lightblue")
dev.off()
```

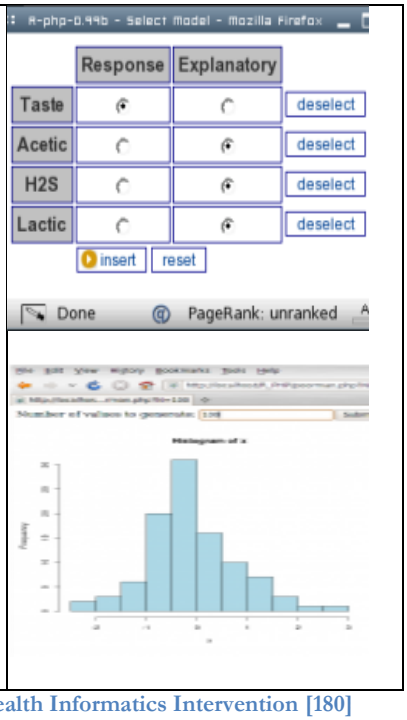


Figure 3.3 Application of R-PHP for teaching purposes to the Public Health Informatics Intervention [180]

All users of the system were pre-identified, while their profile information was saved in a MySQL database for support and research purposes. After the statistical analysis, users will be able to initiate a discussion. All users can participate the discussion depending on whether the report was set to be local to that district alone or global to all system users. After programming the trial prototype and

conducting the tests, it was presented to the Ministry of Health to be granted ethical clearance to start the research and developing the Information system along with the users

3.1.2.2 User Requirements

Requirements analysis was a vital step in aligning the system design and consensus of objectives. Focus group discussion were carried out in different levels of system users separately, from Health Information Systems (HIS), Health Management Information systems (HMIS) and the (DHMTs). In general, the users required a visualization of diseases and community SES indicators, predictive analysis of disease outcomes, disease-SES determinants and disease dispersion per community clusters (census tracts) quantified and reported in geographical maps.

3.1.2.2.1 Health Management Information Systems Unit

The first focus group discussion was conducted with the national team for HMIS where the concerns were: a) the data collected needs primary and secondary analysis, b) the data is aggregated and loses location attribute of the incidents hence their understanding ends at facility where the case has been reported, and c) The DHIS conducts summary statistics alone. More programming could be designed to produce advanced statistics for inferences. In order to accomplish these, data already collected in the DHIS from 2005-to date could not be used to support the desired outputs of the HMIS. This Project collected sample data to analyze secondary and spatial data available.

3.1.2.2.2 Health Information Systems

The Health Information System (HIS) unit was established to integrate information management for policy from the HMIS Unit, DHMTs, Epidemiology Unit, and Vital Statistics office. HIS had an objective to design a data warehouse that will pull data from census, demographic surveys, DHIS, and Vital statistics, to enable secondary data analysis for decision making and informing policy. No system has been developed that incorporates any of these integrations and DHIS aggregated data is posing a challenging situation for HIS to use it effectively along other national data sets offering some information on population health and social determinants to health.

3.1.2.2.3 DHMTs

While DHMTs have just been decentralized, no plans have been laid out yet concerning their use of DHIS data for Epidemiology, planning and making decisions that support their daily operations. There is no training plan concerning statistical data analysis to be conducted at district level, and informatics tools for conducting such analysis. DHMTs desperately need information systems with all information that will support their data analysis and support evidence-based operations, plans, interventions, budgeting, decision making and informing policy makers. How much disbursement differs from district to another very much should depend on the size of populations they serve, the type of disease burdens they carry and the interventions needed to manage them. DHMTs reported the need for informatics training supported by analytical tools that makes it easy for them to access and use the right information at the right time. For instance, the DHMTs have been conducting time series graphs showing diseases outcomes with months and seasons, but this information was based on facility counts and not the community the diseases are coming from. Hence the system will best serve their needs if it can depict trends in diseases at lower geographical level of incidence location, and time (seasonality) which will help them in preparedness to manage population health.

In this research a pre-and-post intervention survey was conducted to assess their epidemiologic and Informatics skills and capacities. This questionnaire tool was adapted from the American Council of State and Territorial Epidemiologists (CSTE) Epidemiology Capacity Assessments (ECAs) and results will be shared in the next publication. Adoption of new systems requires Pre- and post-interventional study which is important in assessing technological uptake and achievement of results. For instance, Lau, 2019, used a randomized control trial to test to assess effectiveness and promote safe usage among youth.

3.1.2.3 Data Preparation

The data collected in the intervention one (above) was migrated from Access Database which supported data entry to an Online MySQL Database which will be used in the rest of the research to produce online analytical reports. A total of 101,000 disease records were entered in the Access

database, ensuring location of disease incidence was recorded. The street addresses were mapped to the census tracts they belonged to (shehia) using standardized query language (SQL). Other queries ran were for aggregating datasets now based on Shehia to allow a table joint with Socio economic data sets like the census. Census data supplied the system with SES variables at shehia level (not publicly available). The 2012 census still is the latest conducted being the sole reason for the disease records collected to be of just 2011-2013. The other options for these datasets joining step were to include Demographic Health Survey (DHS) and the House Hold Surveys (HHS). These had to be removed due to lack of total shehia coverage. It was realized that the surveys utilize Enumeration areas (EA) which is a different stratification method compared to what the nature of this research requires. It is anticipated however, with proper statistical methods and projections the two datasets will be needed to provide intra-Census variability of the data, and support time series analysis.

3.1.2.4 System Design

Analyzing and Mapping of disease occurrence was thought to be an important edition since all DHMTS are well connected and work with their communities. Unfortunately, for more than 10 years these teams were only aware of the health facilities that the diseases are reported to, and had to dig in the registers when there was a surveillance need. Having to see where the cases are coming from is important evidence that will help the DHMTs conduct better epidemiological assessment and interventions. A statistical framework for the systems was proposed as follows

a) Descriptive statistics for disease per shehia by gender, age or months
b) Statistical tests of correlations, to enable hypothesis formulation
c) Regression analysis, to study determinants of health and outcomes in the population
d) Analysis of variance to allow more categorical analysis in the system
e) GIS reports, to generate clusters of communities within a region and select disease and SES reports to study how health disparities are associated in SES in the communities.

Since the core objective of this system is to give free access to statistical analysis software to developing countries to enable real time analysis to public health information the following integrations were important:

1. Access to a free statistical software, in which case R and/or Python were the best choice to suit this purpose since not only for being free, but they offer comprehensive programming environment, packages and extensions that can be portable to integrate to other scripting language for users interfacing compared to SAS, SPSS, STATA etc.
2. A scripting interface that can run statistics and capture output. It was agreed among the ITs that PHP is the best environment to integrate both the statistical software and the database that will carry the data to be used and capture outputs of the analysis
3. An open source database MySQL was chosen for its interoperability to DHIS2 but also to most other systems being developed for example the recent proposed HER.
4. An open source and GIS software that can accept user queries and outputs maps of disease or SES dispersion at shehia level for informed planning and decision making.

After successfully loading the data from Access Database to MySQL database, the PHP was used to create the online platform. 80 users were created in the system, followed by operational aspects of the system starting from Visualization and dashboard, forums design, statistical analysis and the GIS. The online forum at its best tries to digitize the important process initiated by [4] hat achieved data quality assessment, analysis and interpretation, stimulus for integration, problem solving skills, teamwork, practical computer skills, and presentation skills but in a digital environment. If the major reason for decline of these series was funding, then ZCHIS introduce an online forum to continue what was started and hugely benefitted the staff and health sector at larger.

The R-PHP integration has been inspired by work conducted in University of Palermo [179] that integrated R via PHP for teaching purposes where R-PHP statistical software, used as an "engine" by point-and-click module to run statistical analysis by means of a graphical user interface (GUI). This is

important for first time R users and developing countries since to use this module it is not necessary for the user to know the R command line environment. The analysis was pre-programmed using R simplified codes to enable ease to first time statistics learners. It is believed that the levels of R statistical analysis will grow as the users advance their statistical interests within the data analysis track and information dependent culture. This alignment gives the opportunity of producing an application that uses free statistical and IT environments that can customize systems to meet local needs on information systems and knowledge management.

3.1.2.5 Systems Usability and Measurements

Immediately after successful testing and training, a questionnaire was filled to collect the view of the DHMT on the system. The users were then supported for use for six months. After this period, a post assessment was administered to those who received ZCHIS training in the mode of structured questionnaires (ECA). The system is also programmed with users' activity management that is aimed at collecting usability logs and types of logs such as log ins and outs, analysis activities, sharing statistic reports and contributing in discussions. These logs furthermore can be exported into excel for usability analysis. Future versions of this system should enable district administrators to output usability reports that are intended to motivate usability and performance.

3.1.2.5.1 Data Collection

A baseline survey was conducted to define the current situation of informatics skills and data use in performance improvement, planning, decision making, and reporting. Data collected in this survey will serve to evaluate public health officers' familiarity with and ease of use of statistical software and portal, their level of support and activities linked to health surveillance, and their self-reported use of public health data and its applications in decision making, planning and management of public health activities. The questionnaire was uploaded online using a paid service (surveymonkey.com) and the respondents filled them at their own convenience within a month set period. Phone calls were made at users' conveniences in events when more elaboration was needed. A paper questionnaire was made available to them to minimize time spent on their homes pre-paid internet. The same survey (same

questionnaire and methodology) was administered six months after baseline survey (i.e., six months after introduction of software, portal-based analysis, training and reporting of priority diseases in Zanzibar) to the same respondents with their original unique identifiers for post- intervention assessment. Change over the study time period in health data usage and application to practice.

3.1.3 Intervention 3: Informatics Capacity Building for DHMTs

This Intervention is aimed at improving informatics knowledge through on-the-job training and in classroom delivery of basic informatics and statistics training. The main objective is to build analytical and information dissemination capacity of DHMTs. Action Research has enabled the learning environment to be participatory and satisfactory. 5.a is training module that were delivered to the treatment group which was based on the ZCHIS software, co-developed by key DHMTs, and HMIS personnel. Activities that were designed for this intervention were classroom and on-job training.

3.1.3.1 Classroom Training

The researcher trained all DHMTs on the theory of the statistics to be performed by the software on the first week. The ZCHIS software training was given to the treatment group on the second week, the same time which the control group received excel based statistical analysis. This training was meant to build the informatics capacity [25] of the DHMTs so they use it for surveillance and learn to incorporate evidence-based decision making practices in their daily work.

3.1.3.2 On-job Training

After two weeks of formal training was given, on-the-job training visitation once in each district in six months was administered. During the training, users learned how to use the same data they collect, to conduct basic statistics, producing and interpreting reports, and sharing the reports in the dissemination web (or email for a control group) for others to query and discuss.

The training provided hands-on practice in the classroom and enables them to discuss reports and present findings. DHMTs gained skills in data analysis, reports interpretation, information cycle and management, and acquired knowledge essential to evidence-based decisions. On-the-job training

reminded the methods they learned, and helped them practice the similar things they managed to do in class. 5.b are the training modules delivered as excel data analyses. 5.c.i-v are the users practice examples achieved and how they would use ZCHIS in their work setting.

3.2 Timeline and Project Management

The activities were completed from 2016 to 2018, in, Zanzibar. The activities had interspace time slots that are not presented that were due to funding and availability of research subjects when all are needed at the same time. The only activities that were controlled to abide to this schedule were between training and post intervention that was done after six months from the classrooms. In absence of the said challenges this assignment should be able to complete with 12 months.

Phase (time period Six Weeks)	1	2	3	4	5	6	7
Activity 1: To calculate Shehia counts of diseases from the health facility utilization data, and analyze with Shehia-based socio-economic characteristics							
1.1. Scanning health facilities' registers for disease-address capturing, rate calculating & analyzing							
1.2. Statistical Analysis of Health Facility Data and Census Data Using SAS							
Activity2: To Design, Program, and Train Statistical Analysis Software for Analysis Automation and Dissemination Web Portal for District and National Surveillance Officers							
2.1. Designing and programming statistical forms to be used by the software							
2.2. Designing and programming the dissemination web portal for dashboard and analysis							
2.3. Training (classroom and on-job) the statistical tool and the dashboard							
2.4. Allow six months of software use							
Activity 3: To Measure the Rate Change of Information Use Among the DHMTs							
3.1. Pre-Intervention Assessment							
3.2. Post-Intervention Assessment and Analysis							

Table 3.1 Schedule of Interventions and Activities

3.3 Evaluation of Interventions Efforts

Assessing informatics skills after the three Interventions was measured by three sets of questionnaires:

i. The surveillance data-use capacity perception assessment of the research subjects: This is a questionnaire to assess the first intervention using the outcome variables of the hypothesis which are availability, usability, comfort-ability and knowledge amongst the DHMTs using the improved HMIS data to make decisions, interventions and support policy (Annex 4a, Questionnaire 1).

ii. ZCHIS Training Completion Assessment: This was a brief questionnaire administered immediately after the training of the ZCHIS to measure the second intervention with the comfort and understanding of the system to each participant. This was to test skills in using the developed statistical software and portal (Annex 4b Questionnaire 2)

iii. Epidemiologic and informatics assessment using modified ECA CSTE (4c Questionnaire 3)

The survey population is the DHMTs that are the public health officials at district level in health surveillance, program development and management. Zanzibar has 10 districts, and each district has six DHMT officers. There are five national surveillance officers in Zanzibar, three in Unguja Island and two in Pemba Island.

The survey questionnaire was adapted from the Commission of State and Territorial Epidemiologist (CSTE) survey to assess the epidemiological capacity at state and local level. The U.S. CSTE survey questionnaire consists of 108 questions on the following domains:

a) Background and training of surveillance and public health officials;

b) Capacity to perform essential public health functions of monitor health status, diagnoses and investigates health problems, evaluate effectiveness, accessibility and quality of health services, and research for new insight and report solutions.

This research survey targeted similar domains of the CSTE survey but were rephrased to fit the Zanzibar contexts and the roles assigned to the DHMTs (4). The questions were presented in the following main Domains.

a) Survey respondent background and training of surveillance and public health officials;

b) Their perception of capacity in health surveillance and data;

c) Their perception of usability of health data;

d) Their perception, knowledge and capacity to perform essential public health functions of:

d.1) monitoring health status;

d.2) diagnosing and investigating health problems;

d.3) evaluating effectiveness, accessibility and quality of health services; and

d.4) research for new insight and report solutions

d.5) intention and actual use of data for decision making, planning and management of programs.

In addition to the three questionnaires, a practical assignment was given to exercise how the system would be used to develop an evidence based report. Out of reports per each district, the research team could identify at least one champion per district who could support the remaining team in the District to build informatics capacity and evidence based management.

Conceptual Framework selected focused on assessing the net benefit of adopting the Zanzibar Community Health Information by focusing on the Strengthening system quality (SYS_Q), Information Quality (INFO_Q) and the Perceived Ease of Use (PEOU). After introducing and training it to the users, we measure the Perceived Usefulness (PU) and Satisfaction (US), which will assess the Perceived Net Benefit. System (NB) [180]

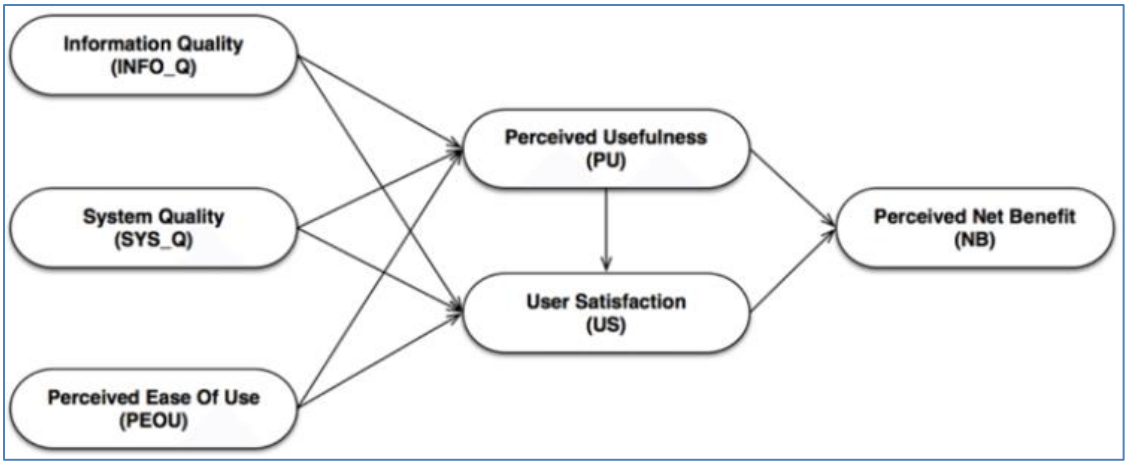


Figure 3.4 Conceptual Model for Adopting the Zanzibar Community Health Information System. Adapted from Ashilby (2015) Source: [158]

The conceptual framework in our case assesses increased and improved usage of health surveillance data because of increased accessibility ease of operation, quality and significance of the data. The modified version in our case will measure the perceived benefit through assessment of User satisfaction and perceived usefulness which are captured from Questionnaire 1; and Data Knowledge, Availability, Accessibility and Comfort-ability which we captured from Questionnaire 2.

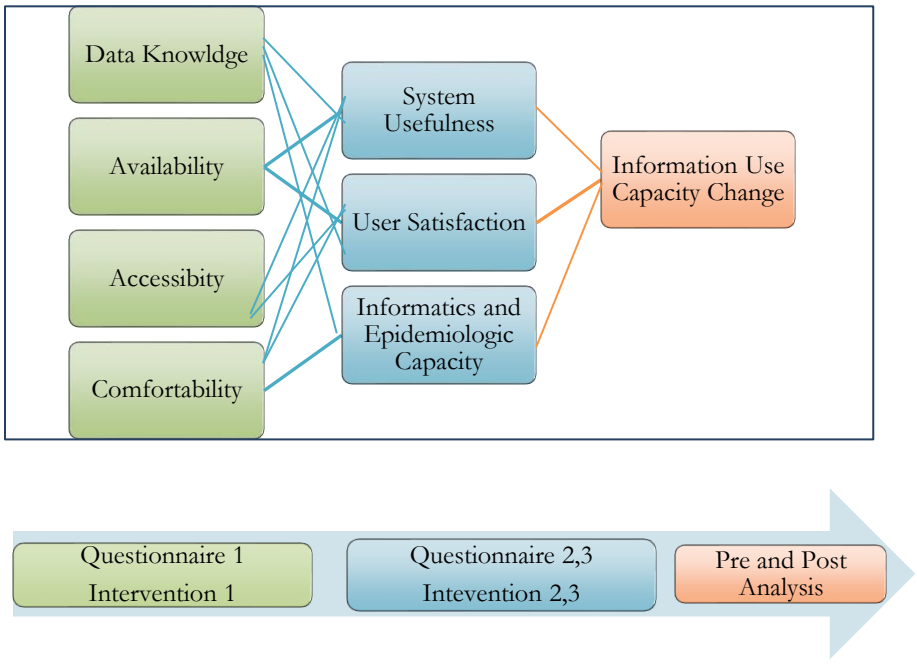


Figure 3.5 Conceptual framework to evaluate Information Use Capacity

Chapter 4. Results

This section summarizes the analyses that were done in this research based on the interventions:

1. Analysis of the HMIS Data (Intervention 1, Including shehia in the dataset)
2. HIS Capacity Building (Intervention 2, ZCHIS development)
3. DHMTs Informatics Capacity Building (Intervention 3, Informatics Training)

4.1 Analysis of the HMIS Data

This step reviews HMIS data support to DHMTs work. HMIS data and census, show different types of explorations that could lead usability to districts. This equips DHMTs with data that will answer their information queries about the health of the populations they oversee. Without shehia, population health is considered as one at a district unit, which contains 30-50 shehias of variable health outcomes. DHMTs have to be equipped to mine knowledge for them to conduct appropriate epidemiology.

4.1.1 Descriptive analysis of the HMIS data with Census

From the following descriptive analysis we compare the amount of information obtained working with data at the shehia level versus district level. There are three districts in which we collected the diseases data from Urban District, West District and Wete District. The difference of disease reports at district and shehia level shows a strong variability due to location from one district to another but more importantly from one shehia to another. The shehia variability is very important in this work and to the DHMTs because the district teams management scope logically means management of sub-districts' (which is shehias for Zanzibar) population rather than treating the entire district as one unified community. The DHMT and HMIS at national level data is aggregated at facility level and later on by district. This implies for any community health analysis, the smallest stratification area will be the district. This would work if analysis is taking place at national level. With decentralization, analysis cannot rely on within district variation especially if each district is conducting its own community health management. The data from a particular district has to vary at shehia level.

The benefit which has been achieved by capturing shehia and returning it into the records is that it empowers each district surveillance officer to separately manage their respective population efficiently and effectively. The figure below presents the map of Zanzibar Urban West Region in a year that had the highest cases of diarrhea (2013). The teams will report to the Ministry of health on the facilities that reported the highest cases of diarrhea, and the ministry will allocate more resources to serve the facilities with workforce and materials. There is no mechanism that will go to the community with evidence to support management of three cases, apart from understanding the estimated catchment population.

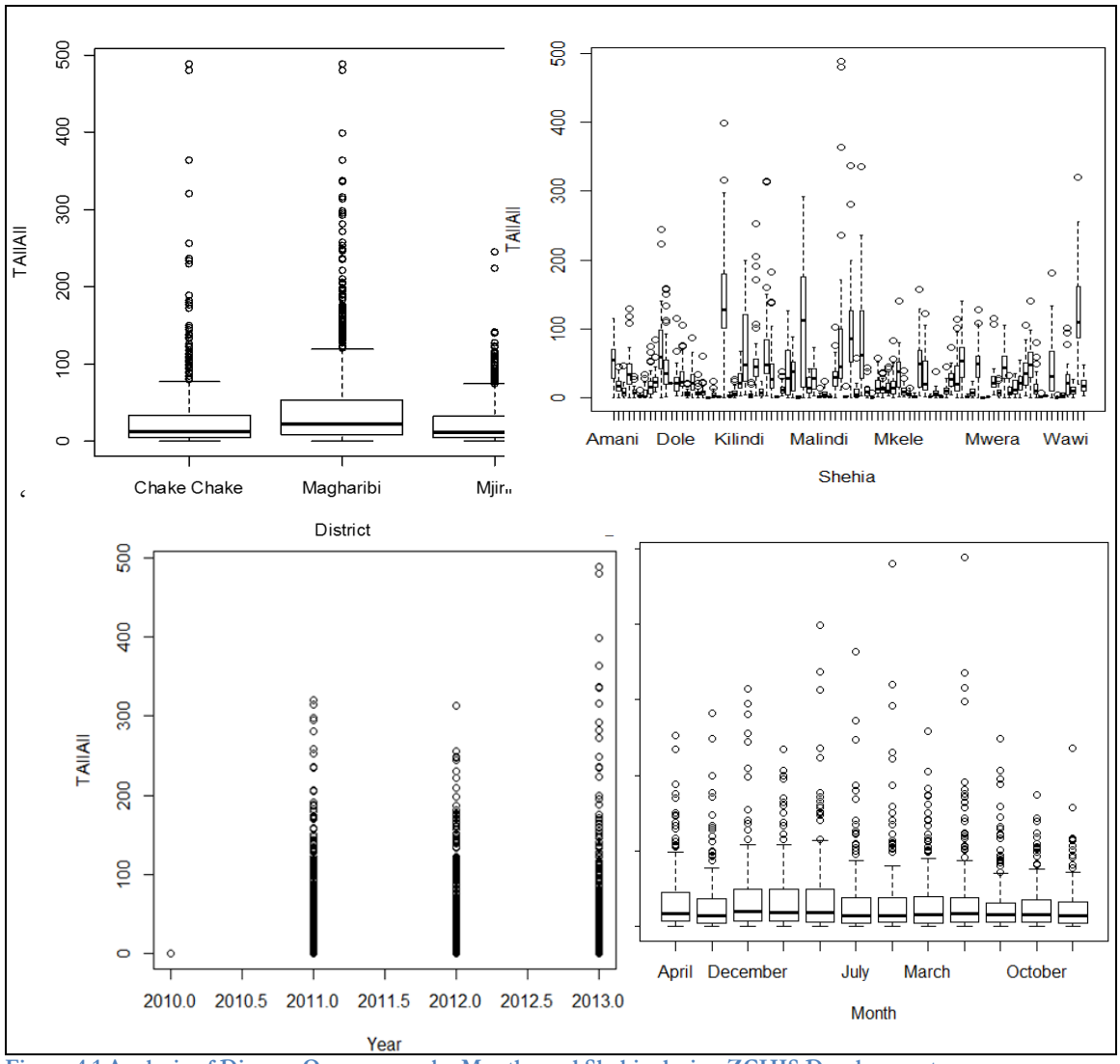


Figure 4.1 Analysis of Disease Occurrences by Months and Shehia during ZCHIS Development

4.1.2 Disease incidences from the communities and socioeconomic status

The following is a mixed model analysis conducted to predict disease occurrence using socioeconomic variables as Fixed Effects and with Random Effect variables being District and shehia. The intention is not to come up with a single model to predict all these outcomes using the predictor variables, but to create a framework that the user could pick from any of the variables and fit a model of the outcome variables generate hypothesis. Regression can help the DHMTs to learn about outcome associated socioeconomic factors that could help identify priorities in the public health domains like designing intervention, better allocation of resources to manage public health. Statistical analysis of several combinations of these diseases and SES has shown significant results.

1a. Piped Water	Piped Water into dwelling, Piped Water to yard/plot
1b. Un Piped Water	Public tap/standpipe, Tube well/borehole, Protected dug well, Unprotected dug well, Protected Spring, Unprotected Spring, Rain water collection, Cart with small tank/drum, Tanker truck, Surface water (river dam lake etc.)
2.a Standard Housing	Electricity (TANESCO/ZECO), Electricity (Wind), Electric iron, Electric/gas cooker, Television + 'Iron Sheets' + Tiles+ Concrete + Cement + 'Ceramic Tiles' + 'Parquet or Polished Wood' + Terrazzo
2b No Standard Housing	Paraffin Light, Asbestos, Grass/Leaves , Coal, Charcoal, Firewood, Wood/Farm Residuals, Animal residuals, Not Applicable,
3.a Standard Toilets	Flush Pour Flush to Piped Sewer System, Flush/Pour Flush to Covered Pit+ Flush/Pour Flush to Septic Tank , Flush/Pour Flush to Somewhere
3.b No Standards Toilets	Ventilated Improved Pit VIP Latrine, Pit Latrine with not-Washable/Soil Slab, Pit Latrine with Washable Slab with Lid, Pit Latrine with Washable Slab without Lid, Pit Latrine without Slab/Open Pit, Pit Latrine without Slab/Open Pit, Composting/Ecoson Latrine, Bucket, No Facility/bush/field/beach

Table 4.1 Main SES variables used in the analysis

Due to the voluminous indicators, running these models have called upon having a statistical analytical online tool that the DHMTS can benefit from anytime need be.

There are around 200 variables in these data sets and 24 different outcome variables if you dissect the population by gender age and specific disease (3). DHMTs should be able to run these analysis on real time, to support their hypothesis planning and immediate and long-term Decisions. The model was embedded in the system to allow similar analysis to take place at users' convenience and a self-guided statistical analysis by the DHMTs. Using census we tried to draw association of records that are being collected routinely through the HMIS and analyzed based on the SES indications like standard household, use of proper toilets and availability of clean drinking water. Table 4.1 summarizes concatenating with SES:

The generalized mixed linear model by maximum likelihood was fit to the subsets of Diarrheal Diseases, Pneumonia and Respiratory Tract Infection. The models were run to compare the main population clusters as recorded in the HMIS that is; between "Adults" and "Children" and between "Male" and female "Population". There are 230 SES variables in the Dataset. While the Principle Component Analysis was attempted, it was less feasible and important parameters were falling out of analysis.

This analysis picked Education, Population employment and Household poverty to study the SES determinant of health at census level. In Education the best indicator chosen was female primary education, due to the presence of Children population in the dataset, and generally the female's role in providing care at household level. For poverty we chose Total count per shehia of Adults Not Worked and Total Worked and Unpaid. Lastly for household, the Indicators are summarized in the table 4.2 above. These models are given as follows:

Pneumonia

```
> summary(PneuAdult_glmm)
Generalized linear mixed model fit by maximum likelihood (Laplace Appr
n) ['glmerMod']
 Family: poisson  ( log )
Formula: TAdultPneu ~ 1 + PriFemale + Economic_TotalProf + TWorkedPaid
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoStdToilets
 (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
  2576.3   2659.1  -1274.1   2548.3     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.3263 -0.3975 -0.2730 -0.2018 13.6824

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 0.9244   0.9615
 District        (Intercept) 0.2199   0.4689
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -2.423e+00  3.128e-01  -7.746 9.47e-15 ***
PriFemale          -1.218e-03  1.134e-03  -1.074 0.282879
Economic_TotalProf -2.265e-05  5.183e-04  -0.044 0.965138
TWorkedPaid         1.041e-03  7.360e-04   1.414 0.157380
TNotWorked          1.592e-03  6.391e-04   2.490 0.012759 *
TWorkedUnpaid       3.455e-03  1.223e-03   2.826 0.004715 **
PipedWater          2.543e-03  1.042e-03   2.441 0.014656 *
UnPipedWater        2.324e-03  1.000e-03   2.324 0.020145 *
StdHousing          4.924e-06  2.056e-05   0.240 0.810717
InStdHousing        3.331e-03  8.767e-04   3.799 0.000145 ***
StdToilets         -5.808e-03  8.207e-04  -7.077 1.47e-12 ***
NoStdToilets       -5.717e-03  7.518e-04  -7.604 2.87e-14 ***
---
```

```
> summary(PneuCh_glmm)
Generalized linear mixed model fit by maximum likelihood (Laplace Appr
mation) ['glmerMod']
 Family: poisson  ( log )
Formula: ChildPneu ~ 1 + PriFemale + Economic_TotalProf + TWorkedPaid
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoStdToilets
     (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
 14741.1  14824.0  -7356.6  14713.1     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.1716 -1.0204 -0.3377  0.1744 22.2011

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.719    1.311
 District        (Intercept) 3.055    1.748
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -8.014e-01  7.475e-01  -1.072  0.28369
PriFemale          -2.646e-03  1.580e-04 -16.749  < 2e-16 ***
Economic_TotalProf -7.007e-04  1.035e-04  -6.772 1.27e-11 ***
TWorkedPaid         3.096e-04  1.188e-04   2.607  0.00915 **
TNotWorked         -3.240e-04  1.605e-04  -2.018  0.04357 *
TWorkedUnpaid      -6.436e-04  2.284e-04  -2.818  0.00483 **
PipedWater          2.040e-03  1.869e-04  10.918  < 2e-16 ***
UnPipedWater        1.946e-03  2.005e-04   9.705  < 2e-16 ***
StdHousing         -1.315e-06  1.641e-06  -0.801  0.42289
InStdHousing       -2.193e-03  1.187e-04 -18.471  < 2e-16 ***
StdToilets          2.863e-03  1.766e-04  16.213  < 2e-16 ***
NoStdToilets        3.170e-03  1.886e-04  16.802  < 2e-16 ***
```

```
> summary(PneuFAdult_glmm)
Generalized linear mixed model fit by maximum likelihood (Laplace A
mation) ['glmerMod']
 Family: poisson  ( log )
Formula: FAdultPneu ~ 1 + PriFemale + Economic_TotalProf + TWorkedP

    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoStdToil
     (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
  1684.6   1767.5   -828.3   1656.6     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.5675 -0.2991 -0.2070 -0.1593 11.6732

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.13257  1.0642
 District        (Intercept) 0.09371  0.3061
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -2.978e+00  2.812e-01 -10.588  < 2e-16 ***
PriFemale          -1.092e-03  1.606e-03  -0.680  0.49636
Economic_TotalProf -3.829e-04  6.725e-04  -0.569  0.56905
TWorkedPaid         1.516e-03  9.503e-04   1.596  0.11055
TNotWorked          1.730e-03  8.797e-04   1.967  0.04923 *
TWorkedUnpaid       3.789e-03  1.625e-03   2.332  0.01972 *
PipedWater          5.573e-03  5.588e-03   0.997  0.31857
UnPipedWater        5.675e-03  5.648e-03   1.005  0.31497
StdHousing          3.787e-06  8.204e-06   0.462  0.64437
InStdHousing        3.378e-03  1.107e-03   3.053  0.00226 **
StdToilets         -9.297e-03  5.332e-03  -1.744  0.08123 .
NoStdToilets       -9.112e-03  5.426e-03  -1.679  0.09311 .
```

```
> summary(PneuMAdult_glmm)
Generalized linear mixed model fit by maximum likelihood (Lapl
roximation) ['glmerMod']
 Family: poisson  ( log )
Formula: MAdultPneu ~ 1 + PriFemale + Economic_TotalProf + TWo
d +
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoSt
s +       (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
  1492.3   1575.2   -732.1   1464.3     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.6631 -0.2733 -0.1956 -0.1504 14.5878

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 0.7578   0.8705
 District        (Intercept) 0.3624   0.6020
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -3.220e+00  3.743e-01  -8.604   <2e-16 ***
PriFemale          -8.169e-04  1.489e-03  -0.549   0.5833
Economic_TotalProf  2.403e-04  6.854e-04   0.351   0.7259
TWorkedPaid         6.144e-04  1.038e-03   0.592   0.5540
TNotWorked          8.159e-04  8.735e-04   0.934   0.3503
TWorkedUnpaid       2.118e-03  1.774e-03   1.194   0.2326
PipedWater          1.041e-03  5.597e-03   0.186   0.8525
UnPipedWater        4.647e-04  5.647e-03   0.082   0.9344
StdHousing          6.838e-06  7.503e-06   0.911   0.3621
InStdHousing        2.205e-03  1.089e-03   2.025   0.0429 *
StdToilets         -3.131e-03  5.167e-03  -0.606   0.5446
NoStdToilets       -2.823e-03  5.238e-03  -0.539   0.5899
```

Figure 4.2 Diarrhea and SES across 4 main population categories Male Female, Adult and Children.

Diarrhea

```
> summary(DiarCh_glmm)
Generalized linear mixed model fit by maximum likelihood (Laplace Approx
 ['glmerMod']
 Family: poisson  ( log )
Formula: ChildDiar ~ 1 + PriFemale + Economic_TotalProf + TWorkedPaid +
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoStdToilets +
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
 11296.6  11379.5  -5634.3  11268.6     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.6205 -0.8233 -0.4511  0.1502 24.8983

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 2.106    1.451
 District        (Intercept) 1.067    1.033
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -8.338e-01  5.054e-01  -1.650 0.098948 .
PriFemale           9.235e-04  3.043e-04   3.035 0.002405 **
Economic_TotalProf  3.805e-04  1.888e-04   2.015 0.043888 *
TWorkedPaid        -8.592e-04  2.396e-04  -3.586 0.000336 ***
TNotWorked         -1.749e-03  2.262e-04  -7.734 1.05e-14 ***
TWorkedUnpaid      -8.487e-04  3.139e-04  -2.704 0.006852 **
PipedWater          1.292e-03  3.482e-04   3.711 0.000207 ***
UnPipedWater        5.126e-04  3.577e-04   1.433 0.151867
StdHousing         -7.061e-06  2.761e-06  -2.557 0.010550 *
InStdHousing       -9.228e-04  2.067e-04  -4.464 8.03e-06 ***
StdToilets         -4.038e-04  3.116e-04  -1.296 0.195035
NoStdToilets        6.008e-04  3.206e-04   1.874 0.060959 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Generalized linear mixed model fit by maximum likelihood (Laplace
 ['glmerMod']
 Family: poisson  ( log )
Formula: TAdultDiar ~ 1 + PriFemale + Economic_TotalProf + TWorke
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoStdTc
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
  6799.0   6881.9  -3385.5   6771.0     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.8774 -0.6916 -0.4789  0.1431 10.7891

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.4587   1.2078
 District        (Intercept) 0.2371   0.4869
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -1.099e+00  2.935e-01  -3.745  0.00018 ***
PriFemale          -1.021e-03  5.881e-04  -1.736  0.08262 .
Economic_TotalProf  1.063e-03  2.778e-04   3.827  0.00013 ***
TWorkedPaid        -1.575e-03  3.580e-04  -4.400 1.08e-05 ***
TNotWorked          5.741e-04  3.186e-04   1.802  0.07158 .
TWorkedUnpaid      -8.893e-04  4.581e-04  -1.941  0.05223 .
PipedWater          7.613e-03  5.698e-04  13.361  < 2e-16 ***
UnPipedWater        7.747e-03  5.818e-04  13.317  < 2e-16 ***
StdHousing          1.231e-05  4.943e-06   2.490  0.01279 *
InStdHousing       -7.516e-04  3.846e-04  -1.954  0.05066 .
StdToilets         -6.014e-03  5.575e-04 -10.789  < 2e-16 ***
NoStdToilets       -5.603e-03  5.510e-04 -10.169  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
> summary(DiarFAdult_glmm)
Generalized linear mixed model fit by maximum likelihood (Lap
 ['glmerMod']
 Family: poisson  ( log )
Formula: FAdultDiar ~ 1 + PriFemale + Economic_TotalProf + TWo
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoSt
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
  4574.5   4657.4  -2273.3   4546.5     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.1353 -0.5643 -0.3473 -0.1940  9.9386

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.5819   1.2577
 District        (Intercept) 0.2863   0.5351
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -1.767e+00  3.272e-01  -5.401 6.61e-08 ***
PriFemale          -1.569e-03  7.458e-04  -2.104 0.035376 *
Economic_TotalProf  8.174e-04  3.680e-04   2.221 0.026359 *
TWorkedPaid        -1.525e-03  4.756e-04  -3.207 0.001342 **
TNotWorked          6.983e-04  4.152e-04   1.682 0.092626 .
TWorkedUnpaid      -1.283e-03  6.045e-04  -2.123 0.033777 *
PipedWater          4.742e-03  5.491e-04   8.636  < 2e-16 ***
UnPipedWater        4.658e-03  5.489e-04   8.486  < 2e-16 ***
StdHousing          7.214e-06  6.810e-06   1.059 0.289447
InStdHousing       -1.030e-03  4.880e-04  -2.112 0.034728 *
StdToilets         -2.306e-03  6.378e-04  -3.615 0.000301 ***
NoStdToilets       -1.698e-03  6.108e-04  -2.780 0.005431 **
```

```
> summary(DiarMAdult_glmm)
Generalized linear mixed model fit by maximum likelihood (Lap
 ['glmerMod']
 Family: poisson  ( log )
Formula: MAdultDiar ~ 1 + PriFemale + Economic_TotalProf + TW
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoS
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
  4184.9   4267.8  -2078.5   4156.9     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.8922 -0.5145 -0.3795 -0.1958  8.9626

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.4145   1.1893
 District        (Intercept) 0.1505   0.3879
Number of obs: 2749, groups:  District:Shehia, 95; District,

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)        -1.746e+00  2.797e-01  -6.242 4.33e-10 ***
PriFemale          -1.027e-05  8.665e-04  -0.012  0.99054
Economic_TotalProf  1.278e-03  4.102e-04   3.116  0.00183 **
TWorkedPaid        -1.415e-03  5.537e-04  -2.555  0.01061 *
TNotWorked          5.034e-04  4.353e-04   1.156  0.24749
TWorkedUnpaid      -7.546e-05  6.800e-04  -0.111  0.91164
PipedWater          1.127e-02  7.333e-04  15.366  < 2e-16 ***
UnPipedWater        1.139e-02  7.435e-04  15.322  < 2e-16 ***
StdHousing          1.772e-05  7.821e-06   2.266  0.02344 *
InStdHousing        1.728e-04  5.595e-04   0.309  0.75738
StdToilets         -1.165e-02  7.124e-04 -16.349  < 2e-16 ***
NoStdToilets       -1.154e-02  6.796e-04 -16.977  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '
```

Figure 4.3 Diarrheal Diseases and Socioeconomic determinants

URTI

```
> summary(URTITCh_glmm)
Generalized linear mixed model fit by maximum likelihood (Lap
  Approximation) [glmerMod]
 Family: poisson  ( log )
Formula: ChildURTI ~ 1 + PriFemale + Economic_TotalProf + TWo
Paid +
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoS
ilets +
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
 42523.8  42606.6 -21247.9  42495.8     2735

Scaled residuals:
   Min     1Q Median     3Q    Max
-8.996 -2.052 -0.649  0.867 37.619

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 2.6632   1.6319
 District        (Intercept) 0.7961   0.8922
Number of obs: 2749, groups:  District:Shehia, 95; District,

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)         1.156e+00  4.653e-01   2.484   0.0130 *
PriFemale           2.416e-04  9.705e-05   2.490   0.0128 *
Economic_TotalProf -1.294e-03  5.153e-05 -25.120   <2e-16 ***
TWorkedPaid         1.451e-03  6.584e-05  22.031   <2e-16 ***
TNotWorked         -7.046e-04  8.020e-05  -8.786   <2e-16 ***
TWorkedUnpaid      -4.541e-05  1.369e-04  -0.332   0.7401
PipedWater         -6.991e-03  1.221e-04 -57.243   <2e-16 ***
UnPipedWater       -7.425e-03  1.270e-04 -58.484   <2e-16 ***
StdHousing         -1.405e-05  9.214e-07 -15.249   <2e-16 ***
InStdHousing       -2.753e-03  7.530e-05 -36.559   <2e-16 ***
StdToilets          9.655e-03  1.152e-04  83.822   <2e-16 ***
NoStdToilets        1.040e-02  1.186e-04  87.649   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’
```

```
> summary(URTITAdult_glmm)
Generalized linear mixed model fit by maximum likelihood (Lap
  Approximation) [glmerMod]
 Family: poisson  ( log )
Formula: TAdultURTI ~ 1 + PriFemale + Economic_TotalProf + TW
dPaid +
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoS
ilets +
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
 32124.9  32207.8 -16048.5  32096.9     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-6.6199 -1.7344 -0.7178  0.7775 20.2874

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.516    1.2313
 District        (Intercept) 0.274    0.5234
Number of obs: 2749, groups:  District:Shehia, 95; District,

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)         1.253e+00  2.927e-01   4.283 1.85e-05 ***
PriFemale          -3.940e-05  1.338e-04  -0.294    0.768
Economic_TotalProf -3.644e-04  6.593e-05  -5.527 3.25e-08 ***
TWorkedPaid         8.455e-04  7.901e-05  10.702  < 2e-16 ***
TNotWorked          9.736e-05  9.054e-05   1.075    0.282
TWorkedUnpaid      -9.790e-04  1.509e-04  -6.489 8.65e-11 ***
PipedWater          1.280e-03  1.790e-04   7.152 8.58e-13 ***
UnPipedWater        1.254e-03  1.852e-04   6.771 1.28e-11 ***
StdHousing         -7.834e-07  1.489e-06  -0.526    0.599
InStdHousing       -1.602e-04  1.045e-04  -1.533    0.125
StdToilets         -1.369e-03  1.666e-04  -8.215  < 2e-16 ***
NoStdToilets       -9.533e-04  1.733e-04  -5.500 3.79e-08 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’

Correlation of Fixed Effects:
```

```
> summary(URTIFAdult_glmm)
Generalized linear mixed model fit by maximum likelihood (Laplac
  Approximation) [glmerMod]
 Family: poisson  ( log )
Formula: FAdultURTI ~ 1 + PriFemale + Economic_TotalProf + TWork
dPaid +
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoStdT
ilets +
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
 23343.3  23426.2 -11657.6  23315.3     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.3524 -1.4190 -0.6406  0.7408 16.7420

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.5359   1.2393
 District        (Intercept) 0.2238   0.4731
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)         7.983e-01  2.742e-01   2.912  0.00359 **
PriFemale          -7.137e-05  1.655e-04  -0.431  0.66632
Economic_TotalProf -2.299e-04  8.356e-05  -2.751  0.00594 **
TWorkedPaid         7.935e-04  9.978e-05   7.952 1.84e-15 ***
TNotWorked          1.390e-04  1.116e-04   1.245  0.21311
TWorkedUnpaid      -1.038e-03  1.927e-04  -5.386 7.22e-08 ***
PipedWater          4.456e-04  2.219e-04   2.008  0.04461 *
UnPipedWater        3.970e-04  2.292e-04   1.732  0.08323 .
StdHousing         -7.104e-07  1.753e-06  -0.405  0.68539
InStdHousing       -5.687e-05  1.312e-04  -0.433  0.66466
StdToilets         -7.084e-04  2.053e-04  -3.450  0.00056 ***
NoStdToilets       -2.742e-04  2.132e-04  -1.286  0.19849
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
Generalized linear mixed model fit by maximum likelihood (Lapl
  Approximation) [glmerMod]
 Family: poisson  ( log )
Formula: MAdultURTI ~ 1 + PriFemale + Economic_TotalProf + TWo
dPaid +
    TNotWorked + TWorkedUnpaid + PipedWater + UnPipedWater +
    StdHousing + StdHousing + InStdHousing + StdToilets + NoSt
ilets +
    (1 | District) + (1 | District:Shehia)
   Data: Data1

     AIC      BIC   logLik deviance df.resid
 16047.8  16130.6  -8009.9  16019.8     2735

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.0159 -1.1628 -0.5391  0.5544 16.6059

Random effects:
 Groups          Name        Variance Std.Dev.
 District:Shehia (Intercept) 1.3646   1.1682
 District        (Intercept) 0.4866   0.6976
Number of obs: 2749, groups:  District:Shehia, 95; District, 7

Fixed effects:
                    Estimate Std. Error z value Pr(>|z|)
(Intercept)         2.516e-01  3.676e-01   0.684 0.493691
PriFemale          -2.100e-05  2.247e-04  -0.093 0.925524
Economic_TotalProf -5.609e-04  1.066e-04  -5.263 1.42e-07 ***
TWorkedPaid         9.008e-04  1.286e-04   7.003 2.50e-12 ***
TNotWorked          2.630e-05  1.500e-04   0.175 0.860852
TWorkedUnpaid      -8.944e-04  2.411e-04  -3.710 0.000207 ***
PipedWater          2.827e-03  3.081e-04   9.173  < 2e-16 ***
UnPipedWater        2.813e-03  3.194e-04   8.808  < 2e-16 ***
StdHousing         -1.237e-06  2.809e-06  -0.440 0.659787
InStdHousing       -2.874e-04  1.716e-04  -1.675 0.093991 .
StdToilets         -2.637e-03  2.873e-04  -9.177  < 2e-16 ***
NoStdToilets       -2.235e-03  2.986e-04  -7.485 7.15e-14 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 4.4 URTI and Socioeconomic Determinants

Other variables likely to be further analyzed in subsets of the population are Secondary education which enables capacity building of the DHMTs to evidently inform policy. At this point, significance of the female, education, and household equalities could help the DHMTs understand the usability of HMIS data to their daily work. Secondary education completion for females, for instance, is significantly correlated with reduced cases in child diarrhea.

```
Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    1.7249498  0.2216378   7.783 9.97e-15 ***
NoStdToilets   0.0012520  0.0004067   3.078 0.002103 **
TWorkedUnpaid  0.0057766  0.0016070   3.595 0.000331 ***
SecFemale     -0.0005019  0.0001506  -3.332 0.000873 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

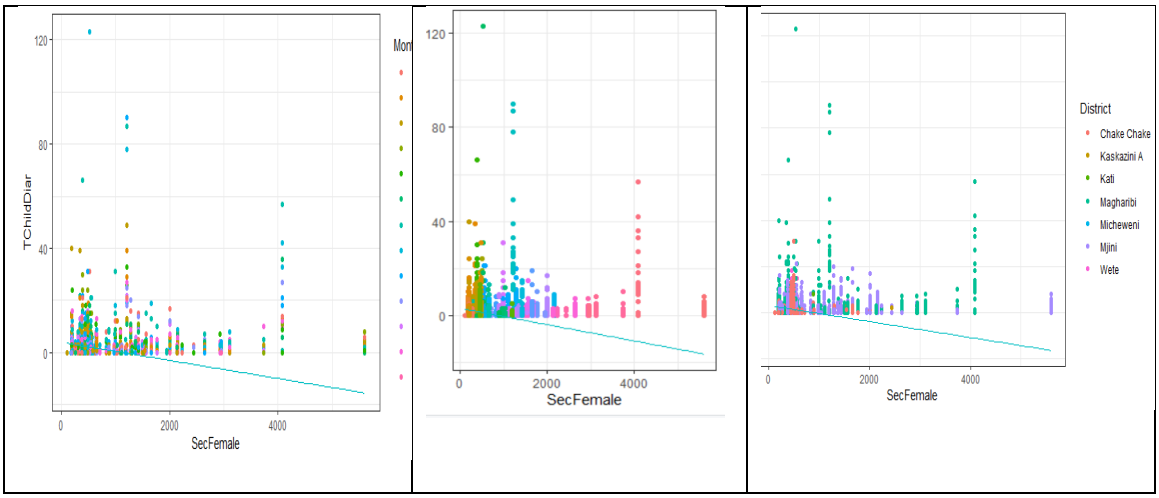


Figure 4.5 Diarrhea in Children by Shehia Count of Female Secondary School Completion

Each shehia in each district for each month can be analyzed to determine where to place intervention, build their evidence management, and inform capacity.

In analyzing household characteristics, it was found that there is a negative correlation to diarrhea cases with households which are un-piped than those which are piped. As opposite to expectation, this can suggest pipe system being a means of transmission to diarrhea cases.

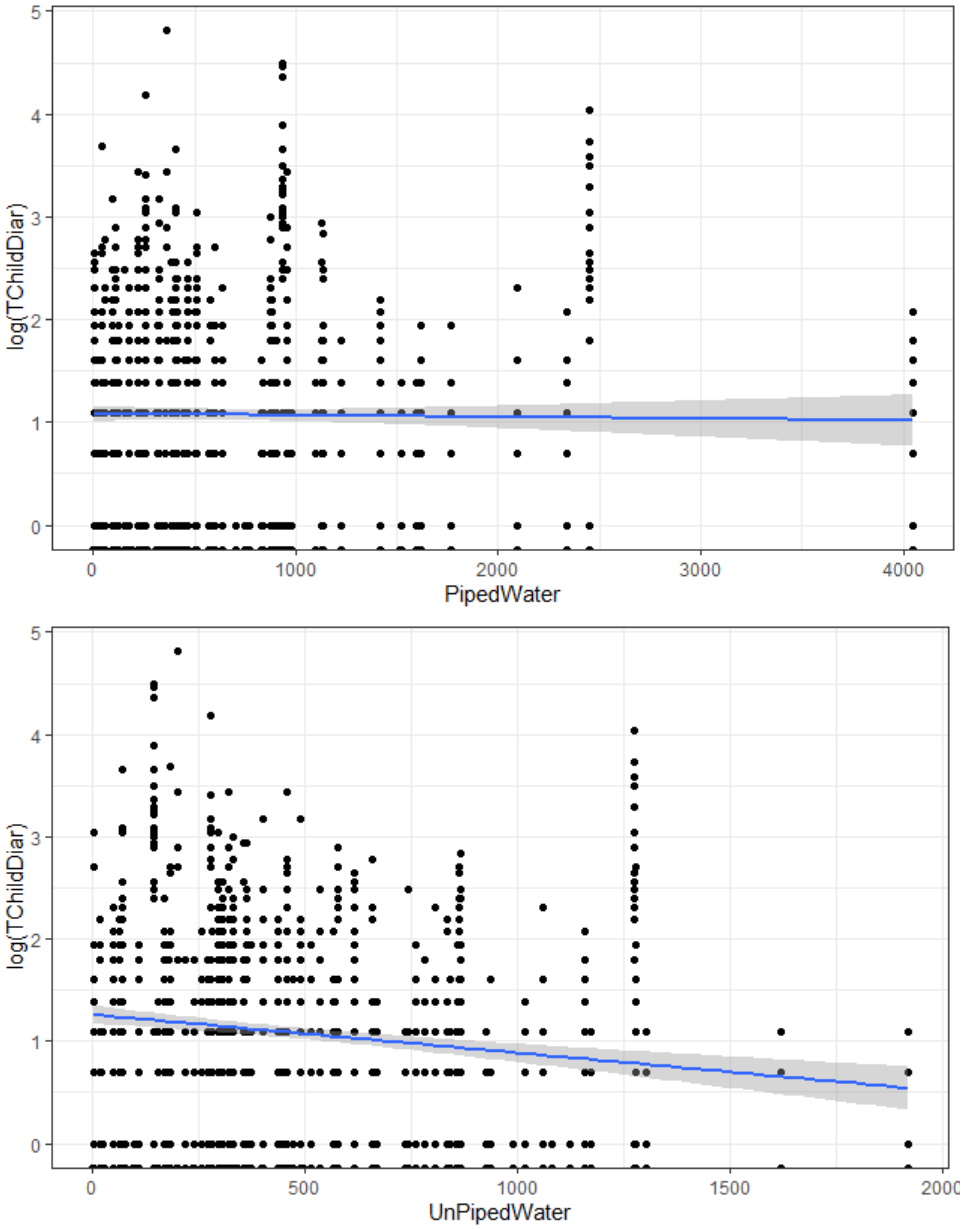


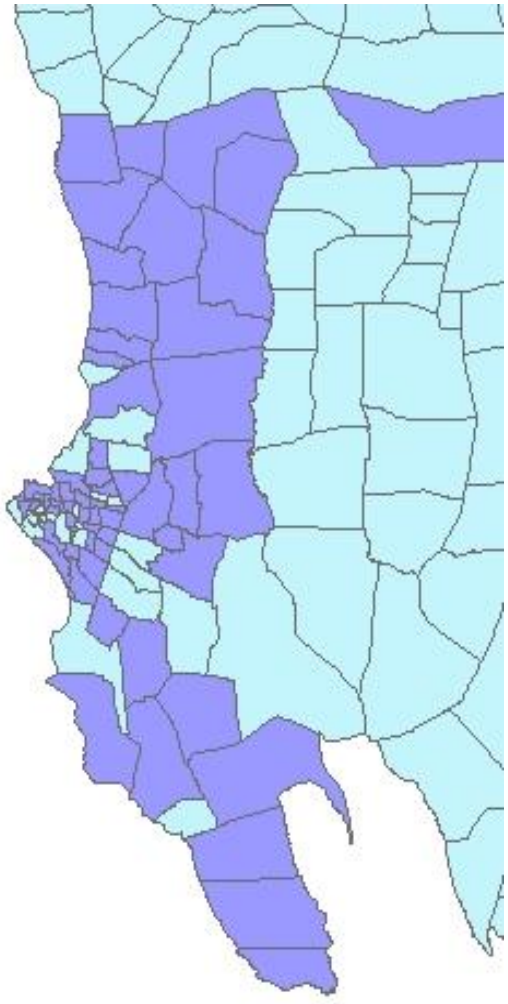
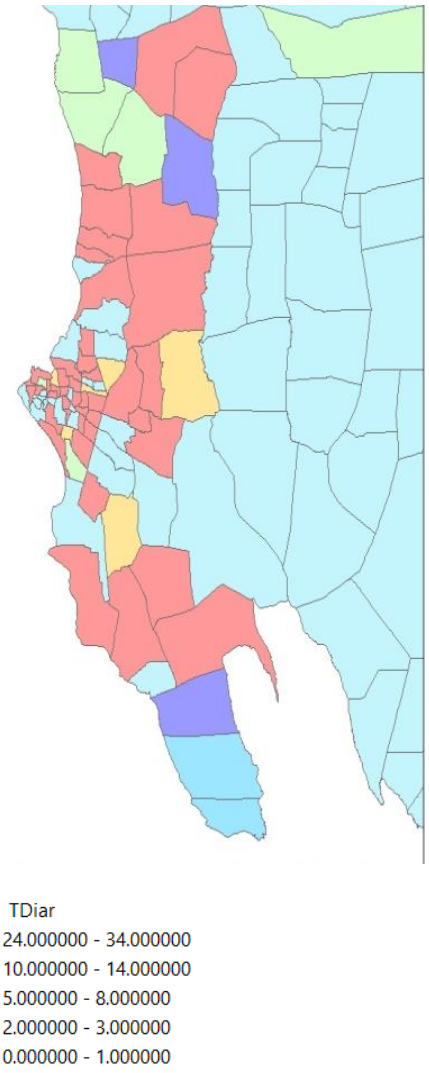
Figure 4.6 Piped and un-piped association to Diarrhea

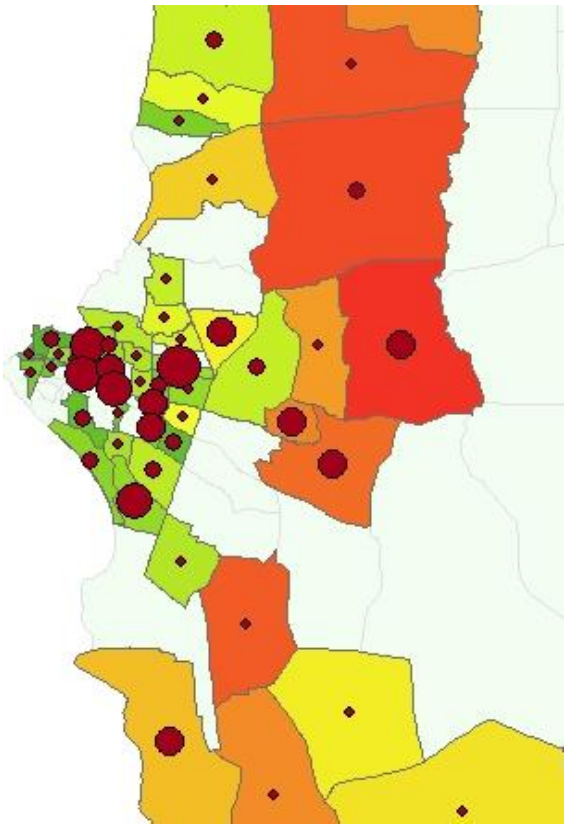
In other words, with the urban water and sewage systems, the rural bore holes could be safer than the tap systems observed in the urban districts. These analyses are not intended for conclusion but rather generating new hypotheses that the DHMTs could act upon to develop research and projects for them to draw their own conclusions.

4.1.3 Geographic Information System (GIS) Diseases, Location and SES

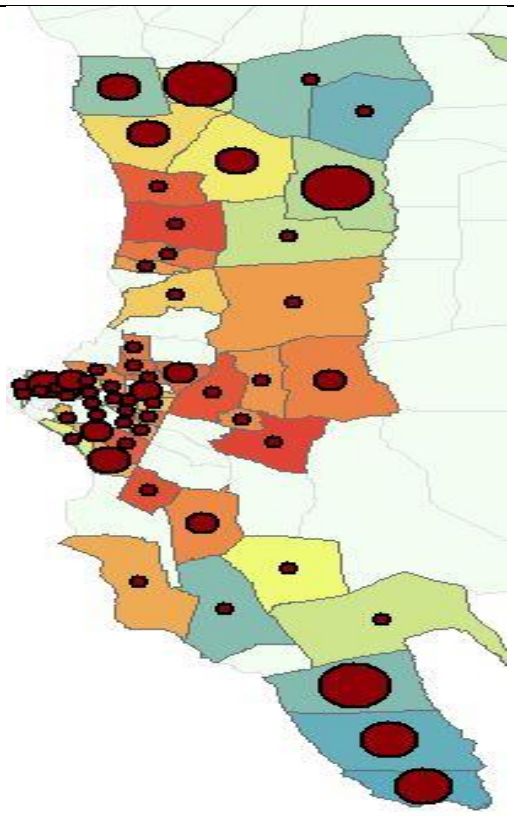
4.1.3.1 Situational Analysis: when there is no "shehia" in the HMIS data used by the DHMTs.

To understand the first contribution to this research we demonstrate the shift into the shehia based analysis versus district aggregated data in the HMIS.

Diarrhea in Urban West region: No Shehia	**Diarrhea in Urban West region: With Shehia**
	



Diarrhea in Urban West region with Shehia Primary Education



Pneumonia in Urban West region with House Hold Characteristics.

Figure 4.7 Diarrhea in Urban West region: with Shehia and Secondary Socioeconomic Variables

Thus, shehia projects were the concentration of these cases, which will enable a surveillance officer to utilize the district resource more efficiently and effectively. More importantly, its properties allows integration with population surveys, ad in this research Census is used as a source of SES indicators that estimates linkages with multiple disease predictors. The above diagrams two maps on the right are demonstrating this.

The reports give the DHMTs the power to identify specific populations to work closely to lower diseases using community extensions. This will be facilitated by reports obtained by the DHMTs through the ZCHIS system. While the monthly data represent facility counts by month useful in resource management, the information extracted is not going to be useful enough for health management if treated as uniform at district/national level. This for instance, as diarrhea cases shows

increase in rainy seasons, intervention for prevention will have to cover the entire district instead of concentrating on specific shehia. The newly designed system allowed for data visualization and analysis not possible before. Three examples shown below:

4.1.3.2 . Dashboard visualization: an addition from DHIS2 Facility based Indicators to ZCHIS Community Extension.

While DHIS has extensively developed its dashboard such that every indicator collected can be output in a dashboard, with descriptive summaries and maps, the data is still representing what was collected at facilities. This is still very useful for health systems strengthening if more is going to be done to improve Information use. However, facility counts lack shehia variables, which would have generated an additional option to integration i.e. one for facility counts (Health Service Administration) and aggregation due to shehia counts (Community health management). Shehia is the only window to utilize the mass amount of records now archived to study population's diseases, risk factor and even health system utilization.

After proper synchronization of ZCHIS to DHIS2 database as a module extension. All indicators (more than 200) depending on use, could be visualized representing the communities the patients are coming from. Currently, there is no system in Zanzibar or Tanzania that monitors and analyses disease trends in the population at real time, nevertheless by the DHMTs. With DHIS supplying data to ZCHIS, and with mobile data entry at health facilities level, consistent analysis of quality information will be achieved, and hence its use. This approach has three main advantages compared to the community data entry project that is being conducted in east African countries:

1. It is highly cost effective compared to household collection of community health incidence that utilize man hours significantly. The only manpower ZCHIS will require is developing scripts for either integration or interoperability where the same DHIS records could be extrapolated to capture the shehias origins, which is the next phase in this research.

2. Health records are confirmed by low-capacity clinical workforce if any. The disease record captured from the facility is confirmed using clinical guidelines, and by appropriate clinical personnel. Passing this information from patient to community health worker requires validation and without constant supervision the data quality and validity will be highly questionable.
3. Threat of duplication of records of the same patient entered at the health facility and in the community. While there are measured being taken to minimize this duplication like prescription and patient encounter certificate, the risk of duplicating data is still high since we are placing a burden to maintain health records to a patient whose culture and social attributes have not prepared them to do so.

4.1.3.3 Analysis Level: System based statistical tests and Analyses.

The summary reports produced in the dashboard support analysis of trends of service utilization and surveillance indicators successfully. This information use serve the daily monitoring but does not offer statistical evidence with confidence intervals to understand the relationships governing utilization rates and health outcomes and the magnitude of these relationship apart from generating hypotheses. This is where statistical tests and analyses become necessary.

What knowledge are we gaining from the daily trends of the dashboards; and in a health system with no statistical workforce to download and utilize knowledge with better confidence intervals, how can we test the hypotheses we generate from the daily trends. ZCHIS main goal is to enable statistical analysis that HMIS data can support, automate and make them available for public health use especially community interventions.

For an example, if a hand wash intervention is to be carried out to lower diarrheas diseases, the DHMTs should be able to target the shehias with the highest cases, and not the facilities that reported patients from multiple shehias (catchment shehias). In designing the intervention secondary data through census, demographic and health surveys and household survey can strengthen hypothesis testing to allocate

4.1.3.4 Lower-level GIS Reports

DHIS2 is outputting GIS maps differing in scope from country to country. On Zanzibar however, the districts are the community representation of HMIS health outcomes, instead of shehias, and it cannot be the health facilities since they are only the point of services Additionally, other projects have been conducted to strengthen GIS reporting directly from DHIS [99] as an open source GIS for HMIS, initiatives that as long as the unit of analysis is at district level, will mainly benefit the central level, and don't decentralized DHMTs which have to dig further from communities. ZCHIS uses patient reported shehia to re-distribute all encounters to represent community indicators in a lower geographical level. When shehia is the unit of analysis, reports are becoming more meaningful for DHMTs to conduct confined surveillance on hotspots and spatio-temporal trends of diseases.

4.2 HIS capacity building

The ZCHIS system was up and running after trials of programming, testing and training. Other additions are being proposed as users get acquainted in using it. Future versions will incorporate as technicality and resources are gained. As per the agreed design, the following were accomplished

a. Descriptive statistics was the first module to be implemented and the first shehia-level presentation of health data. The aim of having this visualization was to introduce the users with the idea of dashboards while starting from the type of analysis they are familiar with like frequency plots, pie charts and so on using drop down menus of diseases, geographical stratification, gender, age months and years. These dashboards introduced the users to start practicing statistical analysis.

The basics were trained to the users without ZCHIS and when it was time to practice, users already knew hypothesis generation and what health and SES variables to test. Using menus, users select the type of test, and results will be captured for sharing and exportation in pdf. Due to the nature of the data and use, the system conducts *chi-square tests, two-sample T tests*, and other graphical analysis.

b. Statistical Analysis: The two main procedures that data would be able to support based on its structure are the Poisson regression and Analysis of Variance. Analysis of variance was included to

allow categorical analysis in the system. The data has been summarized by a gender age (adult, child) and the names of regions. The ability to analyze if diseases differed due to age, sex, months and location was demonstrated.

c. Geospatial Analysis: The GIS reports were categorized into three: 1) the Zanzibar Disease Atlas where users can select time duration, geographical location and disease variables split into gender and age, 2) the Socioeconomic Atlas for Zanzibar where any of the 40 socioeconomic indicators can be printed on a map separately and 3) the hotspot analysis currently being studied where variables can be jointly studied to see the correlation of diseases and socioeconomic indicators.

This is an important component of this research since it empowers the surveillance officers to generate clusters of population within a region and select disease and SES reports to study how health disparities are associated in SES differentiation in the communities. Future versions of the system will include geospatial hotspot analysis for both SES and Disease clusters.

The user's responses results were summarized after concluding the ZCHIS training session (Figure 4.5). 94 % of the users thought the system to fit into their daily use and more than a half-needed GIS and Statistical analysis. The following was obtained by the questionnaire administered:

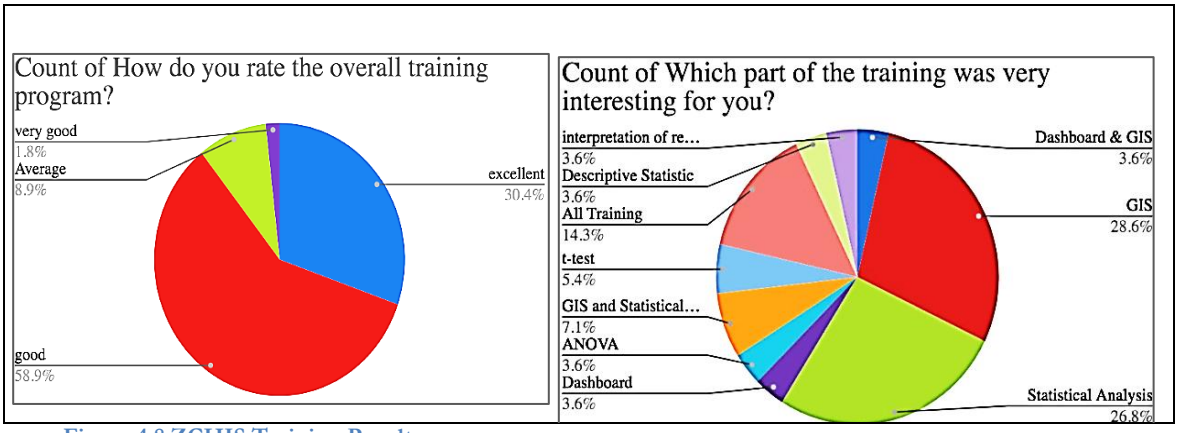


Figure 4.8 ZCHIS Training Results

The following screenshots were taken from the ZCHIS system during the training provided.

Figure 4.9 Statistical Analysis conducted by ZCHIS System

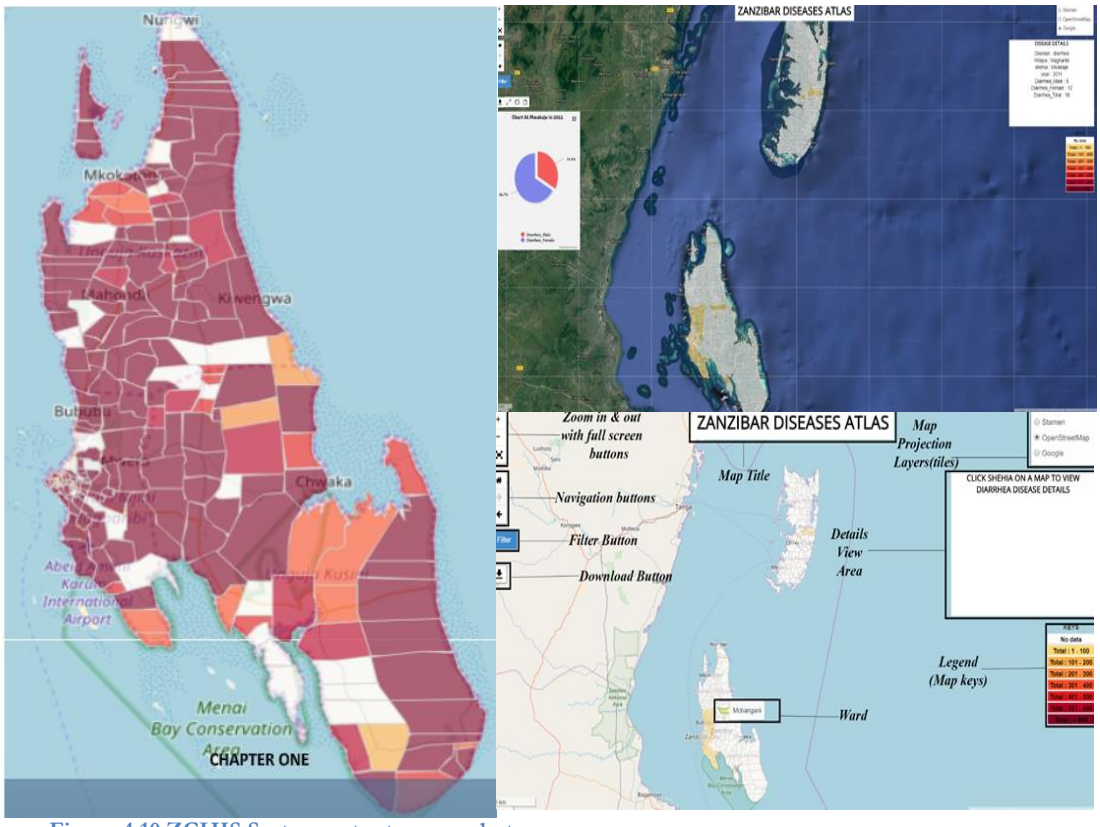


Figure 4.10 ZCHIS System output screen shots.

4.3 . Zanzibar Public Health Informatics Capacity Building

4.3.1.1 Evaluation for Specific Aim 1

The aim of this important step is to evaluate impact of surveillance enhancement on perceived capacity for health surveillance (data quality, usability, availability), and the planning, managing and decision making of public health services.

4.3.1.2 Setting and Sample

The survey population is the DHMTs that are the public health officials at district level in health surveillance, program development and management. Zanzibar has 10 districts, and each district has six DHMT officers. There are five national surveillance officers on Zanzibar, three in Unguja Island, and two in Pemba Island.

4.3.1.3 Questionnaire

The survey questionnaire was adapted from the Commission of State and Territorial Epidemiologist (CSTE) survey to assess the epidemiological capacity at state and local level. The CSTE survey questionnaire consists of 108 questions on the following domains:

a) Background and training of surveillance and public health officials; and

b) Capacity to perform essential public health functions of monitor health status, diagnoses and investigates health problems, evaluate effectiveness, accessibility and quality of health services, and research for new insight and report solutions.

This research survey targeted similar domains of the CSTE survey but were rephrased to fit the Zanzibar contexts and the roles assigned to the DHMTs (4). The questions were presented in the following main Domains.

a) Survey respondent background and training of surveillance and public health officials;

b) Their perception of capacity in health surveillance and data;

c) Their perception of usability of health data; and

d) Their perception, knowledge and capacity to perform essential public health functions of:

d.1) monitoring health status;

d.2) diagnosing and investigating health problems

d.3) evaluating effectiveness, accessibility, and quality of health services; and

d.4) research for new insight and report solutions

d.5) intention and actual use of data for decision making, planning and management of program and services

The design allowed for estimation of changes before and after within groups (DHMTs and national staff) regarding information use for managing, planning and decision making in public health. It will also allow for estimation of differences between trainees in usability, knowledge, skills about software and portal, and knowledge about disease occurrence which could be attributed to the training.

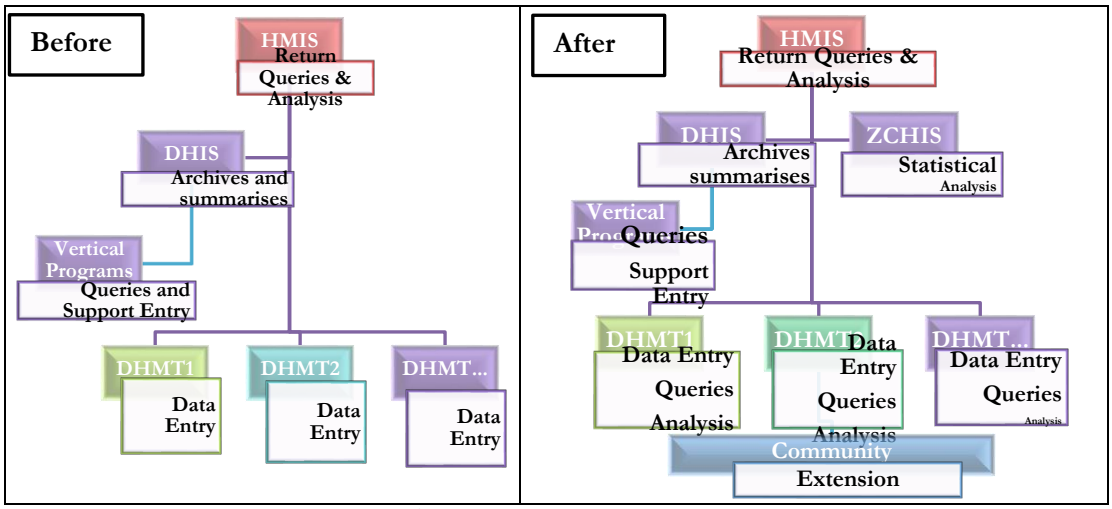


Figure 4.11 Proposed System Architecture for Zanzibar HIS

4.3.1.4 Data Collection

A baseline survey was conducted to define the current situation of informatics skills and data use in performance improvement, planning, decision making, and reporting. Data collected in this survey will serve to evaluate public health officers' familiarity with and ease of use of statistical software and portal, their level of support and activities linked to health surveillance, and their self-reported use of public health data and its applications in decision making, planning and management of public health activities. The questionnaire was uploaded online using a paid service (surveymonkey.com) and the respondents filled them at their own convenience within One month set period. Phone calls were made at users' conveniences in events when navigation or more elaboration was needed. A paper questionnaire was made available to them to minimize time spent on their homes pre-paid internet. The same survey (same questionnaire and methodology) was administered six months after baseline survey (i.e., six months after introduction of software, portal-based analysis, training and reporting of priority diseases in Zanzibar) to the same respondents with their original unique identifiers for post-intervention assessment. Change over the study time period in data usage and application to practice.

4.3.2 Data Analysis for Evaluation

Evaluation of dependent and independent variables was conducted utilizing a linear mixed model using district Designation and time of Intervention if it is before or after. Perception, knowledge and skills (capacity) to perform essential public health measured. Other variables of interest are related to the following domains in the survey questionnaire:

a) Survey respondent background and training of surveillance and public health: participant's characteristics such as age, gender, years of working in public health, formal education and training;

b) Perception of importance of health surveillance data.

4.3.2.1 Measurement of Change:

Outcome values in baseline (before intervention) and follow-up (after intervention) surveys was used to create a measure of changes over time (i.e., value change=after value-before value) for each of the two intervention groups as presented above. Using the change from baseline to follow-up in the "proportion of health officials who agree (agree and strongly agree in a Likert scale) with being better prepared or his local public health office have better capacity to "monitor health status". This follow up sample of the baseline was sufficient to estimate changes in the indicators (i.e., proportion) over time (follow-up – baseline) and between groups for the population of DHMTs. We implemented an aggressive incentive plan (letters to the DHMTs, provision of meals and transportation for each working day, and letters or recognition to develop HMIS research); we managed to keep ever one looped from the beginning of research to the end.

4.3.2.2 Data Processing and Quality Control

Baseline survey responses were downloaded from the survey tool to Excel spreadsheets, and R was used for analysis. Data from both surveys were checked for inconsistencies and questionnaire completeness, and inappropriate response were reviewed. Inappropriate and incomplete values were followed back to the respondents.

4.3.2.3 Data Analysis

4.3.2.3.1 **Baseline Indicators**

An analysis of the baseline indicators to Information use was conducted. While this research is designed to study the change on the indicators due to the capacity building intervention, a foundation of informatics association to baseline indicators was also built. These indicators include if the DHMTs previous training in Epidemiology or Informatics, the years they have worked in the DHMTs (Experience) the years remaining to retirement (Motivation) and if they have received any other training (capacity building). Only revious epidemiologic training showed a strong correlation to Informatics capacity built in this intervention.

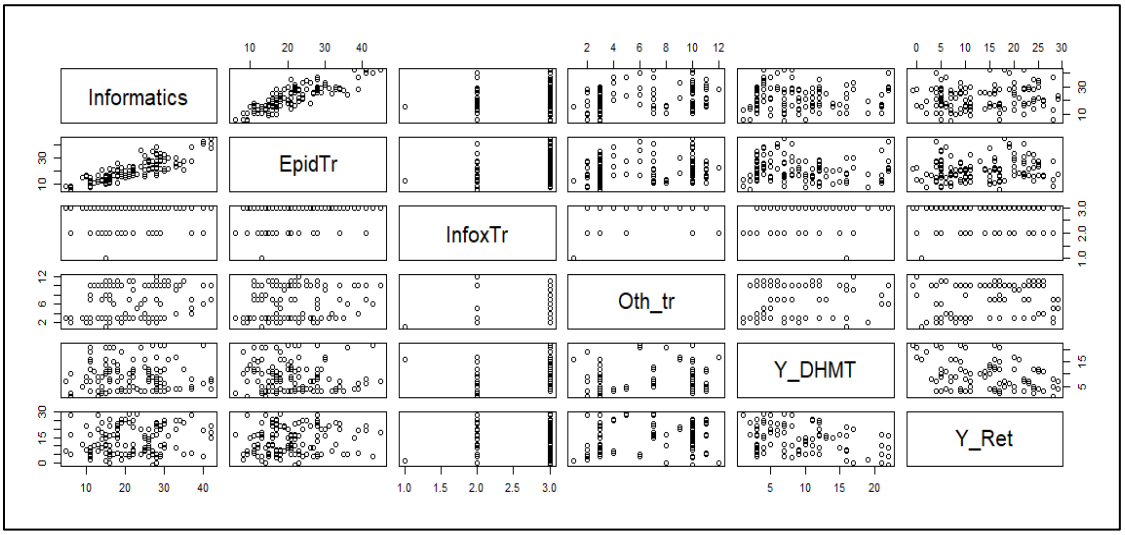


Figure 4.12 Informatics and Baseline Indicators

4.3.2.3.2 **Composite Indicators**

We evaluated dependent variable value difference between the baseline and follow-up measures by levels of independent variables for each of the two groups of respondents: treatment, and control. The appropriate test statistics for these analyses since the dependent variable values were on a Likert scale is non-parametric test and we used a linear mixed effect model using R lme4 and lmeTest. CRAN Libraries. We also evaluated whether dependent variable change from baseline to follow-up. Using the package CRAN Packages lmerTest, lme4, and visualization utilized the ggplot2, the results of analysis of the independent variables with the generalized Linear mixed model was as follows

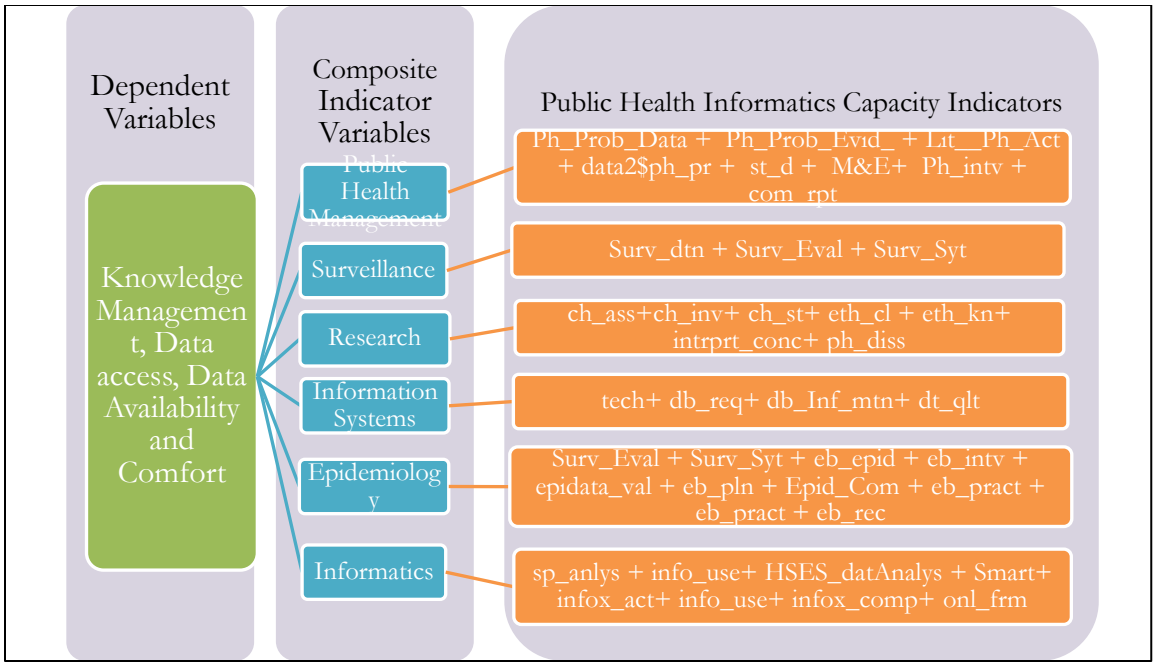


Figure 4.13 Indicators for Information Use Capacity Building

The complete list of Indicators and their full definition is attached in the 6. After a careful review and clustering to the main themes of assessment, the six main categories for reporting results were obtained (Fig. 4.8). These composite indicators are follows:

1. DHMTs' administration and management capacity that includes: identify existence of a public health problem, identify public health problem, and utilize literature for public health action, and monitoring and evaluation (M&E).
2. Surveillance indicators included design and Identify Surveillance data needs, Surveillance evaluation and development of a surveillance system.
3. Research Capacity group includes community health assessment, community health investigation, planning studies for community health, getting ethical clearance for research, apply ethical knowledge to research and conducting a public health Intervention.
4. Informatics System indicators were the use of information technology, designing the database requirements, Information Management and data quality.

5. Epidemiology Indicators grouped the capacity to make recommendation regarding validity of epidemiologic data, to use Current knowledge of causes of disease to guide epidemiological practice, use scientific evidence in preparing recommendations for action or interventions, Communicate epidemiologic information through giving oral presentations or contributing to the development of written documents to non-professional audiences (forum discussions and presentations), assist or develop SMART goals, Assess the needs for special analysis, the basic principles of risk communication and ability to comprehend epidemiologic findings

Informatics indicators included identify informatics activities needs in the DHMT (for performance), Identify informatics, competency needs in the DHMT (for Training), ability to assist or conduct data collection tools, identify data sources and design protocols, conduct data analysis, evaluate conclusion and interpretation, dissemination and participate in online forums.

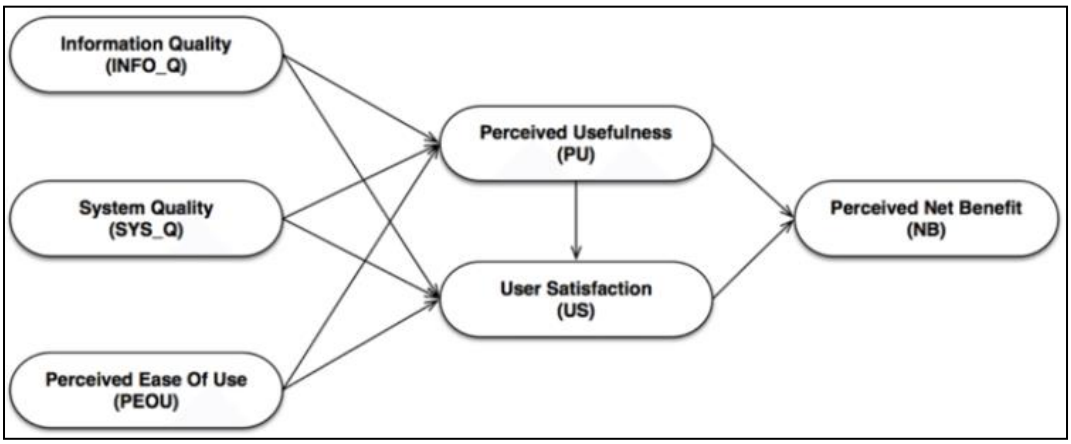


Figure 4.14 Conceptual Model for Adopting the Zanzibar Community Health Information System. Adapted from

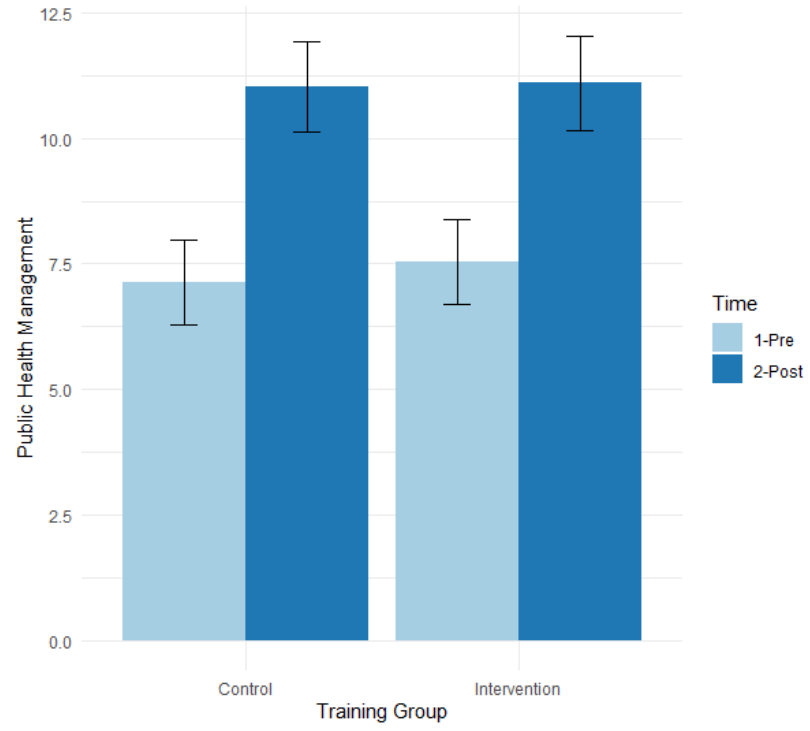
Public Health Management

```
Fixed effects:
                    Estimate Std. Error      df t value Pr(>|t|)
(Intercept)           9.6648     0.8537 45.1046  11.321 8.96e-15 ***
TrainIntervention    -0.1639     0.4509 44.0000  -0.364  0.71792
Time2-Post            3.7333     0.1900 59.0000  19.654  < 2e-16 ***
DesignationDHA       -1.6320     0.7395 44.0000  -2.207  0.03260 *
DesignationDHO       -2.3656     0.7271 44.0000  -3.254  0.00219 **
DesignationDMO        0.6836     0.7058 44.0000   0.969  0.33804
DesignationDPh       -2.1836     0.7058 44.0000  -3.094  0.00343 **
DesignationDPHO      -2.1992     0.7172 44.0000  -3.066  0.00370 **
DistrictCHAKE-CHAKE  -2.4167     0.9093 44.0000  -2.658  0.01092 *
DistrictMICHEWENI    -2.0833     0.9093 44.0000  -2.291  0.02680 *
DistrictMKOANI       -2.3333     0.9093 44.0000  -2.566  0.01377 *
DistrictNorth A       0.8333     0.9093 44.0000   0.916  0.36442
DistrictNorth B      -0.4167     0.9093 44.0000  -0.458  0.64904
DistrictSouth         0.3333     0.9093 44.0000   0.367  0.71568
DistrictUrban         0.5833     0.9093 44.0000   0.642  0.52451
DistrictWestA        -0.8333     0.9093 44.0000  -0.916  0.36442
DistrictWETE         -3.3333     0.9093 44.0000  -3.666  0.00066 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation matrix not shown by default, as p = 17 > 12.
Use print(x, correlation=TRUE)  or
    vcov(x)        if you need it

> anova(modelPh_Mgt)
Type III Analysis of Variance Table with Satterthwaite's method
            Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
Train         0.14    0.14     1    44   0.1322 0.7179210
Time        418.13  418.13     1    59 386.2714 < 2.2e-16 ***
Designation  35.88    7.18     5    44   6.6288 0.0001117 ***
District     50.81    5.65     9    44   5.2156 7.964e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

There is significance of the intercept and the post intervention measurement. For these indicators, there is a significance of Designation/tittle, and some few districts.



The Public Health Management indicators wewe cummulatively improved in both Control and Intervention Groups between the pre and post time periods The Control group equally feel their capacity increased with the training given to them.

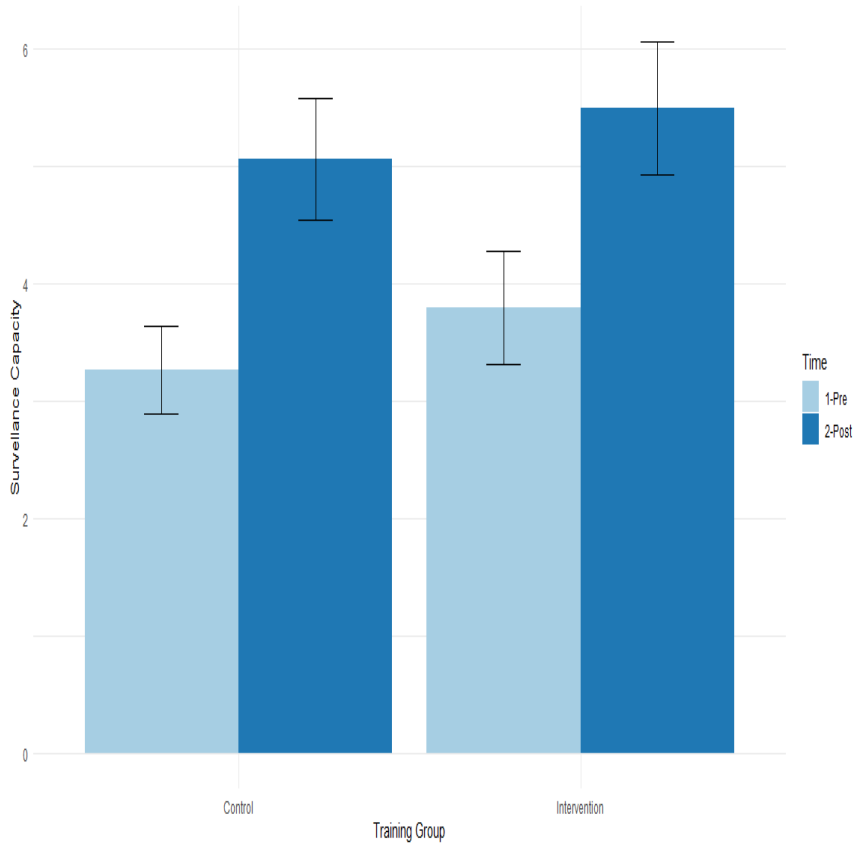
Figure 4.15 Public Health Management Capacity

```
Fixed effects:
                     Estimate Std. Error         df t value Pr(>|t|)
(Intercept)          3.926e+00  5.633e-01  4.518e+01   6.969 1.11e-08 ***
TrainIntervention    2.254e-01  2.974e-01  4.400e+01   0.758 0.452559
Time2-Post           1.750e+00  1.294e-01  5.900e+01  13.527  < 2e-16 ***
DesignationDHA      -1.487e+00  4.878e-01  4.400e+01  -3.049 0.003878 **
DesignationDHO      -1.460e+00  4.796e-01  4.400e+01  -3.044 0.003931 **
DesignationDMO       7.254e-02  4.655e-01  4.400e+01   0.156 0.876885
DesignationDPh      -1.673e+00  4.655e-01  4.400e+01  -3.593 0.000821 ***
DesignationDPHO     -1.432e+00  4.731e-01  4.400e+01  -3.028 0.004109 **
DistrictCHAKE-CHAKE  9.167e-01  5.998e-01  4.400e+01   1.528 0.133583
DistrictMICHEWENI    5.000e-01  5.998e-01  4.400e+01   0.834 0.408983
DistrictMKOANI       1.000e+00  5.998e-01  4.400e+01   1.667 0.102559
DistrictNorth A      5.833e-01  5.998e-01  4.400e+01   0.973 0.336075
DistrictNorth B     -8.333e-02  5.998e-01  4.400e+01  -0.139 0.890131
DistrictSouth       -9.338e-14  5.998e-01  4.400e+01   0.000 1.000000
DistrictUrban        4.167e-01  5.998e-01  4.400e+01   0.695 0.490892
DistrictWestA        4.167e-01  5.998e-01  4.400e+01   0.695 0.490892
DistrictWETE         1.167e+00  5.998e-01  4.400e+01   1.945 0.058161 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation matrix not shown by default, as p = 17 > 12.
Use print(x, correlation=TRUE)  or
    vcov(x)        if you need it

> anova(modelSurv)
Type III Analysis of Variance Table with Satterthwaite's method
            Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
Train        0.288   0.288     1    44   0.5744 0.4525592
Time        91.875  91.875     1    59 182.9747 < 2.2e-16 ***
Designation 14.603   2.921     5    44   5.8167 0.0003309 ***
District     4.825   0.536     9    44   1.0678 0.4048561
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There is significance of the intercept and the post intervention measurement. For these indicators, there is a significance of Designation /tittle, and only one district of Wete.



Indicators wewe cummulatively improved in both Control and Intervention Groups between the pre and post time periods. The intervention slightly improved their surveillance capacity compared to the control group

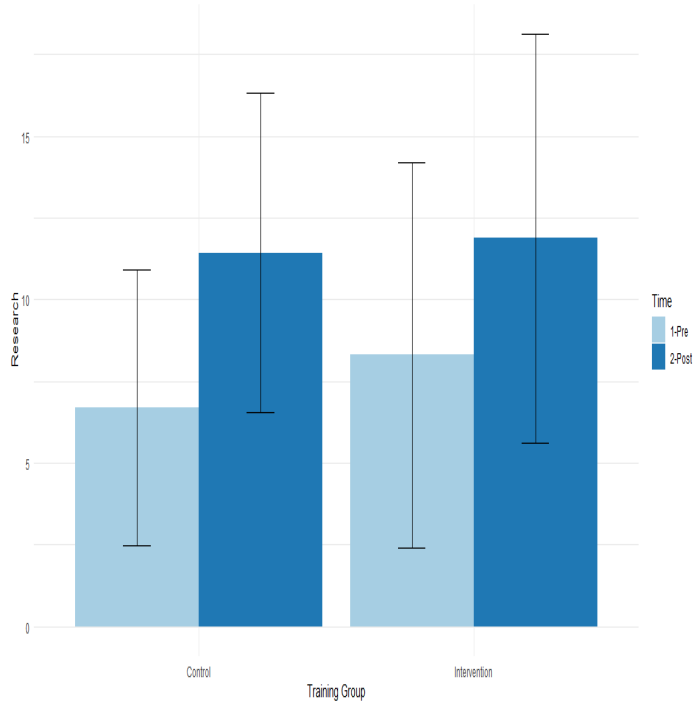
Figure 4.16 Surveillance Capacity

```
Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)        8.485e+00  1.119e+00  4.490e+01   7.581 1.43e-09 ***
TrainIntervention  2.828e-01  5.919e-01  4.400e+01   0.478   0.6352
Time2-Post         5.300e+00  2.246e-01  5.900e+01  23.596  < 2e-16 ***
DesignationDHA    -1.559e+00  9.707e-01  4.400e+01  -1.606   0.1155
DesignationDHO    -1.937e+00  9.543e-01  4.400e+01  -2.030   0.0485 *
DesignationDMO     4.178e+00  9.264e-01  4.400e+01   4.510 4.77e-05 ***
DesignationDPh     4.217e-01  9.264e-01  4.400e+01   0.455   0.6512
DesignationDPHO   -2.265e+00  9.414e-01  4.400e+01  -2.406   0.0204 *
DistrictCHAKE-CHAKE  1.750e+00  1.194e+00  4.400e+01   1.466   0.1497
DistrictMICHEWENI    1.750e+00  1.194e+00  4.400e+01   1.466   0.1497
DistrictMKOANI       1.667e-01  1.194e+00  4.400e+01   0.140   0.8896
DistrictNorth A     -7.500e-01  1.194e+00  4.400e+01  -0.628   0.5330
DistrictNorth B     -3.421e-15  1.194e+00  4.400e+01   0.000   1.0000
DistrictSouth       -2.500e-01  1.194e+00  4.400e+01  -0.209   0.8351
DistrictUrban        4.167e-01  1.194e+00  4.400e+01   0.349   0.7287
DistrictWestA       -2.500e-01  1.194e+00  4.400e+01  -0.209   0.8351
DistrictWETE         1.833e+00  1.194e+00  4.400e+01   1.536   0.1317
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation matrix not shown by default, as p = 17 > 12.
Use print(x, correlation=TRUE)  or
    vcov(x)        if you need it

> anova(modelRcsh)
Type III Analysis of Variance Table with Satterthwaite's method
            Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
Train         0.35    0.35     1    44   0.2283    0.6352
Time        842.70  842.70     1    59 556.7671 < 2.2e-16 ***
Designation  95.48   19.10     5    44  12.6172 1.267e-07 ***
District     17.42    1.94     9    44   1.2787    0.2754
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

There is significance of the intercept and the post intervention measurement. For these indicators, there is a significance of Designation and no significance at district level



While the indicators of research all improve in a similar thrend, the range and variance of this improvement is wider compared to other indicators. in both Control and Intervention Groups between the pre and post time periods.

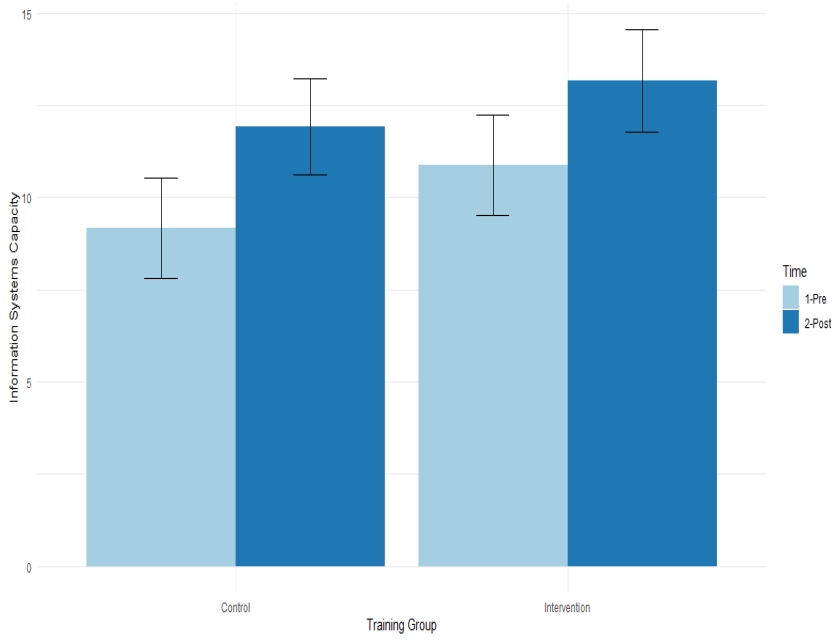
Figure 4.17 Research Capacity

```
Fixed effects:
                        Estimate Std. Error         df t value Pr(>|t|)
(Intercept)           1.442e+01  1.363e+00  4.444e+01  10.579 1.01e-13 ***
TrainIntervention    -3.443e-01  7.229e-01  4.400e+01  -0.476   0.6362
Time2-Post            2.533e+00  1.923e-01  5.900e+01  13.173  < 2e-16 ***
DesignationDHA       -5.322e+00  1.186e+00  4.400e+01  -4.489 5.10e-05 ***
DesignationDHO       -5.638e+00  1.166e+00  4.400e+01  -4.837 1.65e-05 ***
DesignationDMO        5.656e-01  1.131e+00  4.400e+01   0.500   0.6197
DesignationDPh       -1.966e+00  1.131e+00  4.400e+01  -1.737   0.0893 .
DesignationDPHO      -5.253e+00  1.150e+00  4.400e+01  -4.569 3.95e-05 ***
DistrictCHAKE-CHAKE  -3.000e+00  1.458e+00  4.400e+01  -2.058   0.0455 *
DistrictMICHEWENI    -3.583e+00  1.458e+00  4.400e+01  -2.458   0.0180 *
DistrictMKOANI       -2.333e+00  1.458e+00  4.400e+01  -1.601   0.1166
DistrictNorth A       5.833e-01  1.458e+00  4.400e+01   0.400   0.6910
DistrictNorth B       9.167e-01  1.458e+00  4.400e+01   0.629   0.5327
DistrictSouth        -2.269e-12  1.458e+00  4.400e+01   0.000   1.0000
DistrictUrban        -1.667e+00  1.458e+00  4.400e+01  -1.143   0.2591
DistrictWestA        -1.583e+00  1.458e+00  4.400e+01  -1.086   0.2833
DistrictWETE         -2.333e+00  1.458e+00  4.400e+01  -1.601   0.1166
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation matrix not shown by default, as p = 17 > 12.
Use print(x, correlation=TRUE)  or
    vcov(x)        if you need it

> anova(modelIS)
Type III Analysis of Variance Table with Satterthwaite's method
             Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
Train         0.252   0.252     1    44   0.2268   0.63625
Time        192.533 192.533     1    59 173.5153 < 2.2e-16 ***
Designation  61.386  12.277     5    44  11.0644 6.137e-07 ***
District     23.284   2.587     9    44   2.3315   0.03028 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There is significance of the intercept and the post intervention measurement. For these indicators, there is a significance of Designations (DPHO, DHO and DHA), and only slightly significant to districts of Micheweni and Mkoani



Indicators were cummulatively improved in both Control and Intervention groups between the pre and post time periods. The control slightly improved their information system capacity more compared to the control group

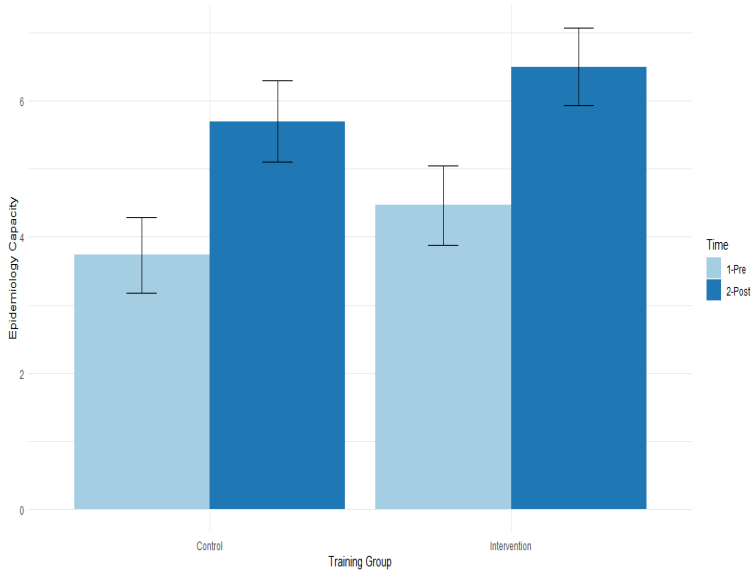
Figure 4.18 Information Systems Capacity

```
Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)         4.912e+00  4.691e-01  4.621e+01  10.471 8.74e-14 ***
TrainIntervention   2.213e-01  2.463e-01  4.400e+01   0.899   0.3737
Time2-Post          2.000e+00  1.465e-01  5.900e+01  13.650  < 2e-16 ***
DesignationDHA     -2.039e+00  4.039e-01  4.400e+01  -5.049 8.19e-06 ***
DesignationDHO     -2.111e+00  3.971e-01  4.400e+01  -5.318 3.36e-06 ***
DesignationDMO      1.022e+00  3.855e-01  4.400e+01   2.652   0.0111 *
DesignationDPh     -1.672e+00  3.855e-01  4.400e+01  -4.338 8.27e-05 ***
DesignationDPHO    -1.834e+00  3.917e-01  4.400e+01  -4.681 2.74e-05 ***
DistrictCHAKE-CHAKE  3.333e-01  4.966e-01  4.400e+01   0.671   0.5056
DistrictMICHEWENI   -7.500e-01  4.966e-01  4.400e+01  -1.510   0.1381
DistrictMKOANI       1.667e-01  4.966e-01  4.400e+01   0.336   0.7388
DistrictNorth A     -3.442e-14  4.966e-01  4.400e+01   0.000   1.0000
DistrictNorth B      3.333e-01  4.966e-01  4.400e+01   0.671   0.5056
DistrictSouth       -4.167e-01  4.966e-01  4.400e+01  -0.839   0.4060
DistrictUrban        9.167e-01  4.966e-01  4.400e+01   1.846   0.0716 .
DistrictWestA        5.833e-01  4.966e-01  4.400e+01   1.175   0.2464
DistrictWETE         6.667e-01  4.966e-01  4.400e+01   1.342   0.1863
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation matrix not shown by default, as p = 17 > 12.
Use print(x, correlation=TRUE)  or
    vcov(x)        if you need it

> anova(modelEpid)
Type III Analysis of Variance Table with Satterthwaite's method
             Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
Train         0.520   0.520     1    44   0.8077   0.37370
Time        120.000 120.000     1    59 186.3158 < 2.2e-16 ***
Designation  69.977  13.995     5    44  21.7296  6.77e-11 ***
District     11.883   1.320     9    44   2.0500   0.05582 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>
```

There is significance of the intercept and the post intervention measurement. For these indicators, there is a significance of all Designations and slightly in the Urban District.



ndicators wewe cummulatively improved in both Control and Intervention Groups between the pre and post time periods. The intervention slightly improved their surveillance capacity compared to the control group

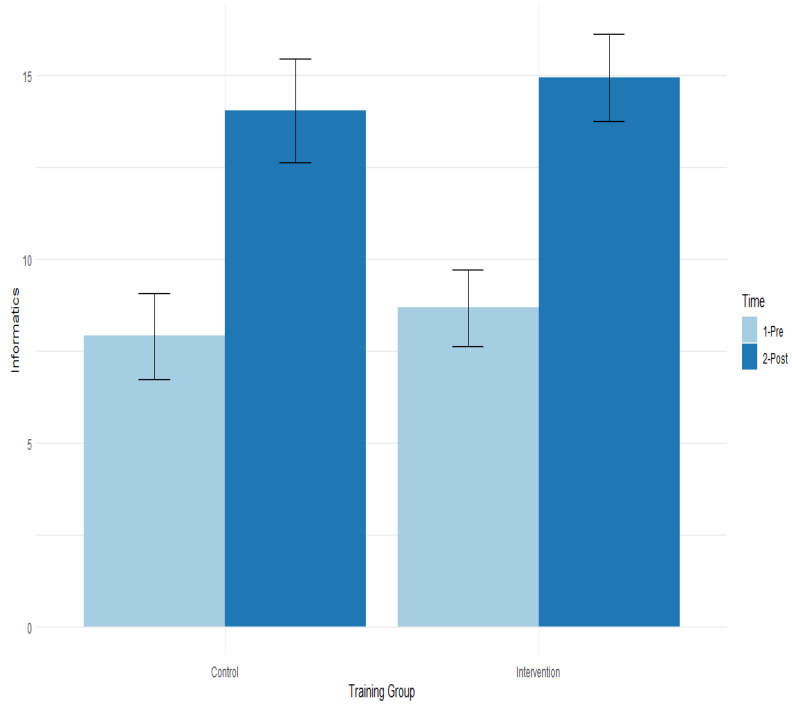
Figure 4.19 Epidemiology Capacity

```
Fixed effects:
                  Estimate Std. Error       df t value Pr(>|t|)
(Intercept)       11.31721    0.83889 46.06219  13.491  < 2e-16 ***
TrainIntervention -0.02459    0.44074 44.00000  -0.056 0.955760
Time2-Post         6.20000    0.25356 59.00000  24.452  < 2e-16 ***
DesignationDHA    -3.26230    0.72287 44.00000  -4.513 4.73e-05 ***
DesignationDHO    -3.30984    0.71068 44.00000  -4.657 2.96e-05 ***
DesignationDMO     2.79754    0.68987 44.00000   4.055 0.000201 ***
DesignationDPh    -2.99754    0.68987 44.00000  -4.345 8.09e-05 ***
DesignationDPHO   -2.65738    0.70105 44.00000  -3.791 0.000454 ***
DistrictCHAKE-CHAKE -2.66667    0.88880 44.00000  -3.000 0.004429 **
DistrictMICHEWENI -3.00000    0.88880 44.00000  -3.375 0.001549 **
DistrictMKOANI    -4.41667    0.88880 44.00000  -4.969 1.07e-05 ***
DistrictNorth A    0.16667    0.88880 44.00000   0.188 0.852116
DistrictNorth B   -1.25000    0.88880 44.00000  -1.406 0.166633
DistrictSouth     -1.16667    0.88880 44.00000  -1.313 0.196114
DistrictUrban      0.41667    0.88880 44.00000   0.469 0.641530
DistrictWestA      0.83333    0.88880 44.00000   0.938 0.353573
DistrictWETE      -3.41667    0.88880 44.00000  -3.844 0.000386 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation matrix not shown by default, as p = 17 > 12.
Use print(x, correlation=TRUE)  or
    vcov(x)        if you need it

> anova(modelInformatics)
Type III Analysis of Variance Table with Satterthwaite's method
             Sum Sq Mean Sq NumDF DenDF  F value    Pr(>F)
Train          0.01    0.01     1    44   0.0031    0.9558
Time        1153.20 1153.20     1    59 597.8805 < 2.2e-16 ***
Designation  240.48   48.10     5    44  24.9355 7.938e-12 ***
District     146.92   16.32     9    44   8.4634 3.356e-07 ***
---
```

There is significance of the intercept and the post intervention measurement. For these indicators, there is a significance of Designation/tittle, and all districts of Pemba side (Micheweni, Wete and Mkoani and Chake Chake.



Indicators wewe cummulatively improved in both ontrol and Intervention Groups between the pre and post time periods. The informatics capacity building has experience a huge jump of the skills trainined.

Figure 4.20. Informatics Capacity

A thorough analysis was conducted to the Informatics category, since Informatics capacity building is the main target of this research. The main focus was based on the mixed model results in how results of the model coefficients differed between the control and intervention group, between pre and post intervention, and between the different districts and between the titles they hold in the DHMTs (Designation). A special emphasis was placed on gender differences across to inform policy on gender equality to workforce and capacity building. The overall composition of female in this study was 36.7%. In general, as was seen in the models presented above, Informatics capacity building in Zanzibar showed significant variation based on the Designation more than it varied across DHMTS. The uniformity in the teams responses is thought to be related with the fact that capacity building activities to the DHMTs are generally a national undertaking that involve all of the teams in similar training and help them build their capacities in parallel; which is also an indicator of inability of the teams to determine capacity gaps needed to train their own teams with full autonomy.

With the exception of a few districts DHMTs, most have responded equally to the intervention with the rate of improvement similar between the male and female workforce.

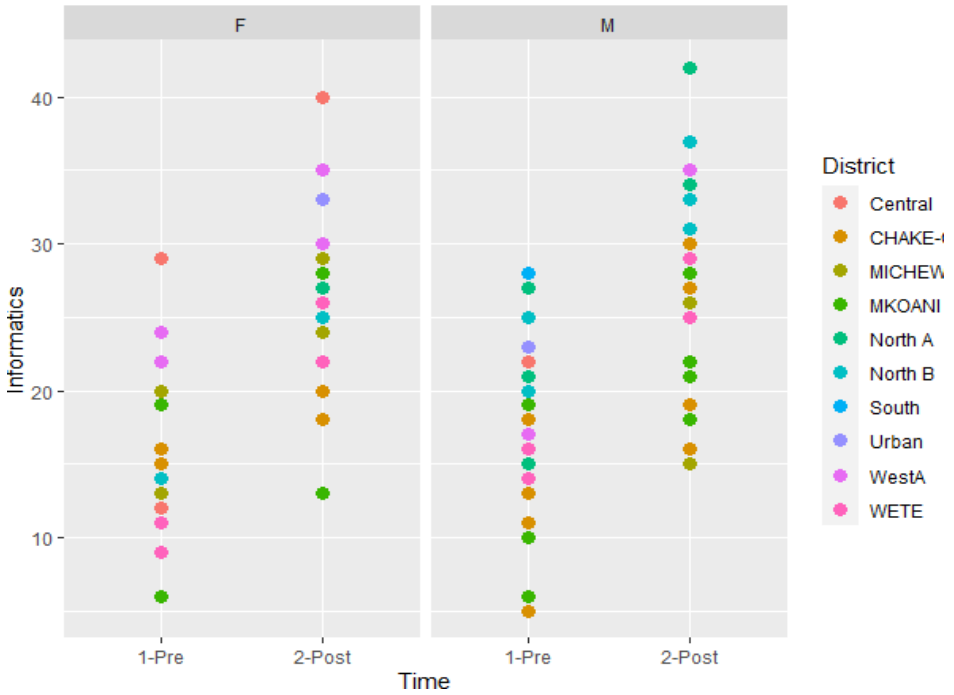


Figure 4.21 Information System Integrated Health after System and DHMTs Capacity Building

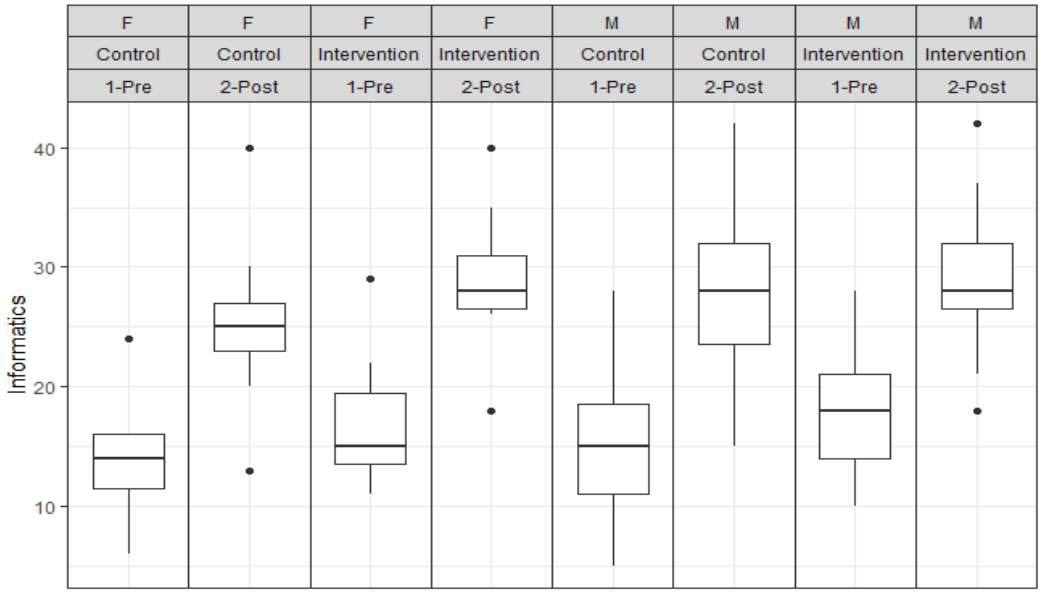


Figure 4.22 Informatics capacity build by Gender Group and Time

As the intervention was split into control group which received Excel based training on Statistical analysis and intervention which receives the Informatics Capacity Building training using ZCHIS, there was no significant difference in capacity building between the control and intervention groups. However, they all responded with improved capacity, which could have multiple implications. These teams have not been receiving routine informatics training to an extent that even analytics using MS Excel had shown significant improvement in their informatics confidence. It could also mean, ZCHIS as a system had not been exhausted enough to allow difference to show in informatics competence, in other words, it improved the capacity as little as any analytic training would, be it Excel or any other data analytics intervention. Subjects of the intervention could also be individually assessed to allow tracking in the future repetition of this survey, as ZCHIS is being improved among other Health system capacity improvement initiative. The most important thing for this analysis is to establish the culture of DHMT capacity measurement, and documenting how their respective districts, their capacities and experiences, their designations and roles placed on individual personnel contribute to ensure Informatics capacity is built. The following plots would be a dashboard output after interventions to study DHMTs individual responses.

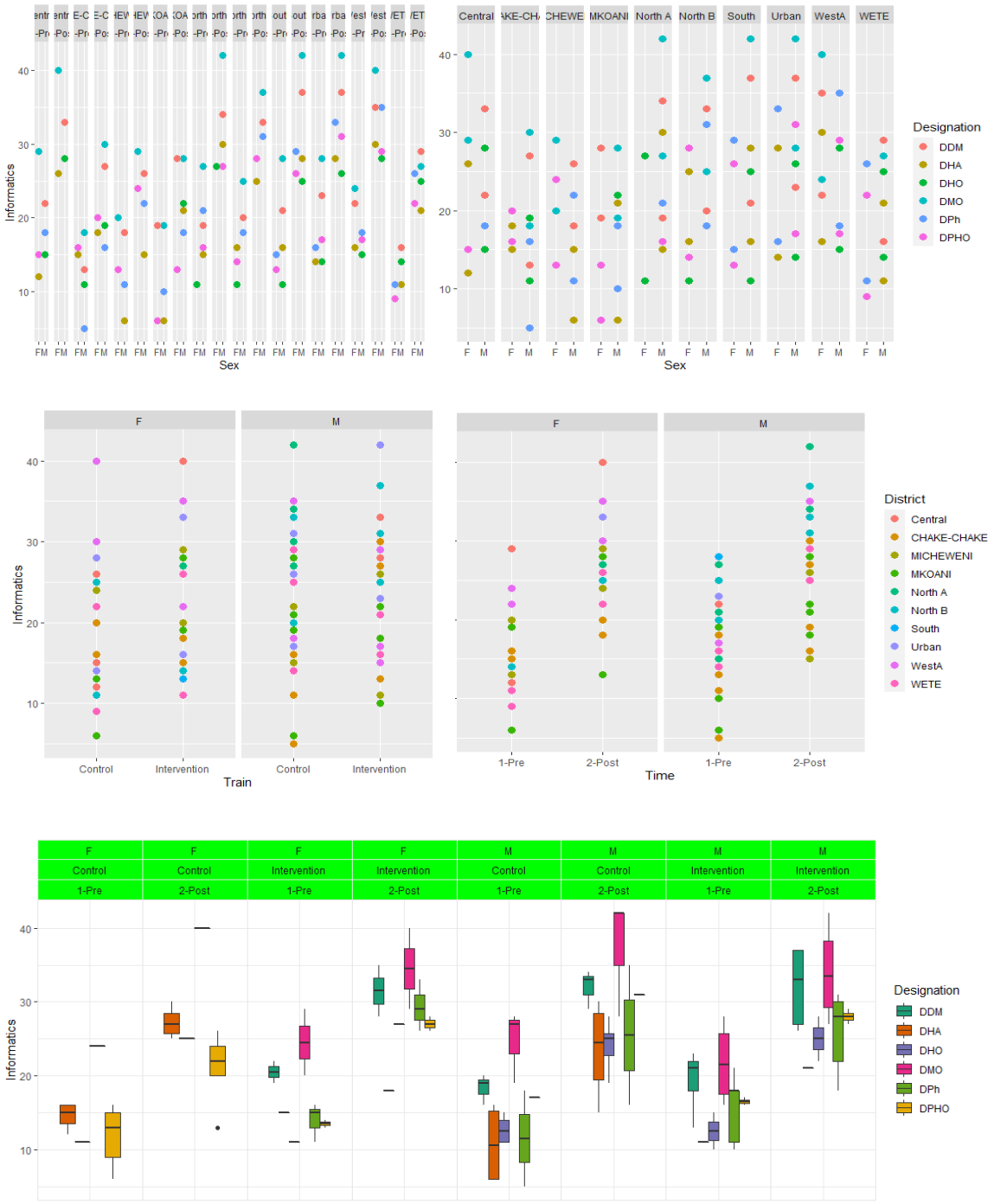


Figure 4.23 Informatics capacity built by District Designation and Gender Group and Time

Lastly, a prediction was conducted based on the coefficients of the mixed model on informatics capacity building indicators. This was conducted on each individual compared between Designation, District and pre-and-post measurements of informatics indicators performance as follows.

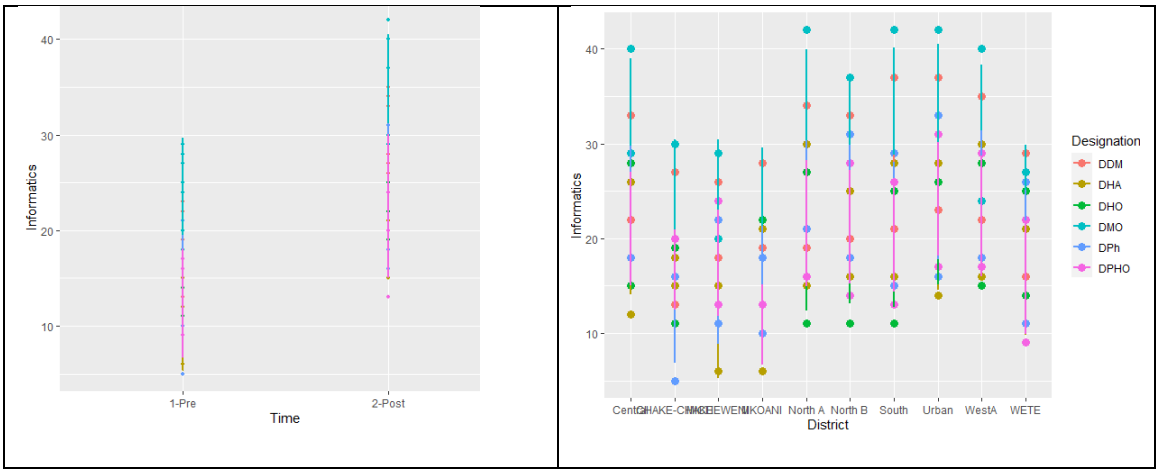


Figure 4.24 Informatics Capacity building Prediction by District and Designation

The analysis was conducted to test the dependent variables of knowledge management, data access, data availability and comfort of data use. The differences on skills improvement were analyzed with fixed effects of Districts, Designation, and time before and after intervention.

4.3.2.3.3 Information Use Dependents Variables Measures (outcomes)

The main outcomes of the intervention are in a logical order:

a) Better and more accessible public health data for planning and implementation of public health programs and services (Data availability);

b) Improved training in health surveillance on Zanzibar; (Knowledge of data); and

c) Better use of health surveillance data for planning, managing and decision making in public health services (Ease of access and use of data and Comfort of using data). Dependent variables will be used to measure outcomes at baseline, and a measure of its change as a function of the impact of the surveillance improvement strategy.

4.3.2.3.3.1 Knowledge Management

The DHMTs' knowledge management was perceived to be high at the beginning of the intervention with an intercept of 3.9 out of 5. However, there is a consistent decrease of this perception between

the pre and post intervention periods. There is also a slight significance observed due to designation by the Pharmacists with a p value of 0.02

```
Fixed effects:
                             Estimate Std. Error         df t value Pr(>|t|)
(Intercept)                 3.900e+00  4.278e-01  4.498e+01   9.116 8.73e-12 ***
TrainIntervention           2.623e-01  2.261e-01  4.400e+01   1.160   0.2523
Time2-Post                  4.000e-01  8.957e-02  5.900e+01   4.466 3.66e-05 ***
data2$DesignationDHA       -4.689e-01  3.708e-01  4.400e+01  -1.264   0.2128
data2$DesignationDHO       -2.951e-01  3.646e-01  4.400e+01  -0.809   0.4227
data2$DesignationDMO        3.762e-01  3.539e-01  4.400e+01   1.063   0.2936
data2$DesignationDPh       -8.262e-01  3.539e-01  4.400e+01  -2.335   0.0242 *
data2$DesignationDPHO      -1.713e-01  3.596e-01  4.400e+01  -0.476   0.6362
data2$DistrictCHAKE-CHAKE   4.167e-01  4.560e-01  4.400e+01   0.914   0.3658
data2$DistrictMICHEWENI    -2.500e-01  4.560e-01  4.400e+01  -0.548   0.5863
data2$DistrictMKOANI       -1.352e-13  4.560e-01  4.400e+01   0.000   1.0000
data2$DistrictNorth A      -2.500e-01  4.560e-01  4.400e+01  -0.548   0.5863
data2$DistrictNorth B      -5.833e-01  4.560e-01  4.400e+01  -1.279   0.2075
data2$DistrictSouth        -1.667e-01  4.560e-01  4.400e+01  -0.366   0.7165
data2$DistrictUrban         4.167e-01  4.560e-01  4.400e+01   0.914   0.3658
data2$DistrictWestA         8.333e-02  4.560e-01  4.400e+01   0.183   0.8558
data2$DistrictWETE         -5.000e-01  4.560e-01  4.400e+01  -1.097   0.2788
---
```

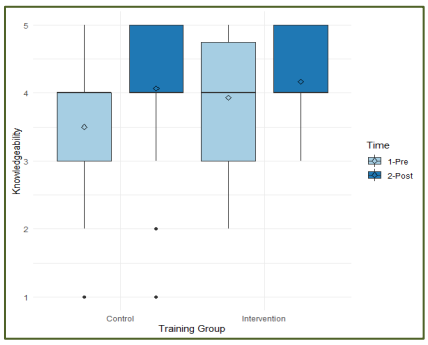


Figure 4.25 Knowledge Capacity Improvement

4.3.2.3.3.2 Accessibility

The DHMTs perception of data access was perceived to be very high at the beginning of the intervention with an intercept of 4.3 out of 5. However, there is a consistent decrease of this perception between the pre and post intervention periods. There is also a slight significance observed due to designation by the Pharmacist (p= 0.02) and DHO (p= 0.03).

```
Fixed effects:
                            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)                  4.30328    0.40676 45.67425  10.579 7.19e-14 ***
TrainIntervention            0.35246    0.21417 44.00000   1.646  0.10695
Time2-Post                  -0.35000    0.11104 59.00000  -3.152  0.00255 **
data2$DesignationDHA        -0.47377    0.35126 44.00000  -1.349  0.18431
data2$DesignationDHO        -0.75902    0.34534 44.00000  -2.198  0.03326 *
data2$DesignationDMO        -0.31475    0.33523 44.00000  -0.939  0.35289
data2$DesignationDPh        -0.73525    0.33523 44.00000  -2.193  0.03362 *
data2$DesignationDPHO       -0.54426    0.34066 44.00000  -1.598  0.11727
data2$DistrictCHAKE-CHAKE   -0.08333    0.43189 44.00000  -0.193  0.84789
data2$DistrictMICHEWENI      0.16667    0.43189 44.00000   0.386  0.70143
data2$DistrictMKOANI        -0.08333    0.43189 44.00000  -0.193  0.84789
data2$DistrictNorth A       -0.33333    0.43189 44.00000  -0.772  0.44436
data2$DistrictNorth B       -0.50000    0.43189 44.00000  -1.158  0.25323
data2$DistrictSouth         -0.25000    0.43189 44.00000  -0.579  0.56564
data2$DistrictUrban          0.16667    0.43189 44.00000   0.386  0.70143
data2$DistrictWestA         -0.08333    0.43189 44.00000  -0.193  0.84789
data2$DistrictWETE          -0.25000    0.43189 44.00000  -0.579  0.56564
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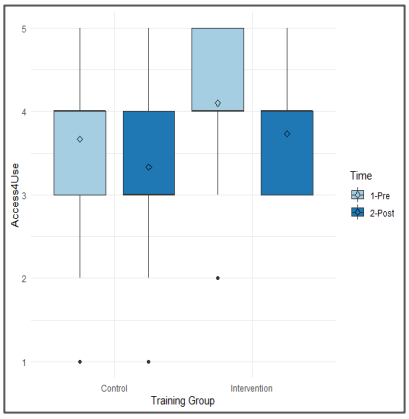

Figure 4.26 Information Access improvement

4.3.2.3.3.3 Availability

The DHMTs perception of data availability was perceived to be very high at the beginning of the intervention with an intercept of 4 out of 5. However, there is a consistent decrease of this perception between the pre and post intervention periods. There is also a slight significance observed

```
Fixed effects:
                            Estimate Std. Error       df t value Pr(>|t|)
(Intercept)                  4.01202    0.46395 45.96458   8.647 3.37e-11 ***
TrainIntervention           -0.04098    0.24389 43.99999  -0.168  0.86732
Time2-Post                  -0.40000    0.13696 59.00001  -2.921  0.00494 **
data2$DesignationDHA        -0.37049    0.40001 43.99999  -0.926  0.35939
data2$DesignationDHO        -0.51639    0.39326 43.99999  -1.313  0.19595
data2$DesignationDMO        -0.25410    0.38174 43.99999  -0.666  0.50913
data2$DesignationDPh        -0.59590    0.38174 43.99999  -1.561  0.12569
data2$DesignationDPHO       -0.01230    0.38793 43.99999  -0.032  0.97486
data2$DistrictCHAKE-CHAKE   -0.08333    0.49182 43.99999  -0.169  0.86623
data2$DistrictMICHEWENI     -0.58333    0.49182 43.99999  -1.186  0.24196
data2$DistrictMKOANI        -0.16667    0.49182 43.99999  -0.339  0.73632
data2$DistrictNorth A       -0.08333    0.49182 43.99999  -0.169  0.86623
data2$DistrictNorth B       -0.75000    0.49182 43.99999  -1.525  0.13443
data2$DistrictSouth         -0.08333    0.49182 43.99999  -0.169  0.86623
data2$DistrictUrban          0.33333    0.49182 43.99999   0.678  0.50148
data2$DistrictWestA          0.83333    0.49182 43.99999   1.694  0.09726 .
data2$DistrictWETE          -0.75000    0.49182 43.99999  -1.525  0.13443
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
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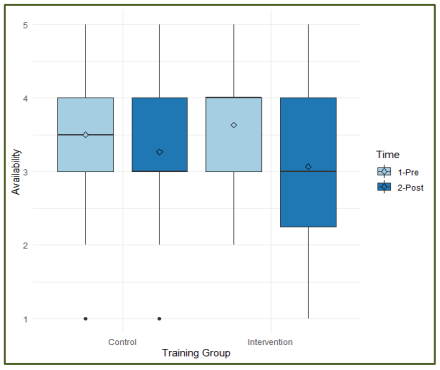

Figure 4.27 Information Availability

due to designation by the Pharmacist and DHO with a p value of 0.09. The perception of availability of quality information has consistently been reduced among the DHMTS with the exception of two districts or Urban and West.

4.3.2.3.3.4 Comfort Using the System

The DHMTs perception of data use comfort was perceived to be high at the beginning of the intervention with an intercept of 3.875. There is a decrease of this perception between the pre and post intervention periods. There is a slight significance observed due to designation by the Pharmacist and DHA (p=0.04) DHO (p=0.0039) and DPHO (p=0.046)

```
Fixed effects:
                            Estimate Std. Error         df t value Pr(>|t|)
(Intercept)                3.875e+00  4.513e-01  4.734e+01   8.586 3.25e-11 ***
TrainIntervention          1.066e-01  2.355e-01  4.400e+01   0.453  0.65312
Time2-Post                 3.167e-01  1.722e-01  5.900e+01   1.839  0.07097 .
data2$DesignationDHA      -7.967e-01  3.862e-01  4.400e+01  -2.063  0.04505 *
data2$DesignationDHO      -1.157e+00  3.797e-01  4.400e+01  -3.048  0.00389 **
data2$DesignationDMO      -3.934e-02  3.686e-01  4.400e+01  -0.107  0.91548
data2$DesignationDPh      -7.607e-01  3.686e-01  4.400e+01  -2.064  0.04497 *
data2$DesignationDPHO     -7.680e-01  3.746e-01  4.400e+01  -2.051  0.04630 *
data2$DistrictCHAKE-CHAKE -2.500e-01  4.749e-01  4.400e+01  -0.526  0.60121
data2$DistrictMICHEWENI   -5.833e-01  4.749e-01  4.400e+01  -1.228  0.22582
data2$DistrictMKOANI      -1.667e-01  4.749e-01  4.400e+01  -0.351  0.72728
data2$DistrictNorth A     -8.196e-15  4.749e-01  4.400e+01   0.000  1.00000
data2$DistrictNorth B     -5.833e-01  4.749e-01  4.400e+01  -1.228  0.22582
data2$DistrictSouth        8.333e-02  4.749e-01  4.400e+01   0.175  0.86150
data2$DistrictUrban       -8.625e-15  4.749e-01  4.400e+01   0.000  1.00000
data2$DistrictWestA        8.333e-02  4.749e-01  4.400e+01   0.175  0.86150
data2$DistrictWETE        -1.167e+00  4.749e-01  4.400e+01  -2.457  0.01803 *
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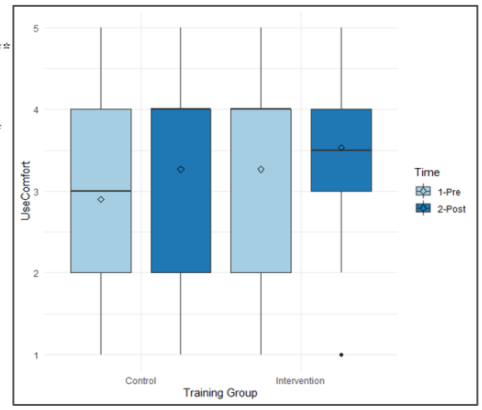

Figure 4.28 Comfort Using the System

Chapter 5. Discussion and Conclusion

5.1. Analysis of Human Resource Capacity Building

The main outcome variables were assessed for before and after the intervention. Additionally, the effect of designation and district showed some significant differences.

5.1.1. Availability of quality data for Public health analysis

The mean perception of availability of data has been reduced among the control group who were trained with Excel/data analysis, also among the Intervention group who were trained with ZCHIS. The ZCHIS group had a higher perception in the beginning of the of data availability, until by the end of the research the two groups came to consensus. Intervention and Control groups have had nearly the same mean perception of 3 out of 5. This is interpreted to be a dissatisfaction of the situation after capacity building, knowing how Informatics could enhance their work, has there been available quality information that ZCHIS systems and other analysis do require. The declined perception is an indicator of awareness on the quality gaps the information still has, until recommendations of this research are fully adopted; where it is expected this outcome will be reversed. ZCHIS system has helped to portray poor access of useable data for use and create demand for quality Information.

5.1.2. Knowledge of the Data

Both the control and the intervention group have increased their perception of knowledge of surveillance data. The two groups have started with similar perception with a minor diversity from the Intervention group, and have reached to the same conclusions irrespectively. This shows a minimum impact the ZCHIS have to the intervention, but the most important thing that has raised their knowledge is conducting analysis even if using Excel statistics.

5.1.3. Accessibility

Ease of access and use of data, have decrease in both groups, perhaps for similar grounds seen in their perception of Availability in (i) above. There is a slight difference of perception of Accessibility between the two groups after the study. Since the control group received excel analysis, they have not

as much been exposed to a system integration perspective like the ZCHIS group, which had the opportunity to train on integration and hence "accessibility". Hence, even if both variables dropped, the Intervention group drop has been minor knowing even if the quality data is not available, it is accessible through system integrations

5.1.4. Comfort of using data

The outcomes on this variable are measuring their comfort on using the information after knowledge gained in this intervention but again the, system is not fully adapted to change their work settings. The excel group has reported an increased comfort in using the data. The ZCHIS group on the other hand has shown mixed results. Majority of the subject who perceived high comfort management have dropped their perceptions, and the mean comfort especially of those who were not comfortable has increased

5.2. Analysis of Systems Capacity Building

The success in creating informatics culture depends heavily on the usability enhancement especially for first time users of such systems. The users were supported to enable use of the system on their own, however that has been very challenging given their capacities. Focus group discussions conducted between the research and the DHMTs each separately revealed

a. Statistical reasoning is a learning process, and more simplified analysis and visualizations would have been the first step to begin this process
b. The outdated data (2010-2012), while their work requires up to date information
c. DHIS and ZCHIS databases are not integrated making them work on two separate systems

It was communicated to them during the discussion that HMIS data is the ultimate goal of this research. Due to the quality and structure of current data, better methods to maximize validity of HMIS data are needed like the interrupted time series and dose-response national platform approach which studies the outcome associated by intervention coverage or intensity at a subnational level [93]. Analysis can also be supported by applying missing data

techniques for example the geo-statistical modeling allowing estimation outpatient data for provinces in Kenya [86]. A rigorous biostatistics approach to this analytical environment can improve the meaning of this system as long the R engine is up and running to support it.

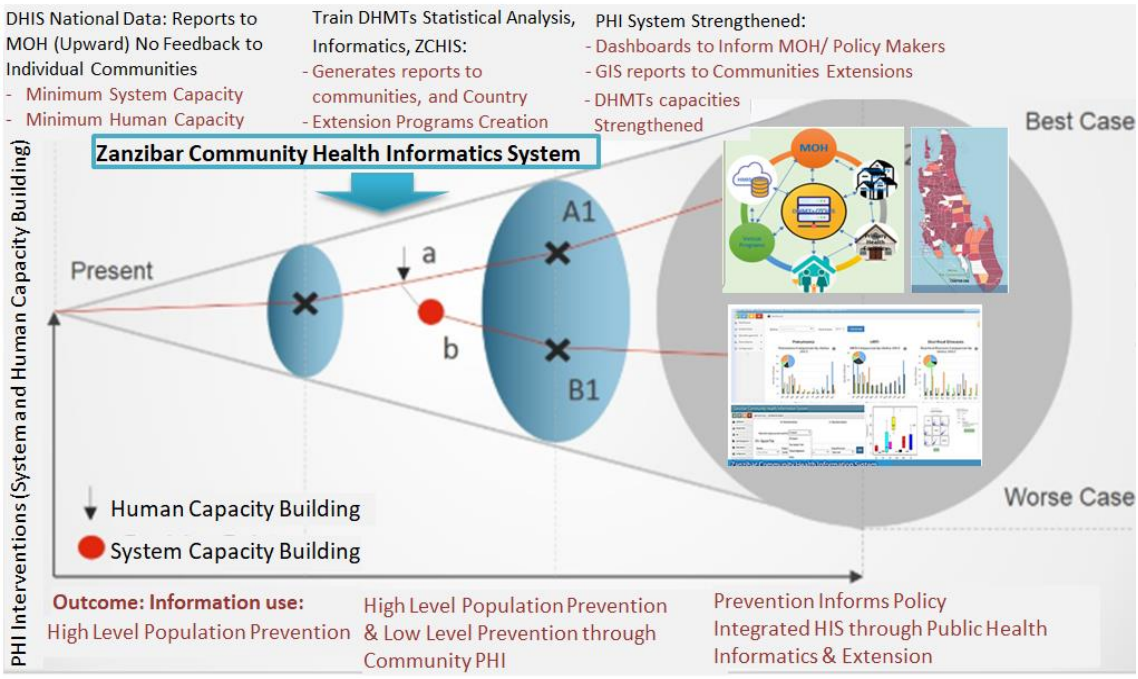

Figure 5.1 Zanzibar HIS with System and DHMTs Capacity Building Interventions

The overall picture is presented in the above diagram where the Y Axis analysis represents the input into the system which is the PHI capacity building. The X Axis different levels of information use based on forces types of the interventions introduced into the system.

5.2.1. Future of HMIS Zanzibar

HMIS data must be useful as far as its objectives, and to the expectations of its stakeholders. Funds can be saved in conducting evaluations [85] using HMIS data and in exchange, support data quality and operations that have deteriorated with DANIDA's absence. The data use strategies must be encompassed within the enterprise architecture frameworks where all building blocks and stakeholders of HMIS information are properly[98]. While HMIS stretched its efforts to suit the needs of VPs, these programs could assist HMIS in data quality initiatives like quarterly feedback

meeting and data use workshops that have established the evidenced success for HMIS Zanzibar. HMIS needs a sustainability strategy that can be fully supported by MOH and VPs substantially.

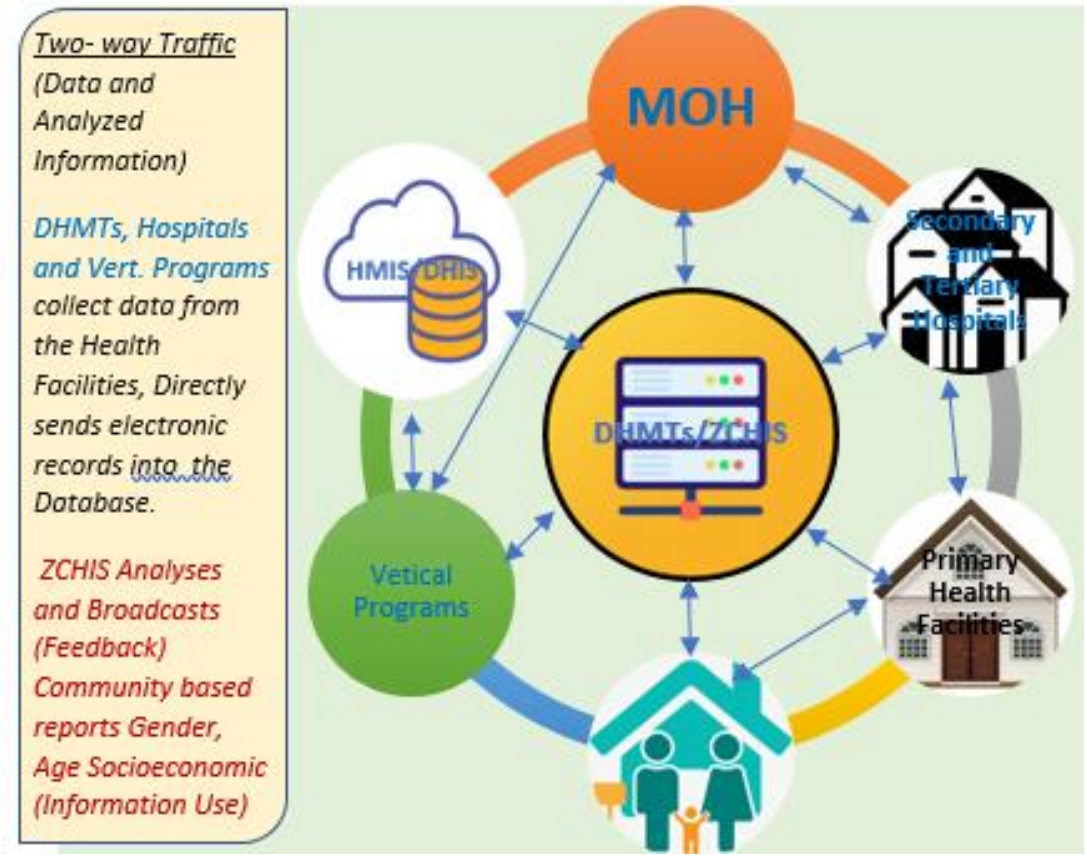

Figure 5.2 Information System Integrated Health after System and DHMTs Capacity Building

5.2.2. Future of ZCHIS

The developed system is a beginning that will enable utilizing the DHIS data presently and in the future as a real time analytical extension that the country has never had. These data integration between Census and DHIS will give hands-on capacity to users of all the levels to make inferences on set indicators at a lower community/geographical level and analyzed with socioeconomic determinants, demographic categories and community clusters. Once the informatics culture is built, it is expected that other national surveys and vital statistics could be pulled into a single data warehouse in such a way the objective of HIS will be met. To utilize this benefit, it is recommended for HMIS to i) De-aggregate the 15 years of DHIS data using statistical estimation to reflect shehia

level, ii) Initiate facility level DHIS data entry for the future data and iii) Implement EHR or roll out the OpenMRS initiative

DHIS data is used across almost all Sub Saharan countries, North Africa, Middle East, and Far East, and success obtained from this project could call upon countries to compare their population's health outcomes using DHIS data census and other demographic and health surveys. With the modern text reading applications [181], it might be useful to test register re-entering of the data from facility level, an initiative that will save Ministry of Health many man-hours and ensure data quality. As a way forward to this work two things must be done and hereby proposed as follows:

1. Automatic mainstreaming of DHIS data into the ZCHIS as opposed to manual data collection that was implemented in the development of ZCHIS. A Python script is being tested to see if the remaining ten years of data can be ad-hoc queried from DHIS to ZCHIS for analysis
2. DHIS data collection must outgrow the paper data collection from the health facilities that leads to aggregation at district level. it was found out that Data collection in the DHIS is capable to be conducted from the health facilities with no additional programming apart from minimal customization that the office of HMIS can take care of. The facilities are partially distributed with computers and training can be easily conducted by the HMIS unit itself.
3. Big data analytics and visualization must be enhanced to amplify the need, benefit, and improve usability of the information systems that improve knowledge use.

ZCHIS remains to be an ever-growing project for Public Health Informatics to be built and improved for users by users.

5.3. Lessons Learned

Health Information Workforce: Although the most concepts reported regarding the health workforce is their lack of capacity, working with the District Health Management Teams has exposed the

researcher on a rare spotted fact of their dedication to serve the population health. Literature does acknowledge how under-resourced this workforce is, and the field work has shown how their work hours, safety and enthusiasm is compromised in such low resource settings.

Additionally, there was an observed tendency of eagerness to learn. This intervention has been successful owing to the overarching demand to gain skills that will improve their work. It is the national team who perceive the DHMTs as facilitators of the national data and operational needs, rather than having separate lines of duties to population health.

Systems Perspective: According to literature, developing countries are susceptible to un-sustained information systems and this is tied to a lack of funding and cost of maintenance. As much as this still holds, two dynamics are becoming extremely useful to solve the sustainability issue: Health Information system Strengthening (standards, integration and Workforce generation) and Information use (from demand, Quality, Accessibility and Workforce generation).

5.4. Limitations and Potential Threats to Validity

This research has faced one major limitation on the assessment of capacity building to the workforce and the system. The responses have been questionable due to the limited perception on the scales of competencies they are required to be in to conduct their work successfully. In a likert scale, a DHMT will report 5 or 4 to a subject area that if assessed by third party instruments, would rate 1 or 2. On the other hand, there is a threat of bias, as the researcher has closely worked with the group to an extent, there is a possibility of ensuring there is a positive response and not perceiving the research as a diagnostic tool to their ongoing situation.

5.5. Recommendations

This research has analyzed two major issues facing Zanzibar's Information System: The health information workforce capacities, and the integrated information system.

The first recommendation is to have a country's assessment of the main systems organs and how much the information being produced is suitable and readily available for information use. While

informaticians will always be engaged in developing systems that improve information use, it is the role of epidemiologists in the countries before computerization to define and streamline information pipelines that support decision making. Documentation of these detailed relationships will not only spot information gaps available but will build information use capacity from within, in such a way, informaticians task with be a guarantee of success and sustainability. Informaticians in these projects as seen with the deployment of DHIS in 2005 are faced with both roles, to introduce dataset indicators and digitize its use. HISP developed DHIS software for collecting and aggregating health statistics, shaped the culture of information use for management, training of local technologists, decision-makers, and health managers, and research Zanzibar Information systems in ways it has not been conducted before. From this recommendation the what-how of the Workforce and the system, will be determined. Few that were observed and are recommended as part of this research are:-

a) Zanzibar needs to train and produce statistics, informatics, and epidemiologist workforces to sustain its public health especially at district level. The success of DHIS seen to-date, and the current informatics research being conducted a decade later are product of few individuals that the HIPS project invested on training from On-job, to formal Masters and Ph.Ds. in Norway and Dar es Salaam. The limitation they face is the country does not have a comprehensive workforce that other African countries do have. While in Zambia there is an epidemiologist from community level to national level, all communicating through their council and through their hierarchies, until recently Zanzibar has not have even more than 5 of such. The national epidemiology unit of the Ministry of Health has only two epidemiologists. Similarly, the Ministry of Health does not have any unit dedicated for Statisticians, apart from the HMIS unit which has a position of one Statistics officer to oversee the country's health statistics under the umbrella of Zanzibar Chief Statistician Office.
b) As in system sustainability, the Vertical Health Programs have been assisted by HMIS to integrate information systems and maintenance. However, HMIS has lost Donor support

since conclusion of DANIDA. The vertical programs could sustain operations as were supported by DANIDA since HMIS through DHIS has become the backbone of health data nationally. A business model agreed by this donor funded programs would elevate the deteriorating HMIS and once systems disintegrate, other successful initiatives will also derail.

c) DHMTs will need to take the leadership role in community health information use by providing clear guidance, process awareness, and community capacity building to support successful integrated system [22]

d) While data quality remains an outcome of the above analyzed complications, not capturing shehia in the DHIS is limiting data usability. While this research has only done a patchwork to portray this fact, and notify the Ministry of health on the needed community health extension to support disease prevention, the methods that were used to capture this detail can-not be a permanent solution. The following are recommended:

   (i.) Use of handwriting-to-text apps to collect health records from the registers and send to the DHIS through interoperable integration seen in the literature.

   (ii.) Taking an immediate action to roll out the electronic medical records that is interoperable to DHIS. This concurs with the recommendations found in a 2011 completion report of HISP on DHIS deployment which to date has not been implemented. In summary, the report states:

There is a need to identify a strategy for working synergistically with other HMIS software packages and organizations and develop capacity to align DHIS deployments with OpenMRS and multiple mobile data collection tools. …There is a need to explore options for increased interoperability between DHIS and other tactical HIS and identify if opportunities exist to synchronize deployment strategies to leverage joint resources in planning, training, and building local technical capacity.

5.6. Innovation

Availability of patient level data analysis for public health which is easily accessible and interpreted is new for Zanzibar and Tanzania in general. After this research, it will be possible for the DHMTs to perform statistical analysis of disease reports from facilities with respect to the community-based information, which is the basis for information use, hence, improving public health. Also, this research is innovative because 1) for the last decade, DHMTs and the HMIS had relied on DHIS as a national health database from the facility-aggregated-counts. At the point of aggregation this research has introduced an additional type of integration, which is Ward-Aggregated-Counts (WACs).

In this research, there is an opportunity for utilizing the location of disease occurrences and to embed this with socioeconomic predictors that are major determinants of health. Countries that cannot afford nationwide electronic medical records (EMR) and use DHIS with no patients' addresses need some sort of disease-location relationships in order to perform appropriate epidemiology. No such work has been conducted in Tanzania to a ward level, the systems seen from other countries all ended at district level. The innovation in this project is not only on giving developing countries access to R statistical software for public health statistical analysis, but more on how it is applied. It is how informatics uses interdisciplinary methodologies of increasing data use, human resource informatics capacity building, and M&E in developing countries and opening doors to work closely with the communities that suffer with the high rates of morbidity and mortality. On the workforce capacity assessments this will be the first time the public health workforce are involved in a self-managed routine performance assessment intervention for continuous performance improvement. It is hoped that they will continue irrespective of what projects are being implemented from time to time. ZCHIS System, also support system logs that are intended to study users improved capacity of using the system. These user logs will be studies in the future.

Lastly, there is innovation in this work for the side of Tanzania through ZCHIS— a system that archives the analysis conducted for closed group discussion of the health trends per different clusters and times. Once fully utilized, this will be the social network of the Public Health workers for

Zanzibar, using the user logs. This uptake can be further researched regarding how it improved system performance.

5.7. Implications

The first implication of this research is capacity built to the DHMTS that has demonstrated informatics demand has increased. This will raise the willingness to use analytical systems and improve their work. The two way collaborations under DHMTs and the communities and between DHMTs and the Ministry of Health will place the DHMTs on top of the health system as intended in the decentralization policy. The upward information sending mechanism will remain for policy and communicating prevention and the downward mechanism will go to the community collaborations in interventions and prevention. Finally, these community engagements will secondarily support DHMTs to inform evidence for policies on a national level.

5.8. Acknowledgement

This project has been supported across many institutions beginning with the Health Management and Informatics Department (HMI) which nurtured the idea from its infancy and enabled it to be communicated from its original perception. The MU Data Science and Informatics Institute for supporting the academic achievements of the researcher, even remotely, when the situation was not favorable. The project humbly recognizes the tireless efforts by the DHMTs and the HMIS, along with the Ministry of Health, which offered the ethical clearance and permissions to proceed. This project was supported by the Zanzibar President Office, Tanzania, and later on by the Tanzanian Commission for Science and Technology (COSTECH). Dissertation and publication year was supported by the Association of American University Women (AAUW).

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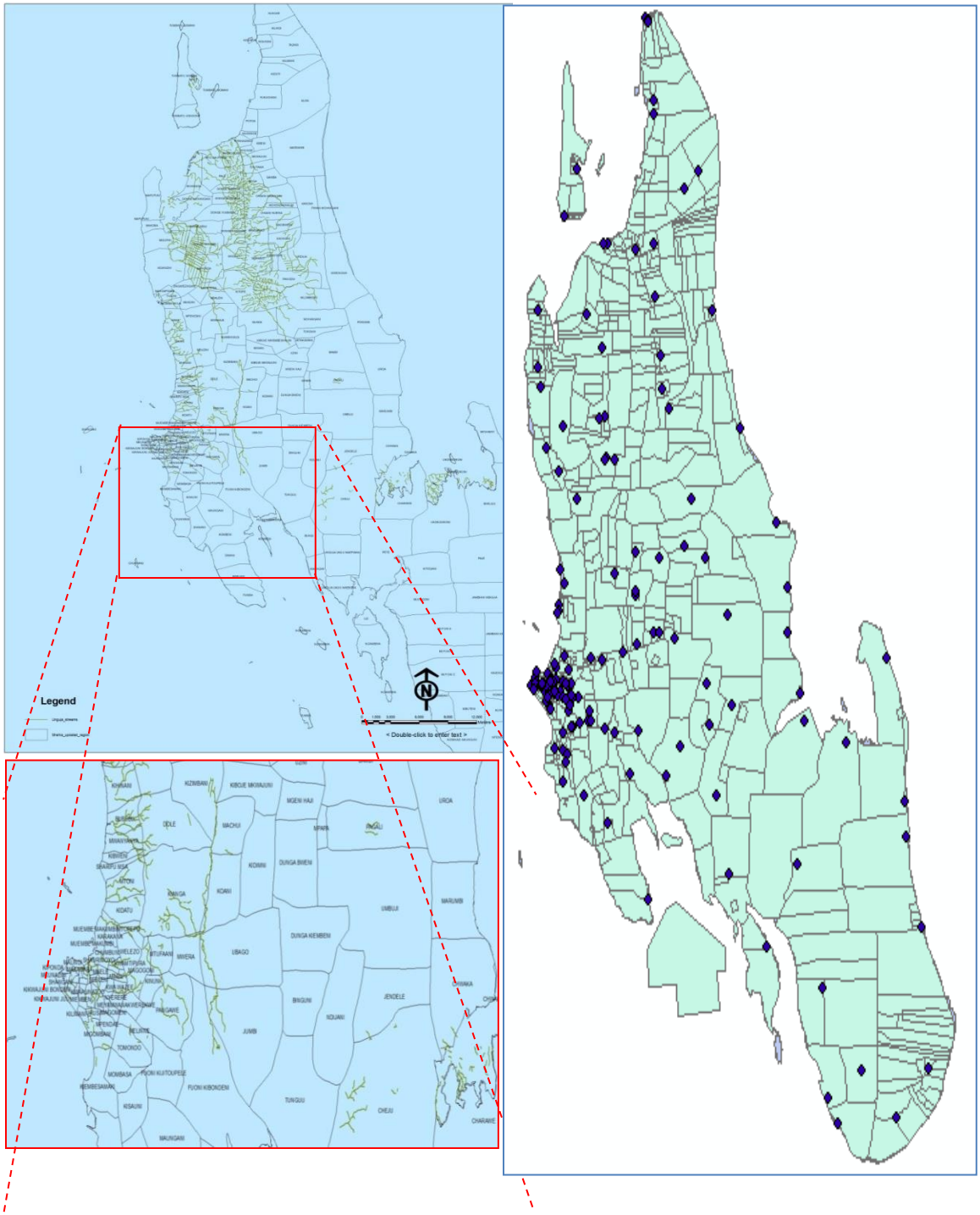
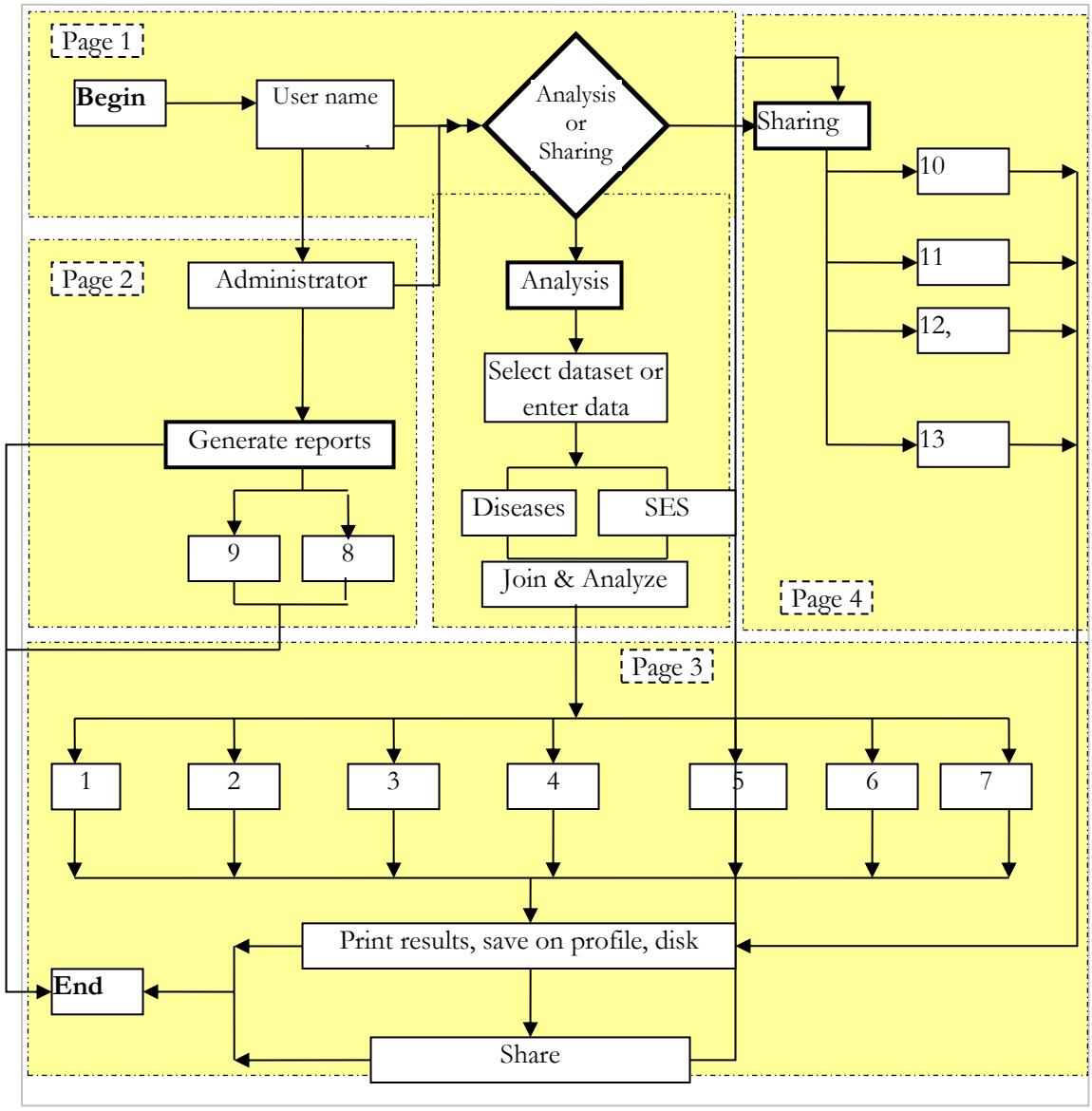
ANNEXES

Annex 1: Health Facilities Distribution between Urban and Rural Areas.



Annex 2: Detail Workflow for the Statistical Analysis Software Tool.



FUNCTIONS:

Statistical Analysis:

1. Descriptive Analyses
2. Inferential Statistics
3. GLM
4. Logistic
5. Graphics
6. OTHERS
7. OTHERS

Generate reports:

8. Individual Reports
9. Group Reports
10. Dashboard Reports

Web Sharing:

10. Browse from Computer
11. Browse from Profile
12. Share public or with group
13. Discussion portal

Annex 3. Diseases and SES Variables

Disease Outcome Variables, Year Month I	Socioeconomic Predictors
TAllAll (Total 3 Diseases, Age, Gender)	SOCIO_Shehia SOCIO_Total Male Female PriTotalPriMalePriFemale SecTotal SecMale SecFemale UniTotal UniMale UniFemale AttndTotal AttndMale AttndFemale PAttendTotal PAttendMale
TAdultAll (Total 3 Diseases Adult)	PAttendFemale Compl TotalComplMale ComplFemale NevCom TotalNevCom MaleNevCom FemaleComplTotal ComplMale
TChildAll (Total 3 Diseases Children)	CompleFemale SwanglishTotal SwanglishMale SwanglishFemale SOCIO_Total Prof SOCIO_Male Prof SOCIO_Female ProfSOCIO_Total
TURTI (Total URTI)	Unprof SocioMale SocioTotal BUildingTotal Owened_by_Household Living_in_without_paying_any_Rent Rented_Privaletly
TAdultURTI (Total Adult URTI)	Rented_by_Employer Rented_by_Govern_at_Subsidized_Rent Owned_by_Employer_-_Free_of_Charge Owned_by_Employer_- _With_Rent Not_Reported OwnershipTotal Title_deed Resdential_license
FAdultURTI(Fema le Adult URTI)	OfferCustomary_ownership Contract No_legal_right Registration_(Zanzibar)RoofTotal Iron_Sheets Tiles Concrete Asbestos
MAdultURTI (Male Adult URTI)	Grass_Leaves Mud_and_Leaves Plastics_Box Tent OtherRoofFloorTotaCement Ceramic_Tiles
ChildURTI (Male Child URTI)	Parquet_or_Polished_WoodTerazzo Vinly_or_Asphalt_Stips Wood_PlanksPalm_Bamboo Earth_Sand Animal_Dung Total_FloorStones
MChildURTI (Male Adult URTI)	Cement_Bricks Sundried_Bricks Baked_Bricks Timber Timber_and_Iron_Sheets Poles_and_MudGrassOtherWall
TPneu (Total Pneumonia)	SleepRoomsTotal One_Room Two_RoomsThree_Rooms Four_Rooms Five_or_moreDrinking WaterTotal Piped_Water_into_dwelling
TAdultPneu (Total Adult Pneumonia)	Piped_Water_to_yard_plot Public_tap_standpipe Tubewell_boreholeProtected_dug_well
FAdultPneu (Female Adult Pneumonia)	Unprotected_dug_wellProtected_Spring Unprotected_Spring Rain_water_collection Bottled_water Cart_with_small_tank_drumTanker_truck
MAdultPneu (Male Adult Pneumonia)	Surface_water_(river_dam_lake_etc) OtherWater ECookingTotalElectricity_(TANESCO_ZECO) Solar_Energy
FChildPneu (Female Child Pneumonia)	Generator_Private_sources Gas_(Industrial) Gas_(Biogas) Electricity_(Wind) Paraffin Coal Charcoal Firewood Wood_Farm_Residuals Animal_residuals Not_Applicable
MChildPneu (Male Child Pneumonia)	OtherCookerELighting Total Non ELight NoLight enerator_Private_sourceAcetylene_La m Kerosene_(lantern_Chimney)
TDiar (Total Diarrhea)	Kerosene_(Wick_lamps) CandlesTorch_Rechargeable_LampsToiletTotal FlushPour_Flush_to_Piped_Sewer_SystemFlush_Pour_Flush_to_Septic_Ta nk
TAdultDiar (Total Adult Diarrhea)	Flush_Pour_Flush_to_Covered_PitFlush_Pour_Flush_to_Somewhere_Else
FAdultDiar (Female Adult Diarrhea)	Ventilated_Improved_Pit_VIP_LatrinePit_Latrine_with_Washable_Slab_wi th_Lid Pit_Latrine_with_Washable_Slab_without_Lid Pit_Latrine_with_not-
MAdultDiar (Male Adult Diarrhea)	Washable_Soil_Slab Pit_Latrine_without_Slab_Open_Pit Composting_Ecoson_Latrine Bucket NoFacility_bush_beach
FChildDiar (Female Children Diarhea)	OtherFacility RefuseTotal Regularly_collected Irregularly_collected Burnt Roadside_dumping Burying_Pit Other_Dumping AccessoryTotal Radio Landline_phone Mobile_phone Bicycle Motor_vehicle Motor_cycle Tricycle

MChildDiar (Male Children Diarrhea)	Tri-Motorcyle_(Bajaj) Television Electric_iron Charcoal_iron Electric_gas_cooker Refrigerator_freezer Computer_laptop Internet_facility PloughPower_tiller Hand_hoe Wheel_barrow Oxen Donkey_camel House Land_farm Shehia TotalProfMaleProf FemaleProf TotalUnprof TotalUnprofMale TotalUnprofFemale TotalSexTWorkedPaid MWorkedPaid FWorkedPaidTWorkedUnpaid MWorkedUnpaid FWorkedUnpaidTNotWorked MNotWorked FNotWorked Total TEmployer MEmployer FEmployer TEmployee MEmployee FEmployee TSelfEmployed MSelfEmployee FSelfEmployee TAgricultures MAgricultures FAgricultures

Annex 4a Data Collection Tools

Questionnaire 1: Surveillance Data Questionnaire for DHMTs

Interviewer: [Instructor Name]

Date: _____

Name: _____

District: _____

Designation: _____

Pre/Post: _____

Please read each questions carefully and rate your answer in a scale from 1(Lowest)-5 (Highest)

How would you rate the data availability for use in surveillance activities

_____

How would you rate the data accessibility for use in surveillance activities

_____

How would you rate the data availability for use in surveillance activities

_____

How would you rate the kour knowledge of Data for use in Surveillance activities

_____

Annex 4b Questionnaire 2

TRAINING ON STATISTICAL ANALYSIS WITH ZHIS SOFTWARE FOR HEALTH DATA

EVALUATION QUSTIONNAIRE

1. How do you rate the overall training program? Tick one

Excellent ❍ Good ❍ Average ❍ Poor ❍ Very poor ❍

2. Was the training content what you expected?

Yes ❍ No ❍

3. Was the training content appropriate for your job?

Yes ❍ No ❍

If yes, please explain:

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

4. Which part of the training was very interesting for you?

Please explain why:

_____

_____
_____
_____
_____
_____
_____

5. How suitable was the mix of presentation versus hands on activities with ZHIS?

Excellent ❍ Good ❍ Average ❍ Poor ❍ Very poor ❍

6. Did you learn anything new?

Yes ❍ No ❍

If yes, please provide details:

_____
_____
_____
_____
_____

7. What aspects of the training did you find most valuable?

_____
_____
_____
_____
_____

8. What aspects of the training could be improved?

_____
_____
_____
_____

_____
_____

9. Do you have any suggestions/recommendation to improve ZHIS software?

_____
_____
_____
_____
_____
_____

Your name [optional]: …….

Your DHMT name: ……..

THANK YOU FOR YOUR PARTICIPATION

Annex 4c: Questionnaire 3

Pre Assessment Questionnaire

1. Individual Capacity Assessment.

The information you provide below is an effort to characterize Public Health Informatics Capacity nationwide. Zanzibar Public Health Informatics Project (ZPHIP) appreciates your participation in this important assessment. Please note that the results are going to be aggregated and only personal information will not be specifically identified. Identifiers will only be used to avoid duplicate entries. This assessment is brief and should take less that 20 minutes to complete. You are allowed to only fill this form once. If you have any questions please contact investigators of ZPHIP.

Pre Assessment Questionnaire

2.

* 1. Please enter the following basic information about yourself.

Age

Sex

District

Designation (DMO, DSO, DHO, Other)

2. Do you work in:

- [ ] Occupational health
- [ ] Substance Abuse
- [ ] Chronic Diseases
- [ ] Infectious Diseases
- [ ] Maternal and Child Health
- [ ] Oral Health
- [ ] Mental Health
- [ ] Injury
- [ ] Environmental Health
- [ ] Bio Terrorism and Emergency Response
- [ ] Other (please specify)

3. Do you work in

- ○ Occupational health
- ○ Substance Abuse
- ○ Chronic Diseases
- ○ Infectious Diseases
- ○ Maternal and Child Health
- ○ Oral Health
- ○ Mental Health
- ○ Injury
- ○ Environmental Health
- ○ Bio Terrorism and Emergency Response
- ○ Other (please specify)

4. What is your level of Education

- ○ MD
- ○ Degree in Public Health
- ○ CO
- ○ PHNB
- ○ CN
- ○ Diploma in any Informatics related field (Information science, systems or technology)
- ○ Diploma in Public Health
- ○ Degree in Informatics
- ○ Other (please specify)

5. Do you have training on:

	Yes	No
Epidemiology	☐	☐
Informatics	☐	☐

Other (please specify)

6. How many years have you work in DHMT

Pre Assessment Questionnaire

3.

8. Please indicate the appropriate level of PHI competency for each skill domain listed below.

	Minimal or none	Basic	Intermidiate	Advanced	Expert
1. Use data to recognize the existence of a public health problem	○	○	○	○	○
2. Collaborate with others inside and outside the agency to use evidence to identify a problem	○	○	○	○	○
3. Perform literature review, finding current data and reports to articulate the need for investigation or public health action.	○	○	○	○	○
4. Design and Identify surveillance and data needs	○	○	○	○	○
5. Implement new or revise existing surveillance system and report key surveillance findings	○	○	○	○	○
6. Support or conduct evaluation of surveillance systems	○	○	○	○	○
7. Assist or conduct a community health status assessment and charecterising investigative processes	○	○	○	○	○
8. Assist or design of an investigation including creating hypothesis	○	○	○	○	○

	Minimal or none	Basic	Intermidiate	Advanced	Expert
9. Follow ethics guidelines and principles when planning studies, conducting research; and collecting disseminating and using data.	○	○	○	○	○
10. Describe human subject research and apply for ethical clearence (ZIRPP)	○	○	○	○	○
11. Differentiate between Public health practice and Public health research.	○	○	○	○	○
12. Apply data ethical Knowledge to research and interventions	○	○	○	○	○
13. Design Database requirements incase a new one is needed	○	○	○	○	○
14. Maintain data, information and databases	○	○	○	○	○
15. Oversee or control data quality (validity, timeliness and completeness)	○	○	○	○	○
16. Assist in monitoring and evaluation programs	○	○	○	○	○
17. Define Cultural/social/political/ framework for recommended Public health informatics intervention	○	○	○	○	○
18. Determine evidence based interventions and control measures in response to findings	○	○	○	○	○
19. Use information and evidence to know how causes of diseases affect epidemiologic practice	○	○	○	○	○

	Minimal or none	Basic	Intermidiate	Advanced	Expert
20. Prepare written and oral reports and presentations that communicate necessary information to the Ministry of Health	○	○	○	○	○
21. Make recommendation regarding validity of epidemiologic data	○	○	○	○	○
22. Use Current knowledge of causes of disease to guide epidemiological practice	○	○	○	○	○
23. Use scientific evidence in preparing recommendations for action or interventions	○	○	○	○	○
24. Communicate epidemiologic information through giving oral presentations or contributing to the development of written documents to non professional audiences (forum discussions and presentations)	○	○	○	○	○
25. Assist or develop SMART goals	○	○	○	○	○
26. Assess the needs for special analyses	○	○	○	○	○
27. Basic principles of risk communication	○	○	○	○	○
28. Ability to comprehend epidemiologic findings	○	○	○	○	○
29. Use communication technologies (mobile phones, laptops, Internet etc)	○	○	○	○	○
30. Use epidemiologic data and evidence for community planning processes	○	○	○	○	○

	Minimal or none	Basic	Intermidiate	Advanced	Expert
31. Evidence based strategic planning and management of its activities	○	○	○	○	○
32. Identify informatics activities needs in the DHMT (perfomance)	○	○	○	○	○
33. Identify informatics competency needs in the DHMT (Training)	○	○	○	○	○
34. Assist or conduct Study design	○	○	○	○	○
35. Assist or conduct data collection tools, identify data sources and design protocols	○	○	○	○	○
36. Assist, conduct or evaluate data analysis (primary and secondary) using health and socioeconomic data	○	○	○	○	○
37. Evaluate conclusions and interpretation from investigations	○	○	○	○	○
38. Assist or conduct a information dissemination through Public Health report or presentations	○	○	○	○	○
39. Assist or conduct use of information and knowledge	○	○	○	○	○
40. Participate in online forum discussions for information sharing and performance improvement.	○	○	○	○	○

VITA

Zeyana Hamid is a Global health Informatics specialist, graduate from the University of Missouri Columbia, Institute of Data Science and Informatics. She has started her public health experience from Zanzibar Tanzania from working with the Ministry of Health and specialized in Computer science, later on to Health Informatics and Health Administration through Fulbright Scholarship and later on in her Ph. D she was a fellow from the Association of American University Women.

She is a motivated public health researcher with a resilient passion in Global Health disparities and application of Informatics for public health. She is well prepared for research in Public Health Informatics, and utilization of relevant data sets within the country and globally.

Her work in analyzing and modeling existing data sets supports information use to study and combat health disparities associated factors by population profiles, place and time. She applies visualization that will quickly assist program managers and policy makers utilize the available knowledge to improve people lives.

The urge to answer the intriguing research questions to population disparities, is a motivation enough for her to support global efforts that minimize morbidities and mortalities. She has continuously built capacity and methodologies to share application of Informatics into community health management.

Her current determination is to streamline data sources pathways though Informatics and Data Science such that data acquisition and access can be simplified and stored algorithms that conducts preprocessing, analyses and visualization. Such application can assist public health practitioners utilize data for decision making in a more routine and frequent fashion and be assisted with access to evidence-based intervention planning for impact and policy formulation.

She took a formal training in managing social inequalities in the beginning of her Ph.D. coursework after realizing that studying health disparities attributed by socioeconomic status (population and area based) will have a very important contribution to health outcomes. This sealed her entire perspective of what skills were needed to have and how her contribution to population health is going to be delivered. There after she built Statistical background, Data science and Big Data analytics additional graduate certificates in Public Health and Geographical Information Systems.

The project that she designed and implemented as part of her Ph.D. work was an online statistical analysis tool using R, PHP and MySQL that utilizes routine Health Management Information System (HIMS) disease surveillance data with Census socioeconomic Indicators, to visualize on descriptive dashboard and GIS maps.

Furthermore, the system utilizes Poisson regression and ANOVA to model and visualize disease counts and census indicators association at Ward level by gender and age. The project was aimed for Zanzibar District-level Health Management Teams (DHMTs) who are engaged directly with the community but do not have the competency to program the statistical analyses needed to support them neither was there data that represents lower geographical locations. This project used Action Research (AR) and focus group discussion to develop requirements and trained the first version of Informatics systems that would transform most developing countries utilizing DHIS and decentralized population health management using DHMTs.

One thing she has come to learn through literature and presenting her work in different audiences is that rural health in United States has similar Informatics needs to many developing countries. Replication of research projects conducted here in such settings could, at low cost, highly benefit the Global Health, where Informatics has many success stories of raising capacities to manage diseases in ways that have never been around before.

Her personal research agenda at this point going forwards is how the public health datasets (primary and secondary) are going to support health-SES analyses that link health delivery and social service to

the clusters of populations, or even individuals who need those services the most. Some innovative applications have been successful in different states and the promise of lowering disparities can be evidently obtained. By capitalizing on the US based successes, support of informatics tools could be provided to developing countries and build capacity to jointly lower global disparities.

Through her Informatics projects in Tanzania, she has gained ability to communicate professionally and effectively while factoring in the different level of team players who have to take part in understanding and more importantly contribute to shape the capacity Information Use.