Benefits and Challenges of Integrating Fragmented Health Information Systems

A Case Study of the Vaccine Supply Chain in Tanzania

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Abstract

Most Health Information Systems (HIS) in developing countries are fragmented and characterized by multiple overlapping and/or duplicate sub-HIS. The fragmentation of HIS is further identified by many researchers as the biggest problem shaping their use and utility. A shared vision to solve the issues of fragmentation is to move towards integrated HIS. Integrated HIS has the potential to improve decision-making and the overall health management.

Focusing on the information systems used for the management of Tanzania's vaccine supply chain, this thesis critically assesses the potential benefits and challenges of integrating various information systems with the national Health Management Information System (HMIS). This is done by analyzing how and why Tanzania's HIS is fragmented, what challenges this fragmentation leads to, and identifying the possibilities and challenges for integration. The research is based on a qualitative case study conducted at different levels of the health system in and around Dar es Salaam, Tanzania, in two separate field trips.

Findings indicate that Tanzania's fragmented HIS leads to multiple challenges that may negatively affect the overall health services. Different formats and inflexible systems, differences in how data is defined and understood, as well as different interests and procedures for the various actors involved, challenges the idea of integrated HIS. Integration can solve some of the existing challenges of fragmentation, but it will also require intricate negotiations and alignment of interests between the myriad of actors involved. Therefore, one should consider if the potential benefits of integration is worth the effort.

Drawing on existing theory on socio-technical information systems, Information Infrastructures, fragmentation and integration, the overall objective of this thesis is to contribute with richer insight into the benefits and challenges of moving from fragmented to integrated HIS in developing countries. It also contributes by applying an integrative framework based on Carlile's (2004) work to analyze fragmentation and discuss how to address integration at the technical, data and organizational level of HIS.

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Table of contents

List of appendices

List of figures

List of tables

Abbreviations

BID	Better Immunization Data
CCIT	Cold Chain Inventory Tool
CHAI	Clinton Health Access Initiative
DHIS2	District Health Information System 2
DIVO	District Immunization and Vaccine Officer
DVDMT	District Vaccination Data Management Tool
eLMIS	Electronic Logistic Management Information System
GAVI	Global Alliance for Vaccines and Immunization
HIS	Health Information System
HISP	Health Information Systems Program
HMIS	Health Management Information System
HMN	Health Metrics Network
II	Information Infrastructure
IVD	Immunization and Vaccine Development
JSI	John Snow Inc.
LMIS	Logistics Management Information System
MOH	Ministry of Health
MOHSW	Ministry of Health and Social Welfare
MSD	Medical Stores Department
NBS	National Bureau of Statistics

OPENLMIS	Open Logistic Management Information System
RIVO	Regional Immunization and Vaccine Officer
R&R	Report and Requisition
SMT	Stock Management Tool
UDSM	University of Dar es Salaam
UiO	University of Oslo
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
VIMS	Vaccine Information Management System
WHO	World Health Organization

1 Introduction

1.1 Motivation

Most Health Information Systems (HIS) in developing countries are fragmented. That is, they are characterized by multiple overlapping and/or duplicate sub-HIS developed by different actors to serve specific needs. The sub-HIS are typically built on different technologies, use different data formats and are connected to different procedures. Fragmented and uncoordinated HIS are identified by many researchers as the biggest problem shaping their use and utility, as it limits the efficient use of health information (Braa & Sahay, 2012). For example, duplicate data collection on paper can lead to overburdened health workers. This can lead to the data collected being of poor quality, which in turn, can lead to the data not being used. Furthermore, difficulties in the coordination and collation of information, and discrepancies in the gathered data, also makes it hard for health managers to know what data to trust, and to get a complete picture of the country's health status.

This also applies for Tanzania's HIS. Tanzania's eHealth strategy (for 2013-2018), developed by the Ministry of Health, Community Development, Elderly, Gender and Children, therefore calls for more utilization of the existing information systems within the national HIS. Combined with a widespread consensus from global actors in the health domain that integrated HIS can solve the issues with fragmentation, this has led to a stressed need - and more efforts towards integration of Tanzania's HIS.

1.2 Context

This research is a part of the Health Information Systems Program (HISP) initiative, supported by the Information Systems research group at the Department of Informatics, University of Oslo (UiO). I have been a part of a bigger research team with fellow students working on similar topics, and we have collaborated by sharing theory and discussing each other's research together with our supervisors throughout the whole research process from fall 2015 to 2017. The empirical study was conducted in two separate field trips to Tanzania over a period of 2 months altogether. The first field trip was conducted in collaboration with two fellow students, and the second field trip was conducted with one fellow student, working on a similar research problem. All fieldwork conducted in Tanzania was also done together with researchers from

HISP Tanzania at the Computer Science and Engineering Department at the University of Dar es Salaam (UDSM), which is collaborating with HISP UiO. The HISP initiative is more thoroughly explained in section 2.2.2.

1.3 Theoretical Framework

The theoretical framework in this thesis is built on existing theory on information system, related research on HIS fragmentation and integration, in addition to a theoretical framework on integration. First, a socio-technical perspective is applied to understand how the context around information systems is important. Then, concepts from Information Infrastructure (II) theory is used to address and explain the complexity of information systems, related to how they evolve as part of larger infrastructures. Furthermore, related research on HIS fragmentation and integration is discussed to better understand the fragmentation and possibilities for integration of Tanzania's HIS. Lastly, an integrative framework, from Carlile (2004), has been adapted to analyze fragmentation in Tanzania's HIS and address the opportunities and challenges for integration at technical, data and organizational level. These levels have different features, involving different means for achieving integration. At the same time, they are interconnected, and iterations through the three levels are necessary for an integration process.

1.4 Scope

The overall objective of this thesis is to contribute with richer insight into the benefits and challenges of moving from fragmented to integrated HIS in developing countries. In order to do this, Tanzania's HIS has been investigated, focusing on the national Health Management Information System (HMIS), and the information systems used for managing the vaccine supply chain and routine immunization services, hereby named as the vaccine information systems. The reason for this focus is that the Immunization and Vaccine Development (IVD) Program in Tanzania uses three different vaccine information systems alone, and one of these systems has overlapping functionality and collects duplicate data with Tanzania's national HMIS. This part of the HIS can be considered as fragmented in itself with multiple information systems developed by different actors, and with two of them having overlapping functionality.

In the domain of public health supply chains, there is a growing interest for linking routine health data (collected by HMIS) and logistics data (collected by LMIS), for enhancing monitoring, evaluation and data validation for both logisticians and health service delivery managers (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016). Because of an ongoing process of linking data in Tanzania's national Logistics Management Information Systems (LMIS) and HMIS, an investigation of this project and the LMIS is therefore also included. This is done in order to establish a broader picture of Tanzania's HIS, understand more of the overall HIS fragmentation, as well as to shed a light on the benefits, possibilities, and challenges for HIS integration in general.

While integration is a commonly used suggestion for solving fragmented HIS, a critical perspective on integration of the different sub-HIS is applied in the discussion of this thesis. That is, integration is not taken as a "for granted" solution. It is discussed what an integration potentially can solve (benefits), but also what the challenges of an integration could be, and if there may be any better solutions.

1.5 Research Question and Objectives

The purpose of this thesis is to address the benefits and challenges of integrating vaccine information systems with the national HMIS in Tanzania. The research question addressed is:

What are the potential benefits and challenges of integrating vaccine information systems with HMIS?

The main objectives identified as important for answering this research question are:

1. Understand how the Tanzanian HIS is fragmented
2. Understand why the Tanzanian HIS is fragmented
3. Identify the challenges created by fragmentation
4. Address the opportunities and challenges for integration of the information systems in the HIS

1.6 Chapter Overview

Chapter 2 provides a background for the investigated case. First, an overview of Tanzania is given, including economic and infrastructural conditions, the overall health status of the country and how the health system is organized and structured. In addition, general information on HIS and Tanzania's HIS, including the national HMIS and LMIS is presented. In the end, a brief explanation of the requirements for a vaccine supply chain and how this is managed in Tanzania is given.

Chapter 3 explains the research approach used in this study, including the chosen research methodology, philosophical assumption, methods for data collection, how the data was analyzed, as well as ethical considerations upon the research conducted.

Chapter 4 presents the theory and related research used as a background in this thesis. A socio-technical view and concepts from information infrastructure (II) theory are given and used as my underlying perspective on information systems. In addition, related research on fragmentation and integration of HIS, in addition to a theoretical framework on integration, is presented.

Chapter 5 presents the empirical findings from the research conducted.

Chapter 6 discuss the empirical findings in light of the research question and objectives, using the theoretical framework from chapter 4

Chapter 7 concludes the thesis by summarizing the discussion and giving some implications for HIS integration. Additionally, some reflections upon the theoretical framework used, and limitations of the thesis is given.

2 Background

This chapter intends to present an overview of the research context for this thesis. First, a brief presentation of Tanzania is given, including economic and infrastructural conditions, the overall health status of the country and how the health system is organized and structured. This is done to provide a country-specific context and understand the infrastructural and economic conditions (or constraints) for managing the HIS, and the possible relationship between the HIS and the health status of the country. Furthermore, to provide some background on the scope, general information on HIS and Tanzania’s HIS, the national HMIS and LMIS, the relation between them and the current project of linking these systems are presented. In addition, a brief explanation of the requirements for a vaccine supply chain and how this is managed in Tanzania is given to introduce the focus on vaccine information systems.

2.1 Tanzania

The United Republic of Tanzania, comprising Tanzania mainland and Zanzibar, is a country in Eastern Africa. It has an estimated population of approximately 55 million people (2016) and a surface area of 947,303 km^2, making it one of the largest countries in Africa. The official languages are Swahili and English (United Nations, 2016; United Nations Development Programme, 2017). Tanzania mainland is divided into 27 administrative regions and 133 districts (Ministry of Health and Social Welfare, 2015).

Figure 1 - Map of Tanzania (Ministry of Health and Social Welfare, 2015, p.10)

The GDP per capita on Tanzania mainland increased from 700.9 USD in 2010 to 952.2 USD in 2014 with agriculture being the most important industry providing approximately 66 percent of employment (Ministry of Finance and Planning, 2016; United Nations, 2016). Poverty has decreased the recent years but is still a big challenge in Tanzania. 10 of the approximately 12 million people living below the poverty line in Tanzania live in rural areas, which are also housing 70 percent of the total population (Ministry of Finance and Planning, 2016; World Bank, 2015). The country has a fast-growing population with an average annual growth of 3.2 percent from 2010 to 2015 (United Nations, 2016).

2.1.1 Infrastructure

Tanzania's infrastructure development is ranked 102nd in 2015, being behind comparative countries, like Kenya and Ghana. The quality of the road network is varied, often weak, and characterized by daily traffic jams. Furthermore, the power utility in Tanzania is unstable and both urban and rural populations suffer from unpredictable access to energy (Ministry of Finance and Planning, 2016). Even though water supply coverage in rural areas has increased (from 40% in 2013 to 67% in 2015), there are still huge differences between the urban and rural areas regarding water quality and access to sanitation facilities. This is, according to the Ministry of Finance and Planning (2016), mainly caused by "dilapidated infrastructure, weak policy and institutional arrangements for sanitation; limited coordination between different entities, and climate change impacts" (Ministry of Finance and Planning, 2016, p.13).

2.1.2 Health Status

The overall health status of the population in Tanzania is improving, but there are big differences between the rural and urban areas. One reason for this is the low access to electricity, safe water, and adequate sanitation facilities in rural areas (Ministry of Health and Social Welfare, 2015). Parts of the population living in poverty suffer from malnutrition and chronic hunger (Ministry of Finance and Planning, 2016). According to United Nations Tanzania (2016), only "…20% of under-five children receive a minimally acceptable diet of complementary foods" (p.27). The country has high maternal mortality rates, estimated at 454 per 100,000 live births, excluding Zanzibar. By 2015, Tanzania managed to reduce the under-five mortality rate to about 54 per 1000 live births, which means that they reached the Millennium Development Goal (MDG) 4 (United Nations Tanzania, 2016). The immunization coverage on children is high, with most vaccines having more than 90 percent coverage (Ministry of Health and Social Welfare, 2015). Still, approximately 98.000 children die each year of preventable diseases in Tanzania. Malaria is the primary cause of health care visits and deaths among children (United Nations Tanzania, 2016). In addition, both HIV/AIDS and tuberculosis (TB) are infectious diseases with high prevalence (Ministry of Health and Social Welfare, 2013). TB-related mortality was estimated to be on 58 per 100 000 in 2013, and Tanzania ranks among the 22 most TB-burdened countries in the world. Further, the estimated number of people living with HIV in Tanzania is 1.5 million people, although the prevalence is slowly decreasing in most of the regions in the country (United Nations Tanzania, 2016).

The Ministry of Health and Social Welfare (MOHSW) reported in a Health Sector Strategic Plan (2015) of the availability of essential medicines in the health facilities being limited. The most important identified factors leading to this are "inadequate funding, poor planning, and coordination, inadequate tracking mechanisms and tools, as well as inadequate pharmaceutical human resources at the facility level resulting in poor inventory management" (p.19-20). Further, they mention external issues like "lack of coordination of externally funded vertical programmes' medicines and health products and donated supplies, and pilferage" (p.20).

2.1.3 Tanzania's Health System

Even though The United Republic of Tanzania comprises both Tanzania mainland and Zanzibar, they have two separate Ministries of Health. The mainland ministry has recently been renamed from Ministry of Health and Social Welfare to Ministry of Health, Community Development, Gender, Elderly, and Children, termed as Ministry of Health (MOH) in this thesis from now on. The mainland health system in Tanzania is hierarchically organized and divided into different levels of health care from community to national level with MOH having the overall responsibility. At the community level (in the villages), it is common to have a few health workers providing basic health care and health education. These health workers are supervised by a dispensary, which is the next level of referral. The dispensaries provide health care to a population between 6000 and 10 000, depending on the size of the catchment area. They mainly offer maternal and child health care, including for example immunization and child delivery, in addition to simple medical treatments. In addition to dispensaries, Tanzania also has health centers which are bigger and have some beds for inpatient treatment. They mainly provide preventive care, but can also do some surgery and reproductive health services. At the next level of health care, there are district hospitals offering both inpatient and outpatient care not provided by the smaller facilities. Further, there are some regional hospitals with more specialized health workers and surgeons, in addition to specialized referral hospitals and national hospitals providing more advanced health care. In addition to the public health services under MOH illustrated in figure 2 below, there are also some private actors running their own facilities, hospitals and pharmacies (Kwesigabo et al., 2012; MOHSW, 2015).

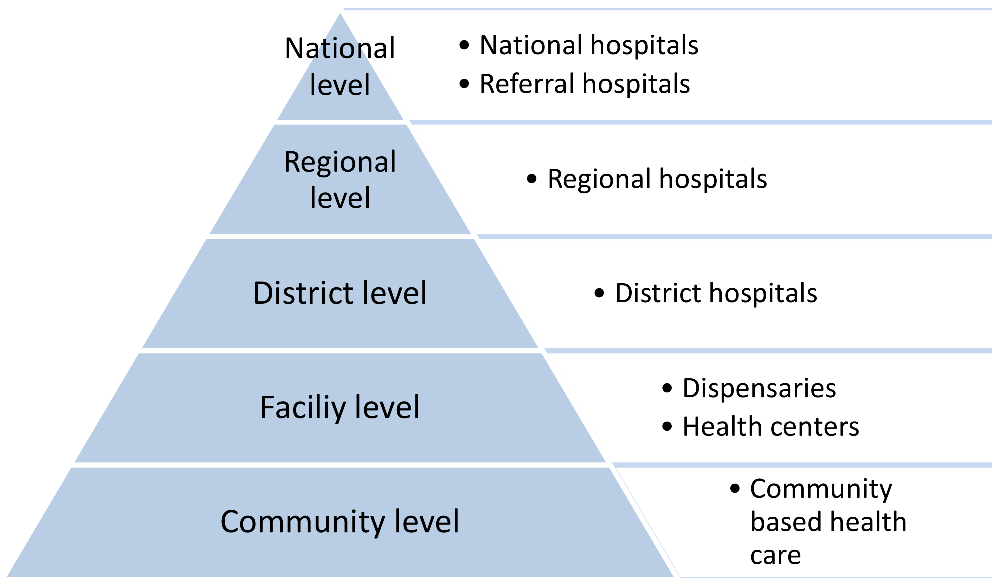


Figure 2 - The hierarchical structure of health care in Tanzania. Based on figure 4 in the Health Sector Strategic Plan IV (MOHSW, 2015, p.12)

One of the biggest challenges in the Tanzanian health system is the lack of qualified health workers, as they fill only 35 percent of the positions. There are also big differences regarding quality and access to health services in rural and urban areas. Even though approximately 90 percent of the Tanzanian population lives 5 kilometers or less from a dispensary or health center, most of the population live in rural areas far away from hospitals and specialist care. Getting sufficient health care can therefore require a long travel and dependency on transportation which, considering Tanzania's poor infrastructure, can be challenging (MOHSW, 2013).

The MOH in Tanzania sees that the application of ICT has the potential to improve the delivery of health care services. In their eHealth strategy for 2013-2018, they have assessed that the key challenge related to ICT capabilities in the health care sector is that "the Tanzanian health sector is characterized by a fragmented landscape of ICT pilot projects and numerous data and health information system (HIS) silos with significant barriers to the effective sharing of information between healthcare participants" (MOHSW, 2013, p.iv).

2.2 Health Information Systems (HIS)

Health Information Systems (HIS) are defined as systems that "…integrate data collection, processing, reporting, and use of the information necessary for improving health service effectiveness and efficiency through better management at all levels of health services" (Lippeveld, Sauerborn, & Bodart, 2000, p.3). Just as there are different types of information needs within health, for example regarding human resources, patients, diseases and drugs, there are different types of sub – information systems of HIS built to manage these information needs.

2.2.1 Health Management Information Systems (HMIS)

A Health Management Information System (HMIS) is one example of a sub-HIS handling aggregated health service delivery data. HMIS are used for collecting and reporting routine health data such as information about patients, diseases, and the health services given. The routine data collected in an HMIS is evaluated and analyzed with the purpose of making evidence-based decisions to determine disease patterns, monitor, detect and respond to outbreaks and improve a country's health services in general (Systems for Improved Access to Pharmaceuticals and Services (SIAPS) Program, 2012; USAID DELIVER PROJECT, Task Order 1, 2011).

2.2.2 Health Information Systems Program (HISP) and DHIS2

HISP is a global network and movement that emerged in the 1990's when Norwegian and South-African researchers took part in the reconstructing of South Africa's health system after the end of apartheid (Braa & Sahay, 2012). A branch of HISP is coordinated and managed by the Department of Informatics at the University of Oslo (HISP UiO), and my research is a part of this initiative. "The overall goal of the Health Information Systems Programme (HISP) at the University of Oslo is to enable and support countries to strengthen their health systems and their capacity to govern their Health Information Systems in a sustainable way to improve the management and delivery of health services" (HISP, 2014, p.1). HISP UiO focuses on the strengthening of health information systems through using information for action and local empowerment, and to support this, they develop, maintain and support the implementation of the open source software DHIS2 (District Health Information System) (HISP, 2014).

DHIS2 is developed with the purpose of collecting, aggregating and visualizing routine data from public health facilities within a country. The data is gathered and analyzed with the aim of supporting decisions at all levels of the health system. This includes enabling health workers to predict service needs and evaluate their own level of service delivery. DHIS2 is implemented across the globe and used as a preferred HMIS in over 47 developing countries. There are system developers in several countries working on the implementation and customization of the software, although its core developers and coordinators are situated in Oslo. There are also local developer teams working on country-specific customization of the software (Braa & Sahay, 2012; DHIS2, n.d.).

Tanzania uses DHIS2 as their national HMIS. Routine health service delivery data is collected on paper at the health facility level and entered manually into DHIS2 with computers at the district level. HISP Tanzania, located at the Computer Science and Engineering Department at the University of Dar es Salaam (UDSM), is responsible for the country-specific development and customization of DHIS2 (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016). HISP Tanzania was established in 2002 and in addition to the implementation of DHIS2, they do research on health informatics and public health. They also have PhD programs and master programs in collaboration with the University of Oslo (UiO), and are in charge of organizing training workshops for all stakeholders of DHIS2 (Braa & Sahay, 2012; HISP Tanzania, n.d.).

2.2.3 Logistics Management Information Systems (LMIS)

Countries need to have a reliable and effective supply chain system for managing medicines, vaccines and other health commodities like gloves or malaria nets. A supply chain system should make sure that health commodities can be effectively managed, distributed and kept in a good condition. A reliable system can also minimize the waste of commodities and prevent stock outs at health facilities.

USAID (United States Agency for International Development) Deliver Project (2011) describes logistics activities within public health in developing countries as "the operational component of supply chain management, including quantification, procurement, inventory management, transportation and fleet management, and data collection and reporting" (p.1). Further, they describe supply chain management as "... the logistics activities plus the coordination and collaboration of staff, levels and functions" (p.1). To have an effective supply chain, there is therefore a need for reliable information to support decision making and coordination of actions. A Logistics Management Information System (LMIS) is an information system that handles data collection for the management of a logistics system, for example data about health commodities (USAID DELIVER PROJECT, Task Order 1, 2011). Thus, while an HMIS is built to collect and report on health service routine data, an LMIS handles health logistics data with the purpose of managing a health commodity supply chain.

In Tanzania, eLMIS (electronic Logistics Management System) is the national LMIS. The system is a local implementation of a configurable and open source software called OpenLMIS which is a global initiative built to manage health commodity supply chains in developing countries (openLMIS, n.d.). eLMIS was implemented in Tanzania in 2013 by the US based company John Snow Inc. (JSI) and is used for the ordering of health commodities from all health facilities to the Medical Stores Department (MSD). Like DHIS2, the system is paper-based at the facility level and computerized from the district level and up (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016). eLMIS and the commodity supply chain in Tanzania will be described more thoroughly in chapter 5 – Findings.

2.2.4 The Relationship between LMIS and HMIS

Even though health management and logistics are two separate domains, and most HMIS and LMIS are developed separately, there is also some overlap between the domains. An LMIS should provide advanced functionality to manage all parts of a supply chain like procurement, distribution and inventory management. At the same time, an HMIS often also collects some logistics data, because "for effective health service delivery, a minimum requirement is to avoid stock outs of commodities…" (Nielsen & Sæbø, 2016, p.142-143).

> A system for health management typically collects data related to stock-out and vaccine cold chain management, which h is usually extended to be a lightweight inventory system (how much was received of a certain commodity, how much was dispensed, how much was discarded and what is the end balance of this month). (Nielsen & Sæbø, 2016, p.143)

This is for example supported by DHIS2, but now there is a "…growing interest within public health supply chains to incorporate systematic analysis of LMIS data and health management information system (HMIS) data..." (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016, p.4). The identified possible benefits from linking LMIS and HMIS data includes enhanced monitoring, evaluation and data validation for both logisticians and health service delivery managers. Decision makers may need data from both systems to better understand service delivery and logistics performance. For example, if a logistician can look at disease patterns from an HMIS, it can be easier to forecast the procurement and distribution of commodities and to respond more effectively to disease outbreaks. Correspondingly, if service delivery managers can look at LMIS data on, for example, what medicines have been given, they can get a better understanding of the patterns in the health service delivery (Systems for Improved Access to Pharmaceuticals and Services (SIAPS) Program, 2012).

2.2.5 Linking DHIS2 and eLMIS in Tanzania

To overcome the challenge of fragmented HIS in Tanzania, the eHealth strategy from MOHSW (2013), mentioned in section 2.1.3, suggests more focus on exploiting and integration of existing systems. As a response to this, JSI and HISP Tanzania are currently looking at the possibilities for integrating eLMIS and DHIS2. The Supply Chain Technical Resource Team (TRT) of the UN Commission on Life-Saving Commodities for Women and Children, including stakeholders from JSI and HISP Tanzania, has developed an integrated HMIS/LMIS dashboard for Tanzania in DHIS2. The purpose of this project is to identify the benefits and usefulness of linking HMIS and LMIS data. The dashboard was launched in May 2016 and is configured to show relevant data from both systems side by side. In this way, the users are able to "understand the relationship between service delivery and consumption and look for abnormal or concerning trends (i.e. a drastic decrease in consumption without a corresponding change in the number of cases diagnosed)" (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016, p.13).

Figure 3 shows the integrated dashboard with examples of graphs that can be displayed. The first graph is from DHIS2 showing the number of cases of postpartum hemorrhage and the second is from eLMIS showing the commodities used as a treatment for the conditions (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016).

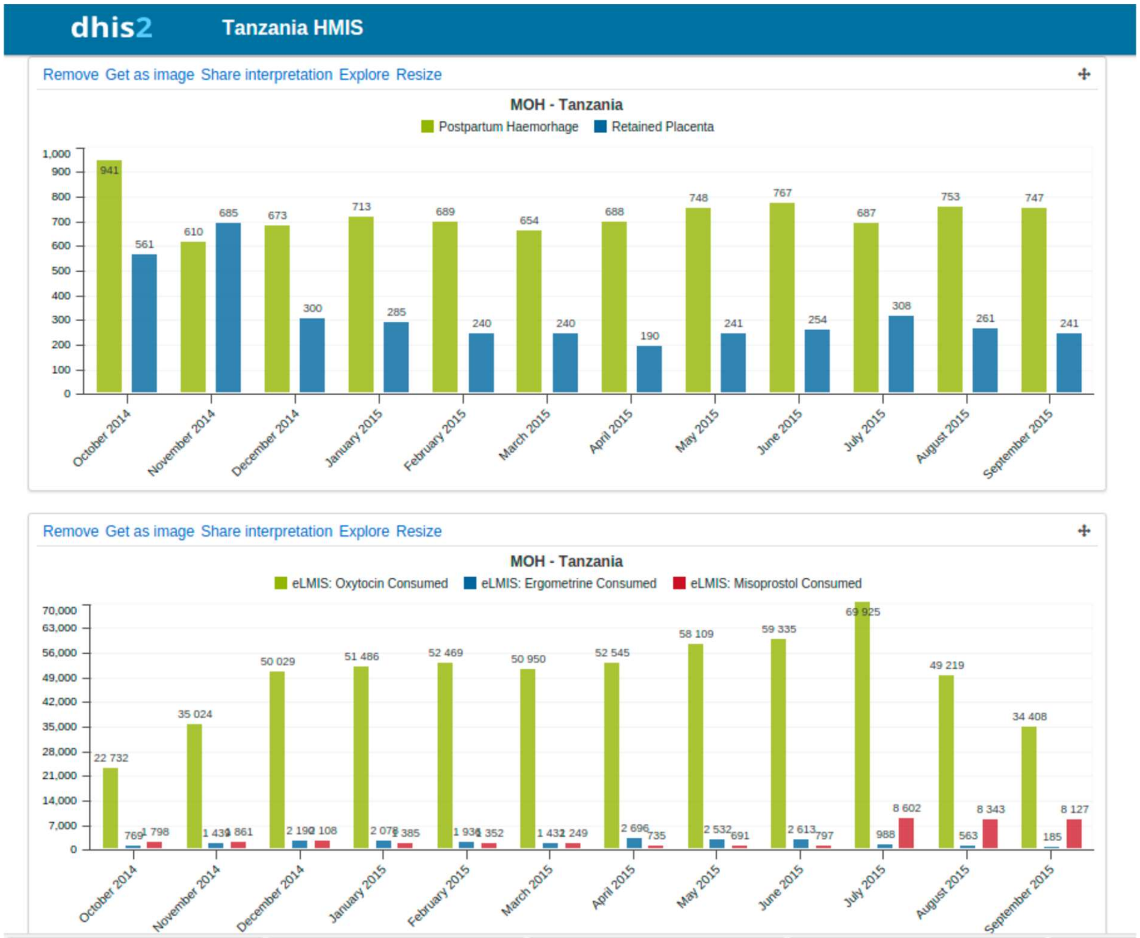


Figure 3 - Example of graphs showed in the dashboard (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016, p.13)

Currently, it is only commodity data from the reproductive and child health program that is included. However, being well received and used at the national level has created a demand for including commodities from other programs as well (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016).

2.3 Vaccine Supply Chain

Vaccines are considered as health commodities, but they also have different requirements than the "regular" health commodities. They are very temperature sensitive, and to function properly, they need to be stored and handled within a certain, cold temperature range at all times. Therefore, the supply chain of vaccines is also called "cold chain" (UNICEF, 2016, n.d.). Vaccines "have a fixed shelf-life and [will] lose viability over time. The loss of viability is irreversible and accelerated if proper storage and temperature conditions are not maintained"

(VillageReach, 2014, p.3). Vaccines that are not handled properly can lose their efficacy, which again will affect the patients and possibly result in more causes of preventable diseases and child mortality. Further, damaged vaccines lead to more wastage, and as some vaccines are expensive and already in short supply in rural communities, this will affect the opportunity to immunize the population (VillageReach, 2014). Therefore, it is necessary to have adequate cold chain equipment, like refrigerators, vaccine carriers and cold boxes, for both storage and transportation of all vaccines (UNICEF, 2016, n.d.).

In countries with insufficient infrastructure, managing and maintaining a well-functioning cold chain can be challenging. Unreliable electricity and power cuts can result in too high temperatures in the cold storages, and a backup power source, like a generator, can be necessary. Frequent power cuts can also lead to higher reliance on effective monitoring systems and manual supervision of the equipment and temperatures (VillageReach, 2014). Furthermore, insufficient road infrastructure can both make it hard to reach the most rural communities with cold vaccines, and it can tear down the vehicles used for vaccine transportation.

In Tanzania, the Immunization and Vaccine Development (IVD) Program is responsible for managing the country's vaccine supply chain. The IVD Program was established in 1975, under the name Expanded Program of Immunization (EPI) and the program's main goal is to reduce the morbidity and mortality due to vaccine preventable diseases. Their responsibilities within the vaccine supply chain include the management of vaccine procurement and -distribution throughout the country, routine immunization of the population and disease surveillance. The IVD program is also responsible for the distribution, maintenance and replacement of proper cold chain equipment (MOHSW, n.d.). Because of the specific requirements for the management of a cold chain, the IVD program has their own sub-HIS with three information systems used for managing vaccine logistics, routine immunization services and cold chain equipment. These information systems will be thoroughly described in chapter 5.

2.4 Summary of Background

Even though the poverty in Tanzania has decreased recent years, this is still a challenge for big parts of the population. Most of the people living below the poverty line, and 70 percent of the total population in Tanzania live in rural areas. This part of the population further has low access to electricity, water and sanitation facilities, leading to big differences in the health status of the people living in rural and urban areas. Tanzania's health system is hierarchically organized and divided into different levels of health care (community, facility, district, regional, national) with the MOH having the overall responsibility.

An HIS involves all health data collection, processing, and use of information necessary for improving the effectiveness of the health service delivery at all health system levels. The MOH in Tanzania has recognized that the country's HIS landscape is fragmented with several HIS silos and ICT pilot projects, and that this hinders the sharing of health information between the actors involved. An HMIS is an example of a sub-HIS for the management of health service delivery data. In Tanzania, DHIS2, developed by HISP, is used as a national HMIS. An LMIS is another sub-HIS used for the management of health commodity supply chains, and in Tanzania, eLMIS is used as a national LMIS. Because an increasing interest of linking HMIS and LMIS data, and as a respond to MOH's suggestion of integrating existing sub-HIS, there is an ongoing project of linking DHIS2 and eLMIS in Tanzania.

Vaccines have different requirements than other health commodities, as they need to be kept in a constant cold temperature. Thus, managing a *cold chain* requires proper equipment for storage and transportation. In Tanzania, the IVD program is responsible for the cold chain management, and they currently use their own sub-HIS with three information systems developed for handling vaccine logistics, routine immunization services and cold chain equipment.

3 Research Approach

In this chapter, I will first present my philosophical assumption for the research and the chosen research methodology. Furthermore, the data collection process, data analyzation and ethical considerations for the study will be described.

3.1 Philosophical Assumption

All researchers will have some underlying assumptions on what they believe is valid research and guide their research approach. My research is based on an interpretive philosophical assumption. Researchers within the interpretive research paradigm have the "… assumption that access to reality (given or socially constructed) is only through social constructions such as language, consciousness and shared meanings" (Myers & Avison, 2002, p.5). Further, interpretive researchers try to "…understand phenomena through the meanings that people assign to them…" (Myers & Avison, 2002, p.5). Within information systems research, interpretive researchers aim to understand the context of the information system and how it is influenced by this context (Myers & Avison, 2002). The interpretive paradigm is an opposition to the positivistic paradigm. A researcher with a positivistic philosophical assumption believes that reality is objectively given and may for example test a theory or hypothesis to find answers (Myers & Avison, 2002). Thus, they strive to establish the "final truth" instead of constructing an inter-subjective understanding of the phenomenon with the informant, as will be typical for an interpretivist.

As an interpretive researcher, I have aimed to understand the phenomenon and surrounding context in my study through the informants' answers. This means that I have not looked for a given, objective truth, but instead gathered subjective meanings and interpretations from informants in the field. Furthermore, I have underlying subjective assumptions of how the world is, based on my own knowledge and input from others, and I believe that this influence how I approach the research. This can, for example, relate to the interview guides made in the data collection process, as the questions were formulated partly based on assumptions on what to expect from the informants. I also had different assumptions in the two separate field trips to Tanzania as I entered the field with different expectations and more knowledge the second time. One example of this is that during the first field trip, we learned that the information systems used for the vaccine supply chain are not communicating with each other or with DHIS2, but that they collect duplicate information. I based my following research on this knowledge and focused on vaccine information systems and their relation to DHIS2 in the second field trip. My own, and the other researchers' assumptions have influenced both the way I did the data collection and how I interpreted and analyzed the data. Hence, the studied phenomenon is understood through an intersubjective understanding with both fellow researchers and the informants' interpretations.

3.2 Research Methodology

Case study is used as a methodological framework for this research. A case study is "…an empirical enquiry that: investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Myers & Avison, 2002, p.7). To answer my research question, I needed to get a thorough understanding of the HIS in Tanzania, especially the HMIS, LMIS and the systems used for management of the vaccine supply chain. Further, to understand the benefits, possibilities, and challenges of integration, I had to find out how the systems are being used at different health system levels, how they are similar and different from each other and get views of the stakeholders using them. I have tried to approach the field with a critical view of the benefits of an integration by trying to not only look for challenges with the existing solutions, but also to identify what is working, and to get the informants' perspectives on the case.

In this case, the boundaries between the actual phenomenon and the context are not clear. It is not only the information systems that are of interest but also surrounding factors. This includes to understand the whole supply chain of both vaccines and regular commodities including the involved stakeholders and to try to identify what this means for the requirements of the information systems. Also, the equipment used for handling and storing vaccines and other types of commodities, the frequency of stock outs and overstocks, electricity and other infrastructural surrounding contexts around the information systems have been taken into consideration.

3.2.1 Research Process

In this study, there has been an iterative process of theory reading, data collection, analyzation and writing over a period of two years and with two separate field trips to Tanzania. The study started with several meetings and discussions with fellow students and our supervisors in the fall of 2015. Furthermore, we collaborated in conducting four interviews with informants being involved in logistics management and/or HIS in developing countries. This, in addition to reading articles and previous literature on the subject, were all a part of the preparation process before conducting fieldwork over a period of three weeks in Tanzania, January 2016.

The first field trip was conducted in collaboration with two fellow students working on the same research area and included interviews, observations, discussions and literature review. During the first four days, our two supervisors traveled together with us, joined two field visits and introduced us to the HISP team at UDSM. Later, we had regular online contact with the supervisors during the whole stay. After returning to Norway, all three students collaborated in writing up all gathered material in more coherent documents. Furthermore, discussions with the supervisors and other students doing similar research were held, with the purpose of getting input and ideas for narrowing down the research. This process, in addition to analyzing the material more thoroughly, led to the development of a more specified research problem and an individual research question to focus on for the next phase of the study and the second field trip to Tanzania in August 2016.

The second field trip was conducted in collaboration with one fellow student and lasted for five weeks. This time, we had individual research questions but overlapping research areas, and we collaborated during the whole data collection process. The following period after this field trip consisted of more analyzation, theory reading, discussions and writing up the whole study.

Table 1 - Overview of the data collection process

Period	Location	Methods	Part of process
September – December 2015	Norway	Discussions Document analysis	Selecting case Fieldwork preparations
January 2016	Tanzania	Interviews Observations Document analysis Testing Discussions	First field trip
January – August 2016	Norway	Analyzing Discussions Reading theory	Specifying research Fieldwork preparations
August 2016	Tanzania	Interviews Observations Discussions Document analysis	Second field trip
September 2016 - April 2017	Norway	Analyzing Discussions Reading theory Writing up	Writing up

3.3 Data Collection

In the following section, I will first describe the goals for the data collection and the selection of participants. Further, the different data collection methods and how the data was recorded will be presented.

3.3.1 Goals

The focus of the first part of the research was to study HMIS and LMIS in developing countries with an overall goal of contributing to strengthen DHIS2 in the area of LMIS. Because of the ongoing process of integrating DHIS2 and the national LMIS (eLMIS) in Tanzania, this was chosen as a suited country to conduct research. The goal of the first field trip to Tanzania was, therefore, to get an overview of the health system and investigate the national LMIS and HMIS including the flow of information and commodities. The purpose of this was to establish a better understanding of the context and further use this knowledge to narrow down the scope of the study to a more specific research area. In this way, the first field trip was more exploratory and a preparation for the second field trip, where the focus was narrower. The goal of the second field trip was to dig deeper into my specified research area. That is, gaining a better understanding of the possible benefits, opportunities, and challenges for integrating the national HMIS and the vaccine information systems. To do this, the aim was to do a thorough study of these information systems and how they are being used by different stakeholders as well as understand the flow of vaccines and related information.

3.3.2 Participants

For both field trips, the different locations for data collection were chosen in collaboration with the HISP team at UDSM. The goal was to cover all levels in the health system, interview relevant stakeholders with different roles, as well as to visit both rural and urban health facilities. Several practical conditions influenced the choice of stakeholders and destinations. This included the need for a driver and an available car on the day for a field visit, at least one available person from HISP Tanzania to arrange and be a part of the visit, as well as time constraints for the informants and the length of the traveling routes. Therefore, this study has involved a limited number of participants, but the selection includes informants with different roles, including system developers, managers and health workers from facility to national level in both rural and urban areas in and around Dar es Salaam. The study has not investigated health services at the community level or at the regional level.

The total number of informants that participated in the data collection process is approximately 45 over a period of 8 weeks altogether. In addition, we sometimes exchanged words and got some opinions from health workers who were at work when we did observations at the facilities and district offices. They are not counted as informants, but became a natural part of the data collection process and were important for establishing an understanding of the context.

When visiting health facilities, the procedure was usually to first meet and conduct interviews at the district office and then travel together with some of these informants to the facility within their district. This was an advantage in the way that they knew the health workers at the facility, so it was easier to communicate through them. At the same time, the district representatives sometimes answered the questions on behalf of the health workers at the facility. In this way, we did not always get the health workers' understanding of the situation, but instead the districts representatives' opinion.

The data collection was arranged in the informants' daily work setting. We talked to health workers at the clinics, managers at their offices and system developers in meeting rooms.

However, this also led to some challenges. In some of the clinics, there were a lot of patients waiting in line to get their treatment. Therefore, some of these interviews and observations had to be sped up and we shortened the interview guides accordingly while on site. At the same time, when conducting the study in the informants' daily work setting, it also became possible to observe routines and a typical work situation at the health facilities. One example of this being an advantage is that when visiting one district vaccine storage, the informant we interviewed told us about how they distributed the vaccines to all facilities monthly. However, while conducting the interview, a health worker from one facility came by with a handwritten note to pick up vaccines they needed on that facility. Hence, we learned that they sometimes practice vaccine distribution outside the regular procedure, and we could ask follow-up questions based on this observation.

3.3.3 Data Collection Methods

This study is based on qualitative data collection methods. The primary method used are interviews, but also observations and document analysis have been a part of the data collection process. We traveled to 16 different sites on national, district and facility level where we, on each site, carried out interviews with one or more informants with different roles. An overview of all data collection done, including the number of informants, methods used and the health system level they were held at, is presented in table 2 below.

Table 2 - Overview of all data collection in Tanzania. *Health workers include nurses, doctors and other workers at a health facility or hospital

Health system level	Number of informants	Informant roles	Methods used
District	6	Health workers*, district pharmacist, HMIS workers	Unstructured interview, observation
District	4	HMIS workers, LMIS workers, district pharmacist	Unstructured interview, observation
District	3	HMIS workers, DIVO	Semi-structured interview, observation
District	3	HMIS worker, district pharmacist, DIVO	Semi-structured interview, observation
District	5	HMIS worker, DIVO, health workers*	Semi-structured interview, observation
Facility	1	Clinical officer	Unstructured interview, observation
Facility	4	Health workers*	Semi-structured interview, observation
Facility	2	LMIS worker, health worker*	Semi-structured interview, observation
Facility	1	Health worker*	Unstructured interview, observation
Facility	1	Health worker*	Semi-structured interview, observation
National	3	Pharmacists	Semi-structured interview
National	4	LMIS workers, HMIS worker, drug storage manager	Semi-structured interview, observation
National	2	Manager, system developer	Semi-structured interview
National	4	Pharmacist, HMIS manager, system developers from JSI	Semi-structured interview and testing
National	2	System developers from JSI	Semi-structured interview, observation

When doing research at the facility level, we looked at the use of paper-based systems, how they collect data for the different information systems and investigated what equipment they had available at the facility. We also learned how they use and monitor the cold chain equipment, manage their drug storages, place orders and how they perform immunization services. At the district level, we mainly looked at how they work with the information systems electronically, learned about their role in the distribution process of vaccines and other commodities, as well as how the pharmacies and vaccine storages are managed at this level. At the national level, we conducted interviews with the IVD Program, the Medical Stores

Department (MSD) and with system developers from JSI. This was good for understanding more of the procurement and distribution of vaccines and other commodities from the top of the supply chain, as well as the role of international actors and health-specific programs.

Further, during both field trips to Tanzania, we had some training at UDSM in how to use DHIS2. In addition, we had several meetings with our main contact persons from the HISP Tanzania team as well as Skype- and email contact with our supervisors to get input and ideas for the current and further work. We stayed near the HISP office at the university where we worked daily by transcribing and analyzing material, reading theory, improving our interview guides and preparing for all further field visits.

Another part of the research was a combined interview and test with informants from JSI. This was initiated by HISP Tanzania as a part of their ongoing project of linking HMIS and LMIS data between DHIS2 and eLMIS. The purpose of this test was to identify the possibilities and challenges for sharing data between the two systems. In order to test this, the HISP team had inserted some logistics data from eLMIS into a test server for DHIS2. Further, we developed a test script to follow, for comparing this commodity data for some selected district and identify possible challenges for data linking. The training server in DHIS2 was down during the meeting, making us unable to follow the testing plan, but we got to compare data for some districts manually. It was further decided that JSI could send the rest of the data to HISP Tanzania by email so the HISP team could compare the data later. This also gave us more available time to conduct our interview where JSI both told us about their projects in Tanzania, and about the health commodity supply chain and the health system in general.

Interview

Semi-structured interviews were the most used data collection method. This is an approach where the researcher can follow a brief interview guide or a checklist of subjects that the interview should cover, but at the same time lets the conversation be open for the informants' topic of interest and improvised follow-up questions. By using this approach, new topics or aspects of the phenomenon that may not have been thought of before the interview can arise (Crang & Cook, 2007). As an interpretive researcher, it was important to have some openness during the interviews to let the informants talk about subjects that they felt was important. An example of this being beneficial in the field is that, after several interviews had been held, I had some presumptions on how the immunization services worked at the health facilities. However, when asking the informant at one facility late in the data collection process to describe the daily immunization work, she mentioned one part of the process that none of the previous informants had mentioned. This was the fact that they estimate a number of vaccines they are going to use during a day and move this amount out of the freezer or fridge and into a cold box every morning. I had not previously thought about this part of the process and it made new questions arise like how this estimation is done and to what degree it affects the vaccines and leads to wastage.

It was useful to have some predefined questions to keep the interview relevant to the research area and to be able to compare answers from different informants in the analysis process. The interview guides became more detailed in the second field trip compared to the first one, as the focus of the research was narrower, and specific questions needed to be asked in order to answer the research question (see appendix A for an example of interview guide from the fieldwork in August). However, even though the questions became more detailed, the interviews were still semi-structured. In the second field trip, we made one interview guide for the district level and one for the facility level, as well as separate interview guides for all visits at the national level. Even though we asked about the same topics, we added and/or removed questions during the whole research process as new aspects emerged and we learned more about the case. This, for example, happened when we learned about the routine of vaccine estimation, mentioned earlier.

Unstructured interviews, as an opposition to structured interviews, is another approach to interviewing. Here, the researcher does not use predefined questions but simply lets the conversation flow freely (Crang & Cook, 2007). In this study, unstructured interviews were mainly used during the first days of fieldwork in January when our supervisors joined us in the data collection and led the interviews. Although we did not have any predefined questions, we had an overall focus on LMIS and HMIS, so one might argue that the interviews never were completely unstructured. However, using this approach in the first field visits was useful to learn about the case with an open mind and look for topics of interest to study more thoroughly later.

Observation

Even though interviews were the primary method for data collection in this study, observations were also widely used. However, these observations were not planned in detail or used as a method alone, but more as a supplement to the interviews. Because all interviews were conducted in the informants' work environment, doing observations was a natural way of creating a better understanding of the phenomenon. While for example talking about the health workers' routines of collecting data, the informants usually showed us the paper ledgers and datasets while explaining. In this way, they could easier connect the interview questions to their daily work routines. In addition, it was easier for me as an outside researcher to understand the phenomenon when I could observe what we talked about, instead of just hearing about it. When asking questions about the electronic systems used for the different information systems, some of the informants also demonstrated the use of the systems for us. In addition, we did observations on the cold chain equipment, drug storages, offices, and pharmacies. The informants also showed us how they monitor the temperature in the cold storages and how they count and keep track of the stocks of all commodities. Moreover, all data collection done at the health facilities can be said to be a combination of observation and interviewing.

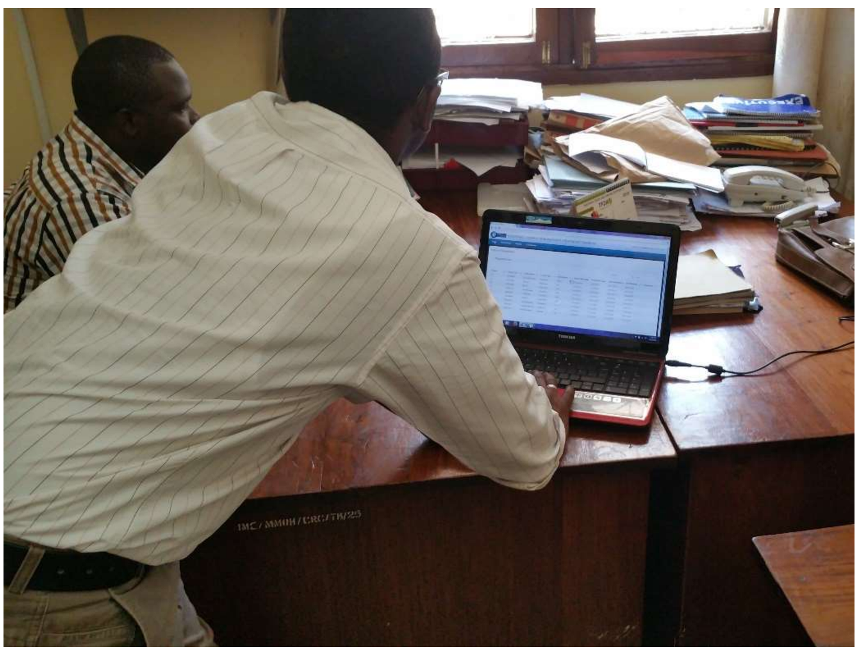


Figure 4 - A district pharmacist demonstrating the use of eLMIS

Document analysis

In this research, document analysis is used to gain more insight of the research area, both before, under and after the field trips. This includes literature on LMIS, HMIS, and commodity supply chains, both in general and for Tanzania in particular. These documents were mostly obtained from international organizations and projects working with health and HIS in Tanzania and other developing countries, like WHO (World Health Organization), UNICEF (United Nations

International Children's Emergency Fund), BID (Better Immunization Data) initiative, USAID, JSI and United Nations Commission on Life-Saving Commodities. Also, eHealth strategies and other relevant documents from the MOH have been read. Doing document analysis was useful to understand more of the country-specific context, various eHealth initiatives and ongoing projects related to HIS. Documents obtained from doing this have also been used as a supplement to the findings from the field.

In addition, before some of the interviews in the field, we did background research while preparing the interview guides. This was mainly prior to the interviews at the national level before meeting with, for example MSD, JSI, and the IVD Program, to be able to discuss topics related to our research and talk about their work with a mutual understanding.

Data recording and - processing

For the recording of data, we did not use a tape recorder but all researchers took notes during the interviews and collaborated in writing up the material immediately after each field visit. An advantage of not using a tape recorder is that you will not need to spend time transcribing the interviews in detail later (Crang & Cook, 2007; Walsham, 1995). If I were to tape record every interview in this study, I would have ended up with an extensive amount of recorded material and transcription work.

The data collection was quite informal with a combination of interviewing, observation and loose conversation with often more than one stakeholder. The environment was often somewhat busy and noisy with health workers and patients, and we sometimes did the interviewing "on the move" while we were showed around at the health facility or district office. Thus, tape recording everything could potentially be rather complicated in this setting, and the quality of the tapes could risk being reduced with background noises. Another thing to bear in mind when considering tape recording is that the informants may be affected by the presence of a tape recorder. A tape recorder can somewhat formalize the setting, and the informant may get uncomfortable or answer differently than without a tape recorder (Crang & Cook, 2007; Walsham, 1995). On the other hand, a disadvantage of not tape recording interviews is that one might miss out on details from the informants as it is impossible for a researcher to remember everything that has been said during the interview (Crang & Cook, 2007; Walsham, 1995). However, in this study, there always were more than one researcher conducting the interviews. In this way, at least one researcher could take notes while another one asked questions. These roles were switched naturally during the interview as we moved along and came up with follow-up questions. As previously mentioned, there also were one or two representatives from HISP Tanzania joining us in the field visits and they acted as researchers, in addition to be our guides and interpreters in the field.

Photos were also taken during each field visit, as a part of the data collection process. The purpose of this was both to use them as part of the material for analysis, but also as a tool to help remember the field setting later. I took photos of my interpretations of what was important and relevant for the study. For example, a photo of the informant was not of relevance, but photos of the equipment at the facility, the HIS registers and the electronic systems they use were more relevant for me. In addition to taking field notes and photos, I kept a field journal writing down my thoughts and experiences for each day. This was good for remembering every field visit and for processing the impressions while staying in the field.

3.4 Data Analysis

I have applied an interpretive approach to my data analyzation following the idea from Walsham that "*...the researcher's best tool for analysis is his or her own mind, supplemented by the minds of others when work and ideas are exposed to them*" (Walsham, 2006, p.325). Transcriptions from each field visit got written, both immediately after each visit, and later in more coherent documents and field reports both in Norway and while in Tanzania. The transcriptions were produced in collaboration, by discussing and comparing all the researchers' field notes to get as reliable and relevant information as possible. To make the analysis process easier, we also made sure to label the most important photos from each field trip. Further, we did comparisons of the data collected and discussed the differences and similarities between the data gathered from different informants. All documents produced from the fieldwork got reviewed by the supervisors and all findings were discussed throughout the whole research period between the researchers, the HISP team in Tanzania and our supervisors. The regular feedback sessions, discussions and meetings both in Norway and Tanzania, have all been part of the analysis process as it has shaped the research through e.g. reformulating the interview guides before the next field visits and redirecting the research when necessary.

Individually, I analyzed the data by sorting, reading and re-reading all written documents from the fieldwork. While staying in Tanzania the second time I also grouped the findings into different categories related to my research area. Some of the main categories I grouped my findings into were *HMIS*, *LMIS,* and *immunization*. Within these categories I also used under-categories. For example, under both the category of immunization and LMIS, I sorted the findings into *storage and equipment*, *ordering*, *distribution* and *data flow*, to mention some. I also made figures for comparing the data flow and procedures from the facility to the national level for the different sub-HIS. Doing this helped me to structure the research and look at my current learning outcomes, compare the different sub-HIS and understand what more data I needed to best answer my research question. This was also done after returning to Norway, combining data from both field trips to get a more comprehensive understanding of all collected data.

Furthermore, an integrative framework, adapted from Carlile (2004), has been used to analyze fragmentation in Tanzania's HIS and address the opportunities and challenges for integration at technical, data and organization level within the HIS. These levels have different features, involving different means for achieving integration, but they are also interconnected, and iterations through the three levels are necessary for an integration process. The framework is presented in chapter 4, and applied in the discussion in chapter 6.

It is debated to what extent it is possible to generalize from interpretive case studies. Following Walsham's (1995) suggestions for generalization from interpretive case studies, the results "should be viewed as 'tendencies', which are valuable in explanations of past data but are not wholly predictive for future situations" (Walsham, 1995, p.79). Therefore, one should see the generalizations as "explanations of particular phenomena derived from empirical interpretive research in specific IS settings (Walsham, 1995, p.79)*"*. In this study, I have not looked for a final truth but instead aimed to understand the studied phenomenon and context through my interpretation of the different informants' answers, and through the other researchers' interpretations. Thus, repeating this study may not lead to the same results as found in this thesis, but the study can contribute to an explanation and generate *rich insight* of the studied case (Walsham, 1995).

3.5 Ethical Considerations

Prior to the fieldwork in Tanzania, I had to find out if my planned research had to be notified to the Data Protection Official for Research (NSD) in Norway. NSD writes on their websites that a project is subject to notification if personal data is to be collected and processed. Even though I was not going to collect any personal data, I took a test to be sure that my project was not subject to notification under the Personal Data Act. This test got approved (see appendix B).

We did not record any sensitive data or information that could identify the informants, so written consent forms were not made. Instead, before each interview, one representative from HISP Tanzania introduced us and made a verbal agreement with the informants, in either Swahili or English, of the purpose of the study. Further, because the HISP team was responsible for contacting the informants and arranging the field visits, we never collected any contact information ourselves. Photos were taken from each field visit, but we always asked for permission, and we never took photos of faces for use in the study. It happened that we got to look at patient registers for immunization, but when photographing these, eventual sensitive information got covered up.

4 Theoretical Background and Related Research

The purpose of this chapter is to introduce the theory and related research that is used as a background for this thesis. First, a socio-technical view and concepts from information infrastructure (II) theory is presented as my underlying perspective on information systems. A socio-technical perspective is applied to understand how the context around information systems is important, and the concepts from II-theory is used to address the complexity of information systems, related to how they evolve as part of larger infrastructures. Next, related research on HIS fragmentation and integration is discussed to better understand the fragmentation and possibilities for integration of Tanzania's HIS. I finally present a theoretical framework for integration. This has been adapted from Carlile (2004) and is applied to address both fragmentation and the opportunities and challenges for integration at different levels, or parts, of an HIS, from the purely technical to the organizational.

4.1 Information Systems

4.1.1 A Socio-Technical Perspective

In the seventies and eighties, there was a widely-adopted assumption that computerization could directly and dramatically improve productivity (Kling, 2007). However, introducing computer systems in organizations did not always succeed, and it was realized that these failures were not always caused by the technology itself. The primary reason for the failures was rather the context around these systems, including user involvement and how the organizations were managed. Therefore, a social system perspective on information systems emerged, moving away from the technological deterministic view, and instead focusing on the relation between the technology and the surrounding social context (Braa & Sahay, 2012; Kling, 2007). As Kling (2007) argues; "…technology alone, even good technology alone, is not sufficient to create social or economic value" (p.207). Further, designing and configuring information systems cannot only be based on technological considerations, but also on an understanding of how people work and the surrounding organizational practices. Therefore, information systems should be viewed as complex, interdependent socio-technical systems comprised of people with different roles and relationships, hardware and software, as well as rules, norms and regulations etc. (Kling, 2007).

Braa & Sahay (2012) argue that this perspective can be relevant to understand HIS in developing countries because HIS "… are made of a web of people, computers, paper, decision-making, management, procedures and institutions, with all the dynamics of a social system" (p. 12). An HIS is not only an information system, but it also involves human and organizational stakeholders. Having a socio-technical perspective can be useful to understand the challenges of changing or developing new information systems because this will also involve organizational changes, like existing work procedures and how the organization is structured (Braa & Sahay, 2012). Integration of an HIS involves changing the information systems. A socio-technical perspective on information systems is therefore used in this thesis as the underlying perspective to understand how also social and organizational factors are involved in a process of HIS integration.

4.1.2 Information Infrastructures

While having a socio-technical perspective is useful for understanding how the context around information systems is important, the theory on Information Infrastructures (IIs) (Hanseth & Lyytinen, 2010) can be helpful to better address and explain the complexity of information systems related to how they evolve as a part of larger infrastructures.

An information infrastructure (II) is defined by Hanseth & Lyytinen (2010) as "a shared, open (and unbounded), heterogeneous and evolving socio-technical system (which we call installed base) consisting of a set of IT capabilities and their user, operations and design communities" (p.4). IIs are *shared* among multiple communities or users and *open* in the way that an unlimited number of "new components can be added and integrated with them in unexpected ways and contexts" (p.4). Components can be technical, but also users, user communities, organizations etc. with different and changing requirements (Hanseth, 2000; Hanseth & Lyytinen, 2010). These characteristics make IIs heterogeneous. First, because they can be seen as socio-technical networks including both technology, humans, organizations, institutions etc. and second, because they are connected and interrelated, constituting what Hanseth (2000) calls *ecologies of infrastructures*. That is, one infrastructure consists of several sub-infrastructures either built as layers upon each other, linked between networks or with integrated independent components, making them interdependent. These ecologies of infrastructures relate to what Henfridsson &

Bygstad (2013, p.908) term as *interconnected system collectives.* This perspective enables us to understand information systems as part of larger infrastructures, instead of stand-alone information systems.

Seeing IIs as evolving from their *installed base* means that infrastructures are not developed from scratch, but they rather build on and extend what is already present (Hanseth, 2000). Further, it is argued that to develop IIs, an approach termed *installed base cultivation* is needed (Hanseth & Henningson, 2014; Hanseth & Lyytinen, 2010). That is, to see "designing a new II as modifying (changing and extending) the installed base, the existing IIs, so that the installed base evolves as far as possible towards what is desired (user requirements*)*" (Hanseth & Henningson, 2014, p.3). Therefore, the designing of a new II will always require integrating into or replacing a part of an existing one so that the installed base evolves incrementally. A rather obvious example of this is the transport infrastructure, where, for example, building a new road always requires it to fit into the existing road infrastructure (Hanseth, 2000). The internet is another example as a constantly expanding II connected to computers and an increasing variety of different devices, used by people all over the world. New parts of the internet cannot be designed independently and from scratch, it always requires building onto or extending what is already in use (Hanseth & Lyytinen, 2010).

In an II, new technical features typically get added to the installed base as extensions or changes to the existing features, and "as the installed base grows, it becomes increasingly difficult to build systems from scratch and to implement substantial changes" (Braa & Sahay, 2012, p.14). Thus, the installed base increases in complexity. Complexity is defined by Hanseth & Henningson (2014) as "the dramatic increase in the number and heterogeneity of included components, relations, and their dynamic and unexpected interactions" (p.2). An important part of complexity theory is the role of side-effects. Changing one part of the II will often require or lead to other parts changing as well, intentionally or not. This makes the evolution of the II path-dependent as side effects can trigger new changes of the II which, in turn, can generate other side-effects and so on (Hanseth & Henningson, 2014).

Based on an II perspective, an HIS can be conceptualized as a heterogeneous HII made up of a range of information systems and different, interrelated actors, both human and organizational and technological components. Information systems within the HII, like HMIS and LMIS, are not seen as stand-alone, but rather as health information sub-systems, or sub-HIIs, and parts of the bigger infrastructure. When introducing new components to an HII, for example, a new information system, this system needs to fit with the existing work practices and systems, that is, the installed base. An HII typically consists of several information systems developed by different actors to serve specific needs. Distributed control of these systems means distributed ownership of information, different types of technologies and formats, different interests and different management strategies. Thus, connecting to the existing installed base of an HII is not always a straightforward process as it will involve complex coordination and negotiation processes with the involved actors (Nielsen & Sæbø, 2016). Having an open HII with a constantly growing installed base, it gets more and more difficult to make changes and build systems from scratch. As Braa and Sahay (2012), state:

> If we combine the concept of HIS being part of information structures, with the concept of the very same systems being, in fact, social systems, it becomes clear that the installed base itself, is made up of a web of social systems. Social systems, made-up of social dynamics and politics, as they are, have considerable resistance to change, which explains why it has proven difficult to change HIS in countries; including developing new standard reporting formats, and building new systems from scratch (p.14).

When it is difficult to build systems from scratch, and the HII has distributed control with independently developed sub-HIIs, a consequence can be that new systems or components get built on top of different parts of the complex installed base. Having a socio-technical, complex, growing installed base with an increasing number of extensions and changes on different parts of the HII can, therefore, lead to fragmentation. This perspective can be useful to understand national HIIs in developing countries, which are widely argued to be fragmented and with a lack of coordination (Braa & Sahay, 2012).

4.2 Fragmentation of HIS

The public health sector in developing countries is typically heterogeneous consisting of several institutions (from dispensaries to hospitals) managed by a range of organizations at different levels of the health system (from community health workers to the national level) (Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007). Further, the different organizational entities comprising the health sector typically build their own information systems to meet their own needs. As a result, countries often have multiple, separate information systems in their HIS. These systems include HMIS that handles service delivery data, LMIS that handles the logistics of health commodities, in addition to other sub-HIS dealing with specific diseases, patient data, finance data and human resources (Braa & Sahay, 2012).

In addition, non-governmental organizations (NGOs), donors and various international aid agencies are often involved in providing health care services in developing countries. They are usually organized as vertical health programs directed towards specific diseases or particular areas of the health sector and not coordinated with other programs (Chilundo & Aanestad, 2004). Typically funded by international organizations, they have the resources to develop their own information systems if they are not satisfied with the quality, content, and availability of the information in the national HIS. Also, the private health sector, running their own clinics and hospitals, often have their own health information systems. This leads to fragmentation of the national HIS with a range of uncoordinated and often overlapping subsystems (Lippeveld et al., 2000; Sæbø, Kossi, Titlestad, Tohouri, & Braa, 2011).

One country-specific example of a fragmented landscape of HIS is discussed by Chilundo & Aanestad (2004), where they assessed the HIS in Mozambique focusing on the information systems for the Malaria, Tuberculosis and HIV/AIDS programs:

> Within these systems different datasets are being collected, there are multiple channels for information flow, and widely varying practices regarding the use of the data. The result is several parallel and overlapping flows, a high work burden on health workers in the primary health care facility, and suboptimal data use for planning and administration. (Chilundo & Aanestad, 2004, p.2)

In this case, malaria was reported through four different reporting channels in different information systems, including the national HMIS and the Malaria program's systems (Chilundo & Aanestad, 2004). Figure 5, from Braa and Sahay (2012), illustrates these different reporting channels and how the data is collected at facility level from the malaria patients (represented by the blue figures in the bottom), and further flows up to the national level. From this figure, we can see inconsistencies in the reporting frequencies from facility to district level, where one of the information systems requires weekly reporting, while the three others require a monthly reporting. The figure also illustrates the different reporting formats, where two of the information systems at province level are computerized, while the other two are in paper format.

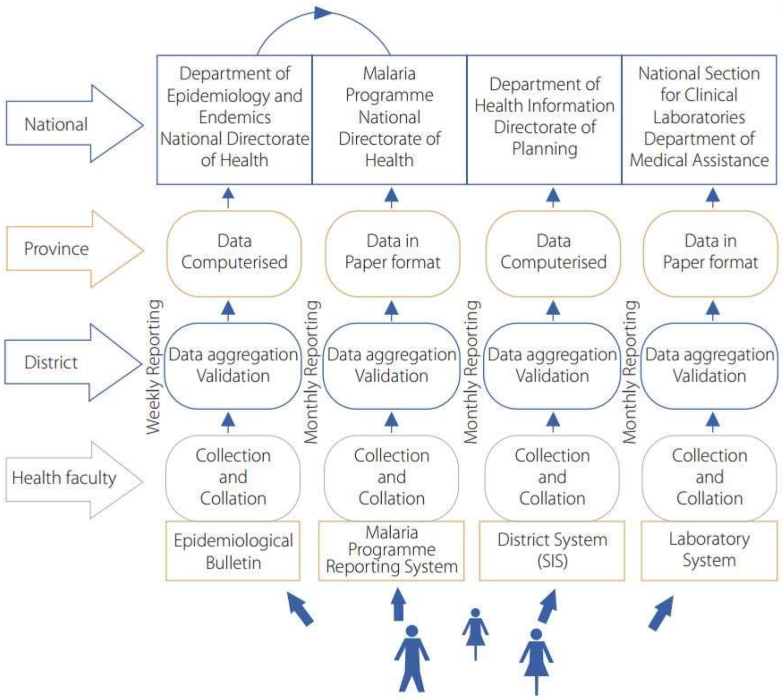


Figure 5 - Reporting channels for Malaria in Mozambique (Braa & Sahay, 2012, p.19)

Even though this example illustrates only one part of the fragmented HIS in Mozambique, this is a typical case for HIS in general in developing countries. Distributed responsibilities for the health data between several ministries, institutions, and donors with different interests and lack of coordination leads to information fragmentation. The different information demands from the different actors further lead to the development of multiple, parallel and sometimes overlapping subsystems with different formats and reporting frequencies (Health Metrics Network, 2008).

4.2.1 Challenges of Fragmentation

The Health Metrics Network (HMN) is a global health partnership under WHO (World Health Organization) established to support the strengthening of HIS in low and middle-income countries. Their main vision is that better information leads to better decisions, which, in turn, leads to better health. They encourage the use of information for decision-making and argue that "decision-makers at all levels of the health system need information that is relevant, reliable and timely" (Health Metrics Network, 2008, p.7). However, the typical case is that the poorly coordinated subsystems within HIS "…cannot deliver timely, accurate and complete data…" (p.6).

Braa and Sahay (2012) state that “fragmentation and lack of coordination of HIS have been identified by various researchers and also managers, as the major problem shaping their use and utility” (p.19). Overlaps and inconsistencies between reporting formats as well as how the data elements are named and defined, result in duplicated data collection; “the reporting of the same data several times in different formats, and sometimes in different ways under multiple names” (Braa & Sahay, 2012, p.19). Therefore, often a lot more data gets reported, than what is actually needed. Further, a typical situation is that new forms get introduced and pushed into the HIS as soon as there are new information needs or demands. These forms get introduced “without coordinating with the old or without abolishing the old forms. As a consequence, multiple partly overlapping forms, providing a lot of irrelevant information are in use at the same time” (Braa & Sahay, 2012). With paper-based systems on facility level, this leads to a high burden for health workers as they need to fill the same information in a range of different reporting forms by hand (Sæbø et al., 2011).

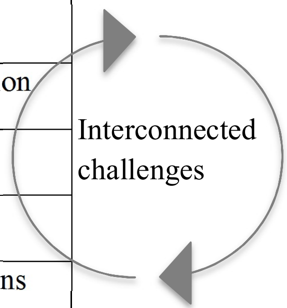
Overburdened health workers and the challenges of data collection can lead to data of poor quality. Poor data quality can consequently lead to the data not being used for decision-making and health improvement (Braa & Sahay, 2012; Sæbø et al., 2011). “Although a vast amount of data may be collected, only a small proportion is synthesized, analysed and used” (Health Metrics Network, 2008, p.6). In turn, because it is not being used, the data remains of poor quality (Braa & Sahay, 2012; Sæbø et al., 2011).

Further, fragmentation leads to health managers at all levels of the health system having to obtain data from multiple different information sources. This can, for example, make it hard for the health managers to get a complete picture of the health status of the population. In addition, the different data being available in different formats, both in several electronic systems and on paper, make it complicated to coordinate and collate the information (Sæbø et al., 2011).

To summarize, the side-effects and challenges of fragmented HIS are many and interconnected. Duplication, overlaps, and inconsistencies in the data and data formats make it hard to coordinate and collate information and leads to overburdened health workers. Overburdened health workers can lead to the data having poor quality, which in turn can lead to the data not being used. Difficulties in the coordination of information also make it hard for the health managers to use the information for making good decisions. The data not being used, makes the data remain of poor quality, all in all making this a vicious cycle. The challenges are summarized in table 3 below.

Table 3 - Typical challenges of fragmented HIS

Fragmentation challenges
Duplication of data and work
Hard to collate and coordinate information
Overburdened health workers
Poor data quality
Poor use of information to make decisions



4.3 Integration

"Given this context of diversity and multiplicity of systems, the heart of the challenge facing policy makers, software developers, users and vendors is, 'how can we have these systems to communicate to each other to get more integrated information? '" (Braa & Sahay, 2012, p.9). Efforts from the HMN, through their framework for strengthening national HIS (2008), has led to a consensus that countries need to work towards an integrated framework for the use and management of information (Braa & Sahay, 2012, HMN, 2008).

A shared vision of moving from a fragmented landscape towards integration is that one can achieve more efficient recording and processing of information, enabling better decision-making and overall health management (Nielsen & Sæbø, 2016). "Integrated information helps managers to take more effective decisions, while data redundancies and duplications can be eliminated or minimized for the users and data providers" (Braa & Sahay, 2012, p.9). If we can bring together the fragmented HIS and ensure coordinated information collection and information sharing between the silos, we can also reduce the burden of parallel data collection and reporting, as well as reduce the costs of running parallel systems (Nielsen & Sæbø, 2016, p.135). However, as also discussed in section 4.1.2, considering the heterogeneous landscape of an HIS, moving towards integrated systems is not necessarily a straightforward process (Nielsen & Sæbø, 2016). The next section aims to better understand integration processes and what they involve and require.

4.3.1 Understanding Integration

People often have different understandings of the meaning of the term 'integration' (Ellingsen & Monteiro, 2008; Gulledge, 2006). In the field of HIS, this will, for example, depend on people's roles in and relations to the health sector. A health worker at a facility can understand integration as the coordination and alignment of different information and routines for data collection. A software developer, on the other hand, can think of integration as the coordination of applications and communication protocols. Some have argued that integration is not possible and that making systems interoperable is a better strategy, as they have understood the term integration as a purely technical process of collating several systems into one big system (Braa & Sahay, 2012). Braa and Sahay (2012), however, argue that integration cannot be seen as purely technical and that it, "…even at the level of software applications, cannot be reduced to an aim of constructing one big system" (p.59). In an organizational context, integration can be understood as the unifying and collaboration of health programs and their routines for e.g. data collection. In this context, integration "…takes the user needs of the HIS, the purpose of the systems, and the wider organizational perspectives as points of departure, and relate those to goals of better efficiency, effectiveness and co-ordination in organizations and enterprises" (p.59). Further, they see interoperability as something that "…refers to the ability of a system to use and share information and functionality, of another system by adhering to common standards" (p.59). In this perspective, interoperability can be seen as a subset of the broader term integration (Braa & Sahay, 2012).

Horizontal and vertical integration

We can distinguish between horizontal and vertical integration. Horizontal integration is conceptualized as "…integration across the various domains or business areas of an organisation, or across organisations". Vertical integration is conceptualized as the hierarchical integration from top to bottom within an organization or "…the line of business from its top management down to operational levels" (Braa & Sahay, 2012, p.63). Within the health sector, vertical integration means to have a smooth, integrated flow of data up and down the hierarchical levels; between the community and facility level where data is collected, and the highest administrative level. Because most data collection at facility level still happens on paper, and there are computer-based systems at the higher levels, one important factor for achieving vertical integration is to develop paper-computer interfaces (Braa & Sahay, 2012).

However, only focusing on vertical integration will not solve the issues of fragmentation. In fact, too much vertical integration is argued to be a leading reason for the fragmentation of HIS in a country. This is because vertical integration also means *silos*. That is, separate, vertical systems, like the ones discussed in section 4.2; health programs building their own, separate information systems with little or no coordination with other health programs and the national systems (Braa & Sahay, 2012).

Horizontal integration within HIS is explained by Braa and Sahay (2012) as the integration of "…the health sector and its environment and wider context of partners, community or public sector" (p.65). This means that horizontal integration involves coordination of the information systems and the associated information flows across the different health programs and health services as well as "other relevant data sources, so that all data can be accessed and analysed at 'one point'" (p.65). A data warehouse approach is explained by Braa and Sahay as a type of horizontal integration which enables integration across the sectors at each level of health care (facility to national) to support the different user needs through the data warehouse. A data warehouse has the ability to "...contain, aggregate data and indicators from various production or transaction systems, for medical records, human resources, logistics, finances and laboratory" (Braa & Sahay, 2012, p.22). It can be understood as a type of database with the capacity to store data from different data sources shared between different stakeholders of the HIS. DHIS2 is presented as a system that can be used as a data warehouse because it is capable of being linked to different types of technologies and share data from different data sources (Braa & Sahay, 2012).

Establishing a data warehouse is central to the HMN strategy to overcome the problems of fragmentation. However, investigating this approach to integration in four different countries, Sæbø et al. (2011) found that a process of integration involves much more than simply having a technical solution like a data warehouse. In cases of fragmentation, caused by different uncoordinated, independent organizational actors, the process of integration is rather a political and organizational issue. Thus, an integration of a country's HIS will include getting stakeholders to communicate and establish agreements on their different roles and data sharing as well as shared standards (Chilundo & Aanestad, 2004; Nielsen & Sæbø, 2016; Sæbø et al., 2011). However, a technical solution, like a data warehouse, can work as an important mean or *boundary object* to enable integration and to align the actors towards a common goal of strengthening the national HIS (Sæbø et al., 2011). In sum, integration can both relate to technical issues, to the sharing of data between subsystems or to organizational issues including aligning of interests and establishing a will to share data and collaborate (Kossi, 2016; Sæbø et al., 2011).

4.3.2 Carlile's Integrative Framework

Carlile's integrative framework (2004) was developed for managing and sharing knowledge across boundaries within an organization. The framework describes three 'progressively complex' boundaries – syntactic, semantic and pragmatic, - which involves three 'progressively complex' processes – transfer, translation, and transformation for knowledge sharing (Carlile, 2004).

Various researchers have also applied it for explaining both architecting and integration within HIS (e.g. Braa & Sahay, 2012; Kossi, 2016; Sæbø et al., 2011). Braa and Sahay (2012), arguing for the importance of standardization in integration efforts, applies Carlile's framework to describe different levels of standardization and interoperability within HIS. Beyond understanding that integration belongs to different levels of the HIS, Sæbø et al. (2011) calls for a more thorough understanding of the interaction between the different levels of integration and use Carlile's framework to address this. They found that the framework was helpful to understand how four countries followed different paths in their integration process.

In this thesis, the framework has been adapted to understand both fragmentation and integration at three different levels in an HIS, namely on the technical level, data level and organizational level. The three levels and what they involve are described further in the next sections.

Technical level

At the technical level or, syntactic boundary, in Carlile's framework, a *common lexicon* is developed for knowledge sharing. Here, differences and dependencies between the actors are known, so the common lexicon is used to *transfer* knowledge (Carlile, 2004). In an HIS, various data collection tools in different formats are used, and both paper-based systems and electronic systems are a part of the technical level. However, paper-based systems are considered as hardware and they cannot be changed without a substantial amount of manual work, they instead need to be replaced. According to Braa & Sahay (2012), the difficulties in changing paper forms "…make up an important driving factor in the fragmentation of HIS and the problems faced by data standardization" (p.68). For the electronic systems, different types of software can be in use for the different health programs (horizontally) and at the different health care levels (vertically). Braa and Sahay explain the syntactic level also as a technical level of data transfer and interoperability including both paper-based systems and electronic systems. For integration at this level, there is a need to agree on technical means for data and information transfer. It is not a matter of *what* is being transferred, but rather *how* it is being transferred between the systems (Braa & Sahay, 2012).

Data level

The transition to a semantic boundary in Carlile's framework occurs when the differences and dependencies become unclear or there are multiple interpretations between the actors. Different interpretations can limit the effective management of knowledge between the actors, so a shared meaning should be developed to understand different interpretations. This will involve a process of *translating* knowledge, which will also include negotiation and agreements between the actors (Carlile, 2004). This level in an HIS is explained by Braa and Sahay as the data-semantic level where "processes of translation of interests and views, are involved in reaching shared meaning and understanding; for example, between different health programmes, on what should be the important and shared data and indicators" (Braa & Sahay, 2012, p.68). In the different sub-HIS there are often different understandings and meanings of the data and information to be collected and used. For integration at this level, there is a need to establish an agreement and shared understanding on *what* data to share and exchange, through e.g. a standardized data set. This can, for example, relate to agreeing on, and standardizing how health indicators are calculated (Braa & Sahay, 2012).

Organizational level

Moving from the semantic boundary to a pragmatic boundary in Carlile's framework there are even more increased novelty and different interests between the actors that need to be resolved. The increased novelty hinders the actors in sharing and assessing their knowledge. Therefore, domain-specific knowledge and the common knowledge between the actors need to be *transformed*. Different interests between actors must be aligned and this will necessarily require a substantial practical and political effort (Carlile, 2004).

Braa and Sahay (2012) describe this level as a social, organizational and political level and the level of decision-making where the actors can use their power to decide standards at the technical and data level. The different actors within an HIS will have different interests, information demands, procedures (e.g. data collection routines), information flows, as well as varied resources (staff and funding etc.). Integration here is about aligning interests between the actors by transforming social and organizational structures, "…so as to accommodate new ways of sharing information across organisational boundaries, implementing new systems and new routines, and shared by several health programmes" (Braa & Sahay, 2012, p.69). That is, to agree on health data sharing between the actors (health programs and other institutions) as well as aligning and agreeing on responsibilities, the routines for data collection and data management, and on health information ownership.

Carlile argues that it is necessary to have several iterations through the boundaries, or levels, to negotiate the actors' interests. Therefore, iterative cycling is presented as a fourth element of the framework for addressing novelty at the pragmatic boundary (Carlile, 2004; Kossi, 2016).

> Addressing the consequences cannot be resolved with one try, but requires an iterative process of sharing and assessing knowledge, creating new agreements, and making changes where needed. As the actors participate in each iterative stage, they get better at identifying what differences and dependencies are of consequence at the boundary; they improve at collectively developing more adequate common lexicon, meaning and interests. (Carlile, 2004, p.563)

Sæbø et al. (2011) argue that the concept of iteration is relevant to understand the standardization processes necessary to achieve HIS integration, because "standards tend to be evolving through negotiations between actors facilitated through ongoing efforts to develop standards in practice" (p.47). Agreements and changes develop in an iterative and evolutionary process (Sæbø et al., 2011). Several cycles are necessary to develop a common understanding and aligned interests because issues and consequences cannot be addressed at the first try. "By cycling through the levels, the aim is to gradually negotiate and solve differences in interests and shared understanding, at the different levels" (Braa & Sahay, 2012, p.69). Issues at the highest levels (organizational/pragmatic or data/semantic) may further need solutions at the lower levels to get solved. This is illustrated by an example from Malawi where the Ministry of Health and the Expanded Program on Immunization tried to solve an issue of huge discrepancies in the immunization data. Even though the actors had agreed to fix this, they were not able to anything before a practical solution for standardization and coordination at the syntactic level were found. First after they had solved the practical issues, they could agree on shared management of information at the data/semantic level, which enabled further coordination and sharing at the pragmatic/organizational level (Braa & Sahay, 2012).

In Sæbø et al.'s (2011) explanation of how four countries worked towards integrated HIS, they show how Sierra Leone followed Carlile's processes of transfer, translation, transformation and iteration. At the technical/syntactic level, Sierra Leone adopted a technical solution for data sharing and identified indicators and data elements, while the paper collection forms were not changed. At the data/semantic level, a new *common lexicon* was created in the data warehouse to remove duplications and overlaps in the previous data collection forms. Then, after they had used the integrated data warehouse for over one year, the actors saw the issues of data quality in the existing forms and agreed on new harmonized forms. This was an iterative process, where the actors met regularly, re-negotiating and reviewing the shared standards. The study also found that DHIS, used as a data warehouse, worked as a "…boundary object in providing the capacity to negotiate interests between the actors and to transform knowledge and practices" (Sæbø et al., 2011, p.56). Thus, boundary objects can be used as means for the negotiations between actors, for example, to mediate between two health programs. When data can be shared between the data warehouse and other systems, the actors can "agree on useful data and indicators to be shared" (Braa & Sahay, 2012, p.69).

To sum up, Carlile's integrative framework has been adapted to describe three levels of fragmentation and integration in HIS; technical level, data level and organizational level and how they are related to each other. The three levels are shown in figure 6 and summarized below.

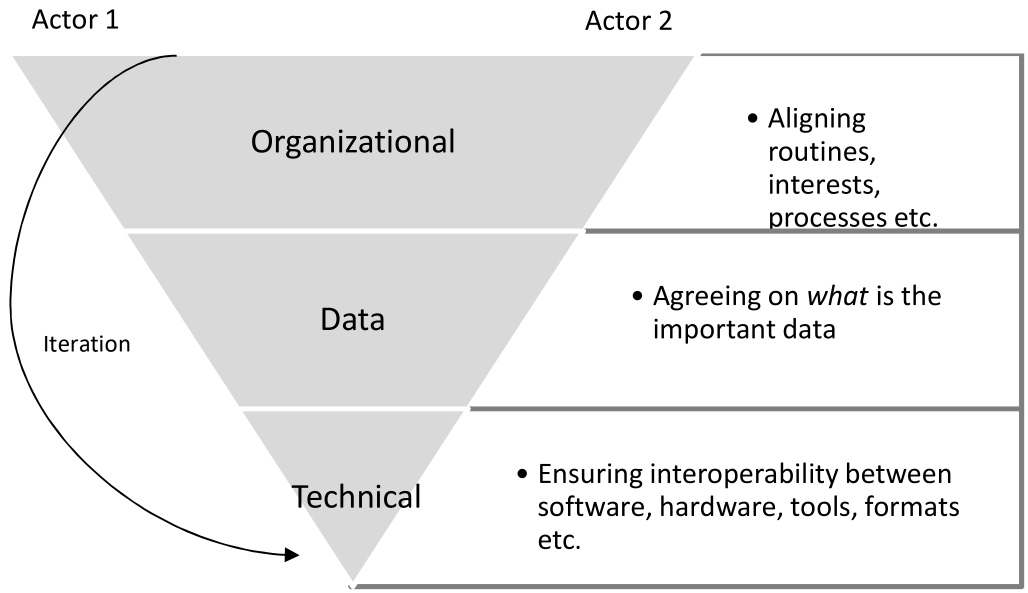


Figure 6 - Three levels of integration and their characteristics (Adapted from figure 2 in Carlile (2004, p.563))

At the technical level in an HIS, there can be various tools and systems, both electronic and paper-based, in different formats and run on different software. Paper-based systems are further difficult to change and makes e.g. standardization challenging. Integration at this level in an HIS requires making the systems able to share and transfer data and thus enabling interoperability.

The data level involves the data to be transferred between the different systems or actors. In an HIS, there is often a myriad of different actors involved. These actors often have their own understandings and meanings of what is the important health data to be collected and processed, and how the data should be defined. Integration at this level will, therefore, require agreements on what data to share and making e.g. a standardized set of the same data definitions.

The organizational level in an HIS involves the various actors and their interests, information demands, procedures for e.g. collecting data, different resources and so on. Integration at this level requires negotiating and aligning these interests and routines, as well as sharing and agreeing on responsibilities, information sharing etc. At this level, the actors can also agree on standards and how to integrate at the technical and data level.

A fourth element of the integrative framework is the iteration through the levels for negotiating on the actors' interests. Several iterations are necessary for an integration process to develop a common understanding and aligning interests between the actors. Aligning interests between actors at the organizational level can also be done by negotiation through a boundary object. That is, if for example, a technical solution proves to be able to solve practical issues for interoperability at the technical level, this can enable further negotiations between the actors on other issues, like how to standardize data.

4.4 Summary of the Theoretical Framework

An HIS conceptualized as an HII, is a heterogeneous socio-technical network consisting of different components, sub-HIIs and actors with different interests. The installed base of the HII is comprised of various interconnected software, routines, reporting formats, national and international actors with distributed responsibilities. New components introduced should fit with what is existing, so that the installed base of the HII evolves incrementally in a so-called installed base cultivation. However, because the HII is constantly expanding, it is also increasing in complexity, making it more and more difficult to make big changes and build systems from scratch.

Related research has shown that fragmentation is a typical case for HIS in developing countries, with distributed responsibilities between a wide range of different actors, which have their own interests and information demands. This, in addition to the lack of coordination and communication between the actors often leads to the development of multiple, parallel and sometimes overlapping sub-HIS. The main challenges related to this is the duplication of data and work, difficulties in coordinating information, overburdened health workers, poor data quality and poor use of information to make decisions. These challenges are interconnected and affecting each other.

Integration is often suggested as a solution to solve the challenges of fragmentation. There can be different understandings of and approaches to integration, but the main point drawn from section 4.3.1 is that HIS integration is not only related to the interoperability of technical systems, but also to the coordination of a wider organizational context. Further, one can distinguish between horizontal integration (across domains or organizations) and vertical integration (hierarchical integration from e.g. top management to the “operational” levels).

With a socio-technical perspective on information systems and drawing on the related research on integration as something related to both technical and organizational aspects, the integrative framework from Carlile (2004) has been adapted to analyze fragmentation and integration in

HIS at different levels. The three levels; technical, data and organizational have different features and involve different processes for integration, but they are also interconnected and multiple iterations through the levels is mentioned as a fourth element necessary in an integration process. The framework can thus be useful to analyze fragmentation and how to address integration at different levels of the HII, and to understand how the levels interact with each other in an integration process. Comparing the fragmentation at the three levels with the opportunities and challenges for integration at the same levels can then be used to critically discuss the potential benefits and challenges for integration.

5 Empirical Findings

The purpose of this chapter is to present the empirical findings from the research conducted. First, the infrastructural context for the case and a brief explanation of the national HMIS is introduced. Next, the regular health commodity supply chain is described, including the flow of commodity supplies and logistics information as well as the information systems used for managing the LMIS. A brief explanation of the ongoing project with the integration of DHIS2 and eLMIS is also presented, before moving on to the findings related to the vaccine supply chain. Here, the different parts of the vaccine supply chain are described thoroughly, including the involved actors, information systems used, the flow of data, the flow of vaccines, as well as the current project of implementing an integrated vaccine information management system (VIMS).

5.1 Infrastructure

The infrastructural conditions in Tanzania vary throughout the country. In relation to the hierarchical health system structure, the highest level has less infrastructural challenges than the lower levels. The weak road infrastructure in Tanzania affects the overall HIS, especially the commodity supply chain and can make it hard to reach out to the most remote facilities. Both the informants from JSI and MSD also mentioned that the poor road quality wears out the vehicles used for the transportation of commodities, requiring substantial resources for maintenance work and possible replacement of the cars.

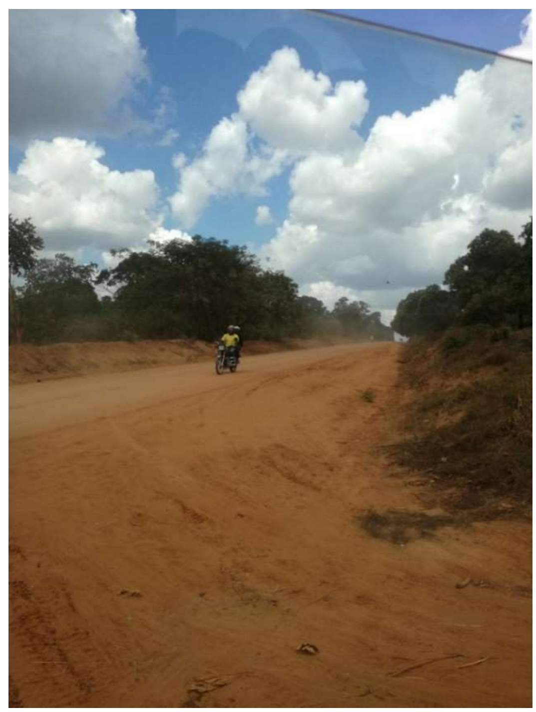


Figure 7 - Example of the road quality in a rural area

Figure 8 - Storage of paper forms outside a district office

No or unstable access to internet and/or electricity at the health centers and dispensaries, especially in the rural areas of the country, makes the facility level dependent on paper-based systems. In one district office we visited, they said that because of unstable internet access, it is sometimes hard to enter HMIS data by the deadline (which is on a given date each month). Another infrastructural issue is the frequent power outages, which is an issue we got to experience a lot ourselves during both stays in Tanzania, even though we lived in urban Dar es Salaam. One power outage also occurred while conducting an interview at a district office. The situation may be even worse in more rural areas housing the biggest part of Tanzania's population. Power outages are affecting and complicating daily work with, for example, computerized systems and internet connection. Most offices, and all district offices we visited use laptops instead of stationary computers, making them able to continue their daily work in case of power outages.

Power outages can also have critical consequences for the cold chain management, as vaccines need to be kept in a cold, stable temperature. All facilities handling vaccines should, therefore, have a solid backup plan in case the power is out for a longer period. Most facilities we visited had generators as a backup power source. If the generator does not work, the health workers move all vaccines into a cold box and travel to the nearest facility with functioning cold chain equipment for temporary storage.

5.2 HMIS

Data for DHIS2 are registered and aggregated on paper at the facility level, and delivered to, or collected by a representative (HMIS worker) from the district and entered into DHIS2 at a given date monthly. The HMIS workers are part of the District Health Management Team. In one district we visited, the HMIS workers said that they spend 2-3 days traveling to all facilities within the district to collect the paper forms. They also combine these visits with supervision. In most of the other districts, the facilities need to bring the forms to the district office themselves. When the HMIS-workers at the district level type in data in DHIS2, they also do quality assurances of the data and produce statistical reports that they give to the facilities as a feedback mechanism. Some of the HMIS-workers at the district offices we visited told us about challenges of bad data quality in DHIS2.

At one dispensary we visited, the health worker showed us how immunization data is processed in three different forms at the facilities before it is typed into DHIS2 at the district level. There is one immunization register (figure 10) for all information regarding immunization of the children, including the type of vaccine, date, place, information about the mother and child, possibilities for HIV transmission etc. In addition, the health worker uses a tally sheet (figure 11) for registering the number of doses given for the particular vaccines. Then, each month, the health workers aggregate the data from the two forms into a monthly summary form (figure 12), which is the form that gets typed into DHIS2 at the district level. After the data is entered into DHIS2 at the district level, it is available for health managers at all higher levels, including the Regional Health Management Team for data analysis and decision-making. It is worth mentioning that DHIS2 also collects other routine health information than immunization data, but because the focus of the thesis is on the vaccine information systems, the other HMIS forms have not been investigated, and are thus not presented or discussed further in this thesis. The information flow of routine immunization data for DHIS2 is illustrated in figure 9 below.

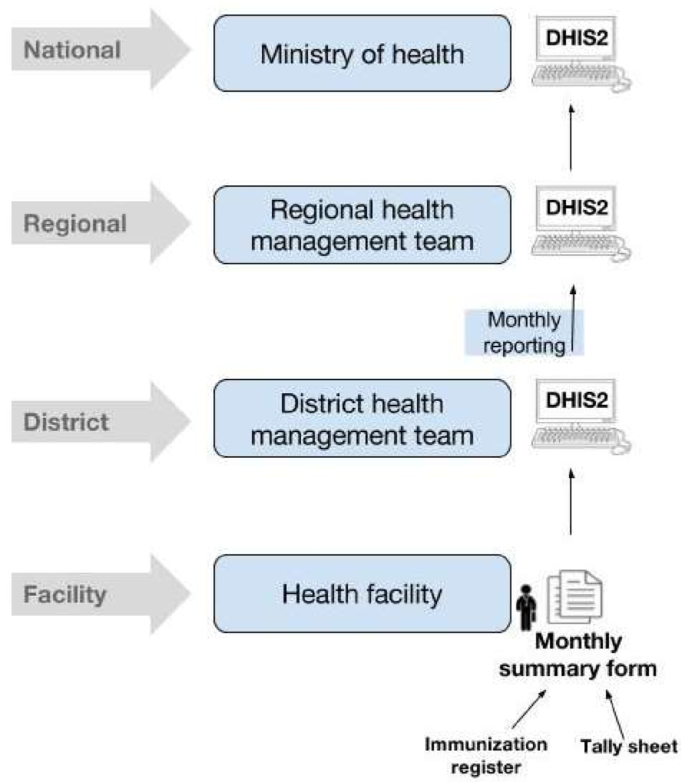


Figure 9 – Illustration of the HMIS information flow of routine immunization data

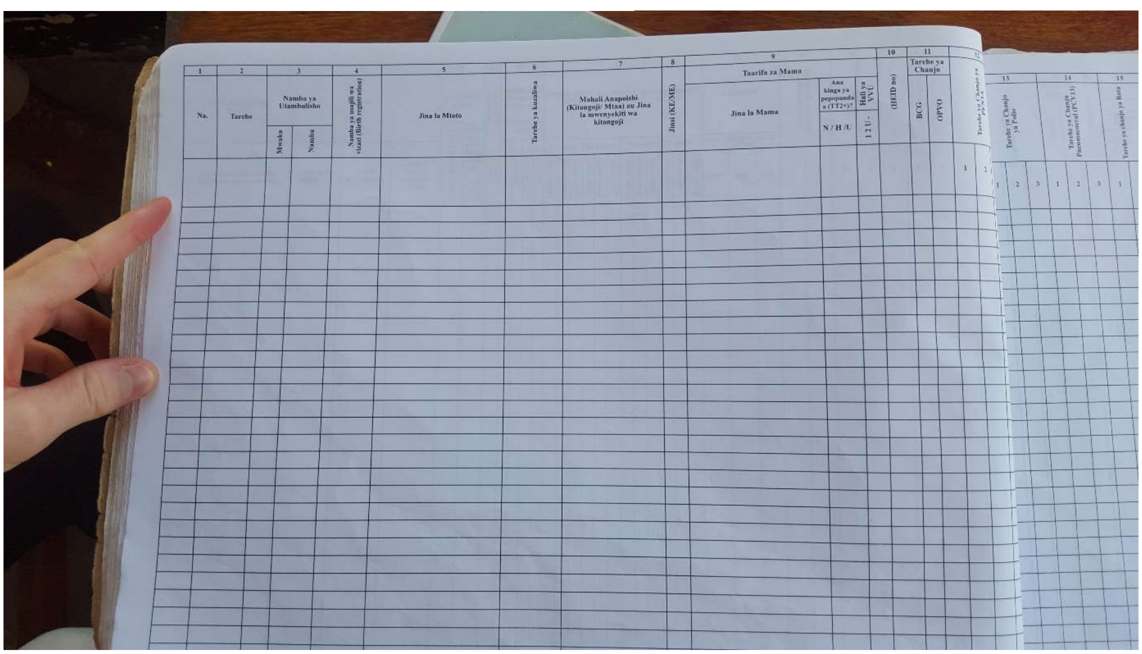


Figure 10 - Part of immunization register

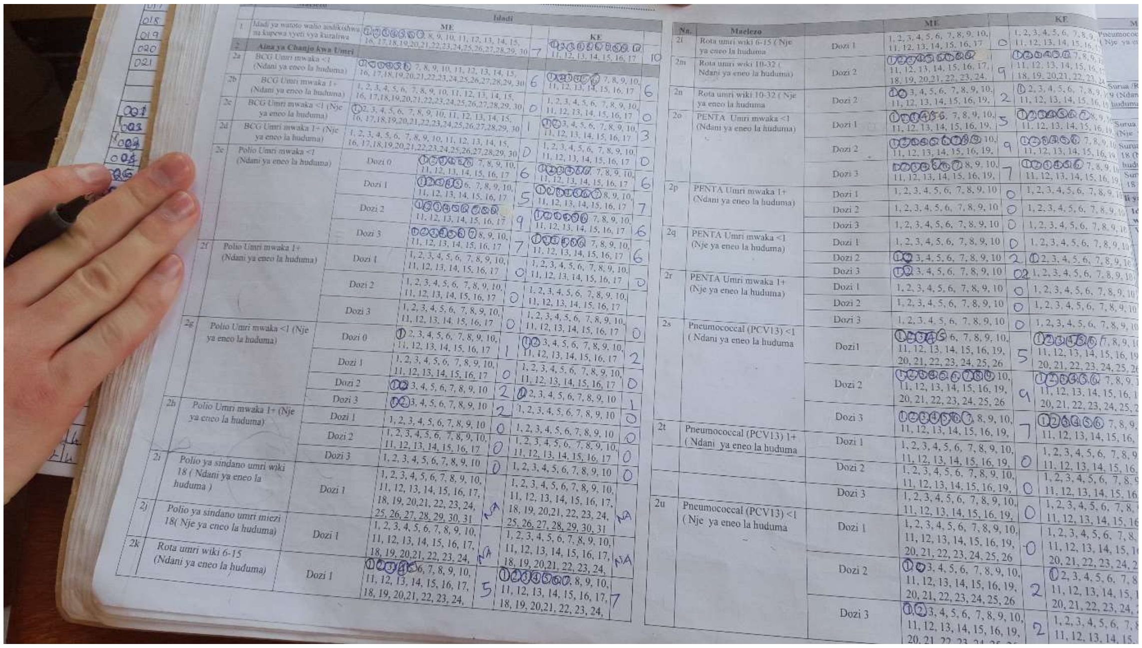


Figure 11 - Tally sheet

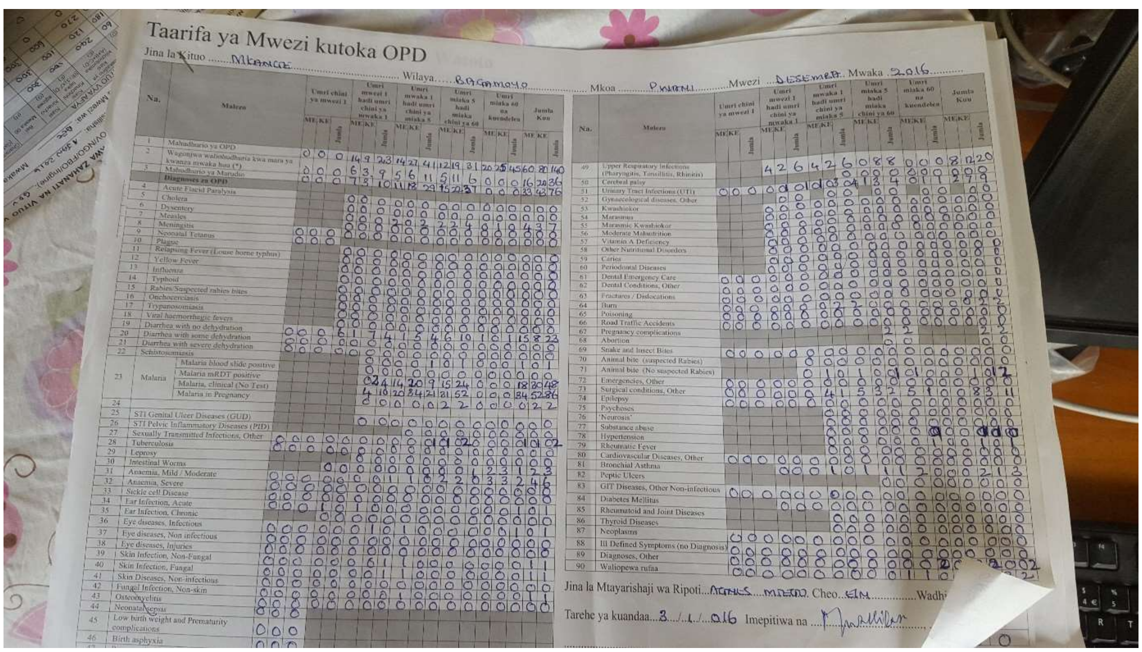


Figure 12 - Monthly summary form

5.3 Health Commodity Supply Chain

The health commodity supply chain includes the management, ordering, and distribution of all health commodities. The Medical Stores Department (MSD) is in charge of all procurement, storage, and distribution of the commodities and has one central warehouse and nine zonal warehouses. The commodities are ordered from and distributed to all hospitals, pharmacies, health centers and dispensaries throughout the country directly from MSD. The ordering- and distribution process, including the relation between all the levels, are described more thoroughly in the next sections.

Ordering process

As mentioned in chapter 2, Tanzania uses eLMIS as a national LMIS. It is used for reporting logistics information and the ordering of health commodities from facility level to the national level. eLMIS is used at the district level all over the country, and at facility level in one urban district within Dar es Salaam. For reporting and ordering of health commodities through eLMIS, a form called R&R (report & requisition) form is used. The orders in these forms are based on information from stock registers for the health commodities. The R&R form is paper-based at the facility level before it is collected by or brought to the district office where it is typed into eLMIS manually, typically by the district pharmacist. All facilities are organized into three groups (A, B, C) sending quarterly reports (covering three months) in separate, given months. If for example, group A reports in January, group B will report in February and group C in March. Then, group A reports in April, group B in May and so on.

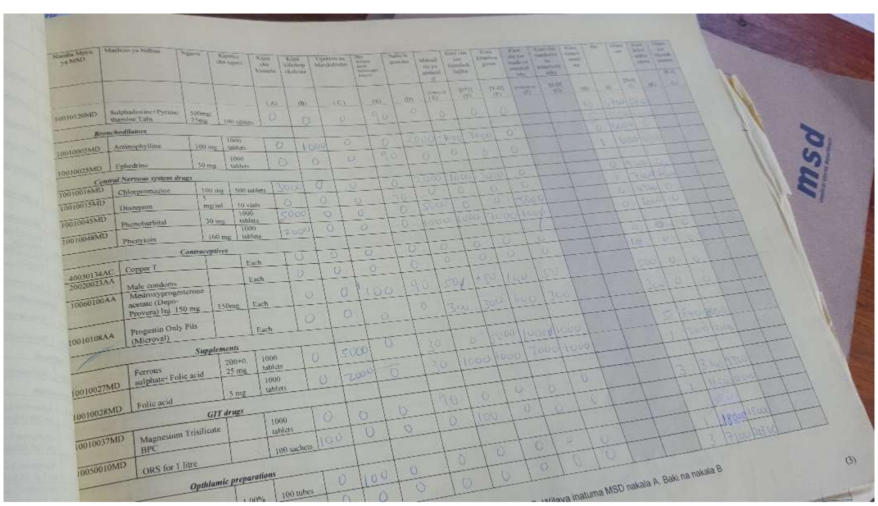


Figure 13 – Paper-based R&R form

When typing the data from the R&R form into eLMIS, the district pharmacist also controls, quality checks and adjusts the forms. Adjustments are for example made to match the order with the facility's budget. This is because the facilities do not have any insight into their available budget, and they therefore often order more than their budget can cover. Adjustments can also be made if the district pharmacist sees obvious mistakes or data that seem to be incorrect, compared to e.g. the data in the previous month. In this case, the district pharmacist will call the facility to confirm and let them know about the adjustment. Sometimes, the data fields for reporting commodities in the paper-based R&R forms are not updated with the electronic form in eLMIS. Because of this, the facilities also have another, separate form they can use for the registering of commodities that are not included in the regular R&R form. After the order is controlled and processed at the district level, it is sent through eLMIS to the MSD zonal warehouse associated with the district. It is also possible to deliver a paper-based R&R form directly to the warehouse. We learned this at one hospital we visited in Dar es Salaam, where they order drugs whenever they need more, through paper forms, and then travel to collect the supplies after about one week.

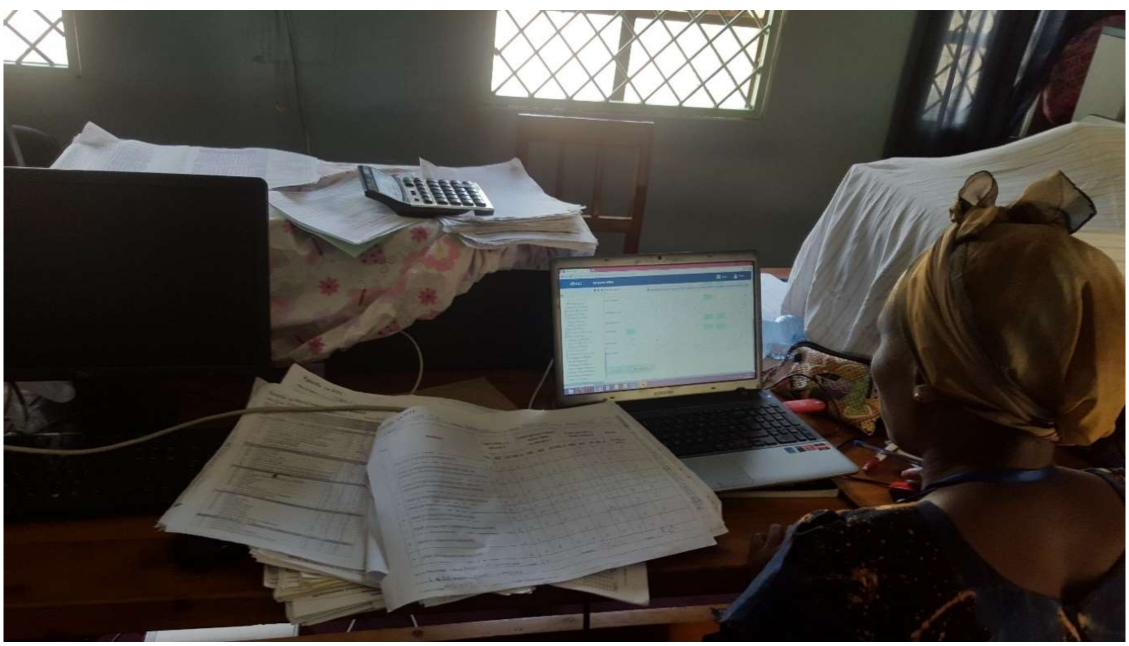


Figure 14 - Woman working with eLMIS

It is possible to place emergency orders through eLMIS if the facilities are out of stock of a commodity. However, one informant at a facility told us that it usually takes two or three weeks for an emergency order to be processed and distributed. Further, informants from MSD said that the warehouses often do not handle emergency orders at all, and if they do, the facilities are required to travel and pick up the supplies themselves. If the facilities are not able to pick up the commodities, the emergency order is simply delivered together with the regular order. This is because MSD do not have the time or capacity to deliver a small number of commodities to a, possibly, remote location outside the normal delivery schedule. Therefore, the facilities often rather redistribute commodities between themselves when out of stock. For this, they use the mobile application WhatsApp to communicate. If commodities are available at other facilities nearby, it is easier and faster to redistribute than to place emergency orders. Redistribution is coordinated with the district pharmacist and registered in the R&R forms and eLMIS as *loss/adjustments* of the commodity. Facilities can also order supplies from private actors, but public health facilities can only, by law, do this if MSD is out of stock of the commodities they want to order. Ordering from private actors are more expensive, and because they do not have the same quality procedures and regulations as MSD, there is also a risk of getting commodities with lower quality.

In addition to eLMIS, Tanzania has a SMS-based logistics system called ILS gateway, used at the facility level. The system allows reporting of 20 health commodities, filling up the size of one SMS. The system also sends SMS notifications to the facilities before an upcoming supervision visit from the district, and to remind them to deliver R&R forms. The data reported through the ILS gateway can be accessed by the district pharmacist in a web interface. CTC2 is another example of a logistics system used in Tanzania which we saw in use at one hospital, at the care and treatment center (CTC) for HIV/AIDS treatment. This is an electronic system used to manage the logistics of ARV (antiretroviral) drugs and to keep track of the treatment of HIV/AIDS patients. At the hospital where we got introduced to this system, all patients are registered with a unique ID used specifically for CTC2 to connect patient data and treatment history. For the ordering of new ARV medicines, the pharmacist working at the CTC, prints out an R&R form from CTC2 and types this into eLMIS.

Distribution

MSD is responsible for all procurement, storage, and distribution of health commodities in the public health sector in Tanzania. About 85 – 90 percent of all health commodities are procured from outside the country and received at the central MSD warehouse in Dar es Salaam. The central warehouse also works as an administrative section, distributes all commodities to the 9 other zonal MSD warehouses throughout the country.

At the MSD warehouses, orders are processed through an ERP (Enterprise Resource Planning) – system called EPICOR9. This system also handles stock management at the warehouses. Because eLMIS and EPICOR9 are not integrated, the workers at the warehouses need to manually transfer information between the two systems. That is, they print out the R&R form from eLMIS and type this information into EPICOR9. Previously, there have been some unsuccessful attempts to integrate the systems, but now, MSD has managed to develop their own interface for transferring information from eLMIS to EPICOR9. This means that when an order is placed in eLMIS, it is being processed and automatically forwarded to EPICOR9. The main challenge they encountered in developing this interface was that the data (for health commodities) in the two systems are defined with different codes. Per January 2016, the interface was only implemented in Dar es Salaam and at one other warehouse, but MSDs ambition was to have a roll out to all zones as soon as possible. Another ambition is to also enable information transfer from EPICOR9 to eLMIS.

The health commodity orders can get adjusted at the zonal level for the same reasons as at the district, but also to match the available stock at the warehouse. The warehouses do not communicate with the facilities, so if an adjustment is made, the facilities will not know this before they receive their supplies. After adjusting and processing the order in EPICOR 9, MSD delivers the supplies directly to the facilities (that is, all hospitals, dispensaries and health centers at all levels) every three months. They deliver the commodities in a staggered distribution cycle following the same groups (A, B, C) as in the ordering process, mentioned in the previous section. The reason for this delivery schedule, is that with over 6000 health facilities, it is, according to MSD, hard to distribute to all facilities within the same distribution cycle (Supply Chain Technical Resource Team & UN Commission on Life-Saving Commodities, 2016). Figure 15 below illustrates the flow of LMIS information, as well as the health commodity distribution process at the different levels in the health care sector. It should, however, be noted that it is unclear how the information flows between the central and zonal MSD warehouses.

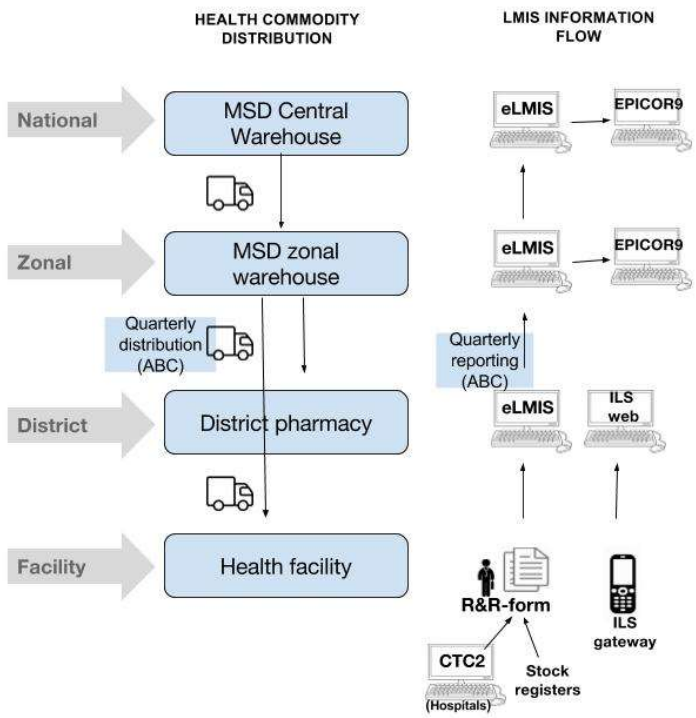


Figure 15 – Flow of LMIS information, and the distribution of health commodities

Storage and equipment

The health commodity storages, or pharmacies, at the facilities seem to be in various conditions. At one hospital pharmacy, the commodities were stored in, seemingly, quite unorganized shelves and with stacks of commodity boxes on the floor. However, the pharmacy staff did not mention any problems with the organizing of the stocks. At all the storages, the health workers or pharmacists use individual stock cards / tally cards to manage the stock status for the health commodities. These cards are placed next to the stock of commodities in the shelves. In addition, they have bigger stock registers where they write information for all the commodities. In both the stock cards and the bigger registers, they write down the amount they have received, when, and from whom, as well as the current stock balance. They also do regular physical counts of all commodities. The frequency of these counts varies from storage to storage. Some told us they performed annual counts, other said monthly, and some said that it varies from monthly to quarterly. Most facilities experience stock outs of some health commodities from time to time. One district pharmacist in Dar es Salaam said that “even in Dar, and even with eLMIS which is a good system, there are still stock outs”. This implies that the stock out problem is not necessarily caused by the information system itself, but rather by other surrounding factors, like funding, politics and other organizational aspects. Informants from MSD also told us that they have to deal with national stock outs at the warehouses from time to time.

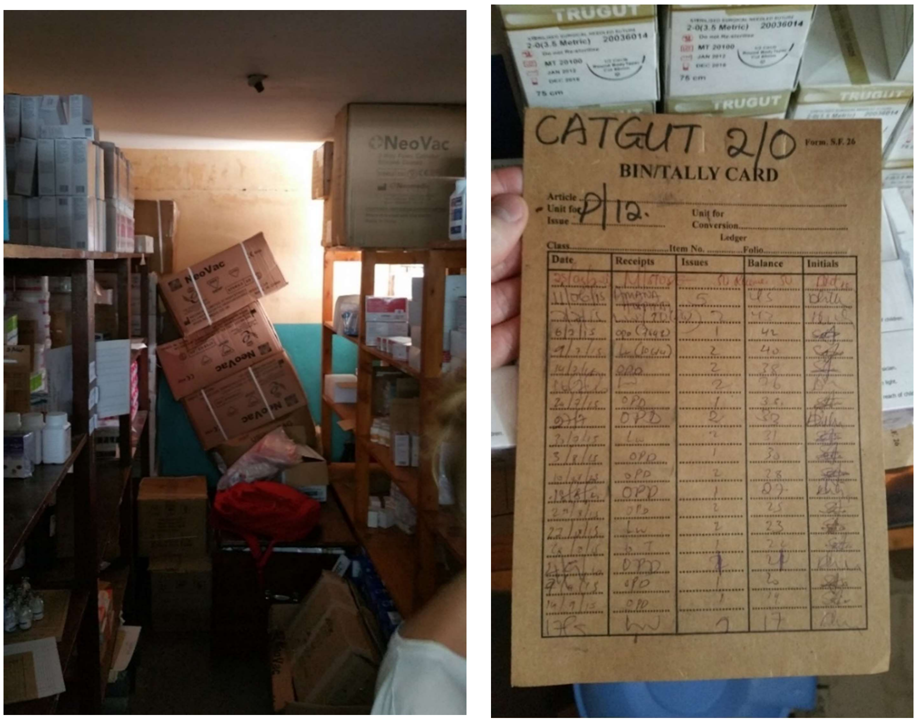


Figure 16 – Pharmacy storage (to the left) and stock card/tally card (to the right)

Health commodity funding

When asking informants from MSD how they deal with national stock outs of commodities, one of them said “what can we do without the money?”. Economy and funding is an issue when it comes to the procurement and distribution of health commodities, and it hinders MSD to act if commodities are out of stock at the warehouses. All facilities have a given budget which is controlled in EPICOR9 by MSD. As previously mentioned, almost all facilities order more commodities than their budget can cover, leading to order adjustments at the district level. Because EPICOR9 is not integrated with eLMIS yet, the budget information is not available in eLMIS, and thus not available at the lower levels. Therefore, the district pharmacists get budget information printed out on paper from MSD’s EPICOR9, and try to adjust the orders according to the cost of the commodities. Adjustments are also made at MSD’s warehouses. When MSD adjusts the orders, they need to prioritize which health commodities they can reduce the amount of to meet the budget. If the facility's budget has been used up, the facility is in debt to MSD, and when this debt reaches a certain limit, the facility stops receiving commodities. However, all facilities in Tanzania will always receive high prioritized and life-saving commodities, including malaria medication, vaccines and ARVs (antiretroviral drugs used as HIV/AIDS medication), as these are funded by different health programs.

5.4 Linking DHIS2 and eLMIS

As mentioned in chapter 2, there is an ongoing project of linking data between eLMIS and DHIS2. As a part of the fieldwork in Tanzania, we got to participate in a test session with HISP and JSI in the startup phase of this project, where we compared the data in DHIS2 and eLMIS. During this test session, we found that there are some differences in how the data elements are named and coded. For example, some of the districts and facilities were named differently, but defined with different codes, and some facilities had the same codes, but were defined with different names. Without a standardized definition of the codes and names of the districts and facilities, it may be hard to share data between the systems. In addition, the required reporting frequency are dissimilar, as DHIS2 has monthly reporting and eLMIS has staggered quarterly reporting in the three groups (A, B, C). This led to challenges in the testing of data, as we had to find the corresponding three months of data in DHIS2 for the quarter in eLMIS.

5.5 Vaccine supply chain

The vaccine supply chain is quite similar to the supply chain for regular health commodities, but there are also some differences. MSD's central warehouse stores all vaccines, and distributes them to the 26 other regional vaccine storages based on orders from the lower levels. The District Immunization and Vaccine Officers (DIVOs) collect the vaccines at the regional storages, and distribute them to all facilities within the district. Currently, the vaccine supply chain has three different information systems for different purposes: SMT (Stock Management Tool), DVDMT (District Vaccination Data Management Tool) and CCIT (Cold Chain Inventory Tool). More details on the vaccine supply chain, the information systems used and the relation between the levels are more thoroughly described in the next sections.

5.5.1 The IVD Program

As mentioned in chapter 2, the IVD program is responsible for all immunization activities in Tanzania with a goal of reducing the morbidity and mortality due to vaccine preventable diseases. In addition to ensuring routine immunization and all the management around the vaccine supply chain, the IVD program has a surveillance team responsible for monitoring diseases and preparing for possible disease outbreaks. The program is run by the MOH, but they also get some international funding from different organizations, including WHO and UNICEF. With the IVD program having the overall responsibility from the national level, the ordering and distribution of vaccines, as well as the flow of service delivery data happen through the regional level, the district level and the facility level. The IVD program is not communicating directly with the facilities, but the regional and district levels are working like intermediaries. That is, all levels are responsible for the level under them, for example ensuring that they have proper cold chain equipment and enough vaccines. All facilities in Tanzania, whether they are public or private, are supported by the IVD program. Whenever a new vaccine is introduced, or there are changes or updates in immunization procedures, the IVD program is also responsible for ensuring that all involved health workers get trained for this.

5.5.2 Immunization Service Delivery

There is a governmental policy in Tanzania saying that there should be one dispensary per village. However, there are about 12 000 villages, but only about 5000 – 6000 dispensaries. For every village located 10 kilometers or more away from a dispensary, the government must ensure that this population gets mobile immunization services. The mobile immunization service is carried out by a health worker from the nearest facility, providing immunization services monthly to all villages nearby. All people living less than 10 kilometers away from a dispensary, have to travel there to receive immunization services.

To register the patients coming for immunization, the health workers use paper-based immunization registers/ledgers. Here, they fill out information on the child, mother, type of vaccine, if the patient has any diseases or specific medical conditions like HIV and so on. This is used to keep track of what vaccines have been given to whom. In that way, they also know when the patients should come for their next vaccine dose. If a child does not show up to get a scheduled vaccine, the health facility sends a community health worker to track down the mother and cross-check whether or not the child has gotten the vaccine, and/or educate the mother about the importance of immunization. In addition to the immunization register, the health workers also fill out a tally sheet counting number of doses given for each vaccine. Each month, all information from the immunization ledger and the tally sheet gets compiled into a monthly, paper-based summary form. The summary form is delivered to, or picked up by the DIVO monthly which types this information into an electronic system.

The electronic system they use for registering routine immunization data is called DVDMT (District Vaccination Data Management Tool). This is an excel-based system used for statistical purposes and decision making regarding immunization. The system is developed by WHO, and also used in several other countries. In DVDMT, the DIVO can also have an overview of the performance of all facilities within the district. Graphs produced in DVDMT are further supposed to be used as a feedback mechanism for the facilities and presented in regular meetings. One DIVO said that they conduct quarterly meetings with the facilities to share this information. Another informant told us that these meetings *usually* are held quarterly, but not always.

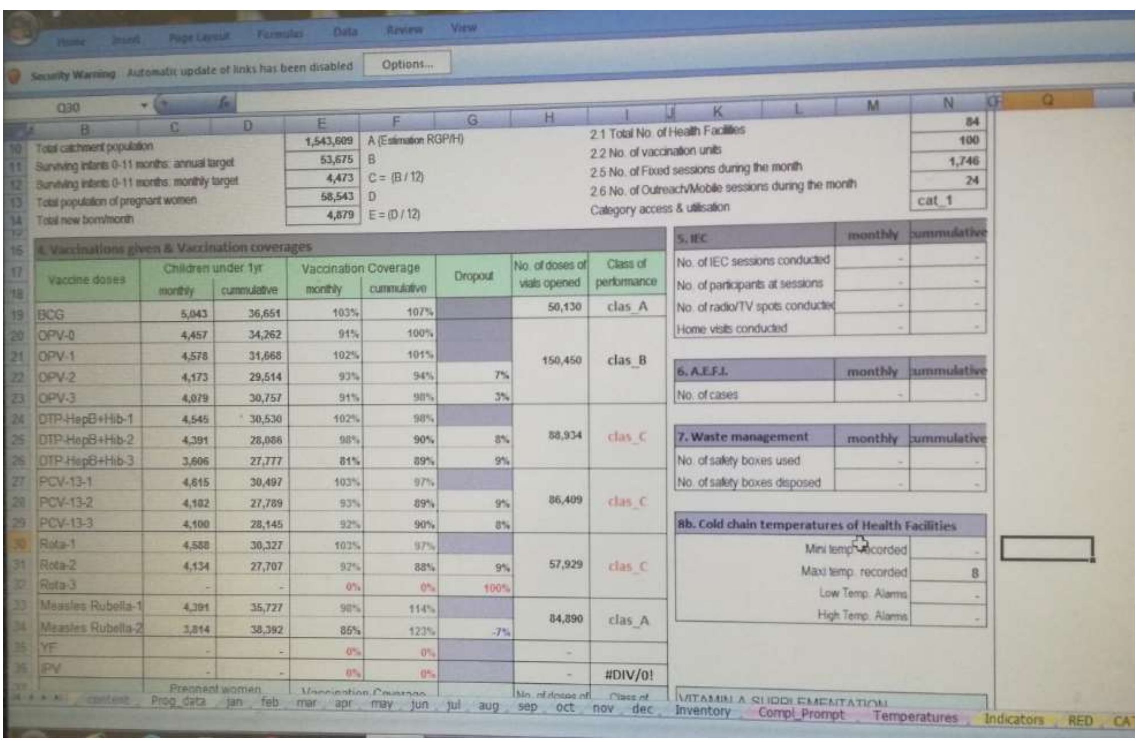


Figure 17 – DVDMT-form in excel

From the district level, the data is sent monthly in an excel-file by email to the regions, where the Regional Immunization and Vaccine Officer (RIVO) processes the information and further sends it to the IVD-program. The IVD-program aggregates all routine immunization data for all regions, and sends this information monthly to WHO by email. The flow of routine immunization data through DVDMT is illustrated in figure 18 below.

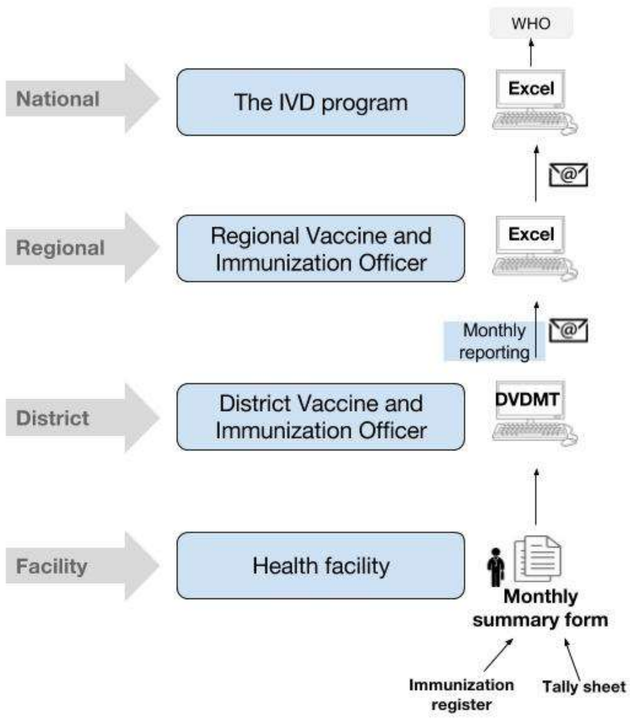


Figure 18 – Flow of routine immunization data through DVDMT

In addition to the immunization registers kept at the facilities, all patients get their own immunization card. Information is cross-checked, updated and transferred between the card and the immunization register for each immunization visit. In this way, the child's parents can know what vaccines the child has received and when they are supposed to get their next dose. The health workers also fill in the weight of the child and other health information in this card, so that they can monitor the child's growth. With this immunization card, the children are also able to receive their vaccine doses in different facilities, and are not forced to travel to the same facility to complete the immunization process.

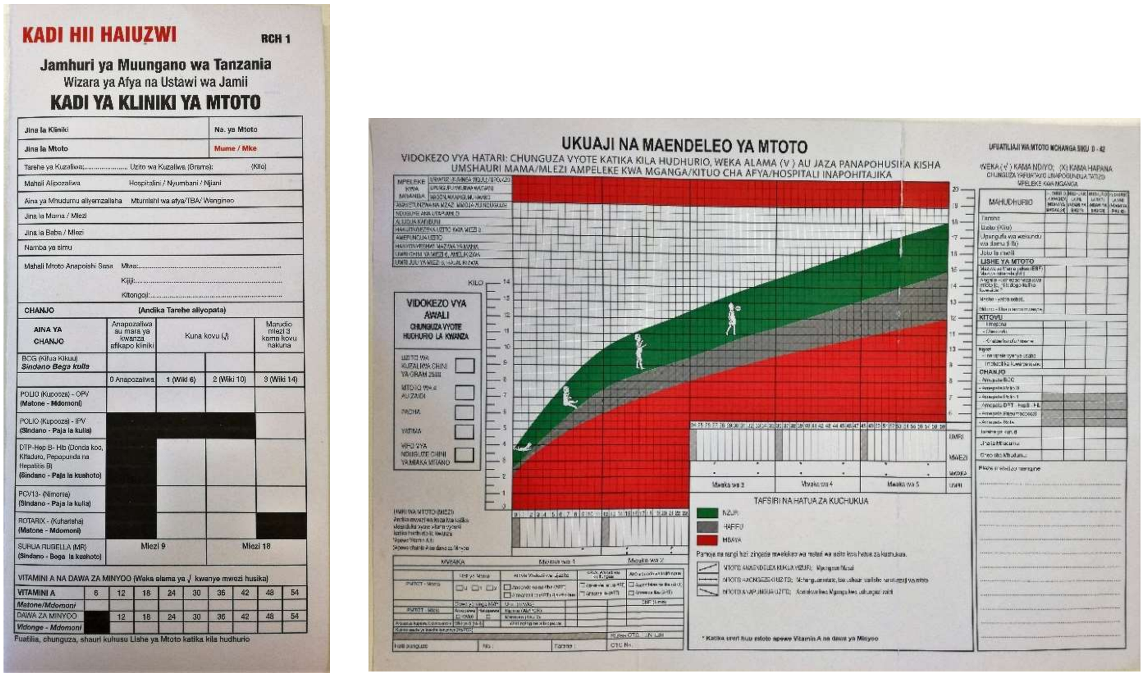


Figure 19 – Outside (to the left) and inside of a patient immunization card

The procedure for registering routine immunization data in a register, tally sheet and a monthly summary form, is the same for registering immunization data in DHIS2, described in section 5.2. Thus, the health workers do the same work twice. We were told that the forms collect duplicate data, and is typed into separate systems at the district level (DHIS2 and DVDMT). Both informants from the IVD program and from JSI said that when comparing the data collected in the two systems, the data often do not match. A DIVO from another district also informed us that the data in DHIS2 and DVDMT do not match, and that it could be beneficial to have *one* reporting system for routine immunization data. When asking to what extend the DIVOs share information or communicate with the HMIS workers, one DIVO said that they compare the information in DHIS2 and DVDMT monthly.

5.5.3 Vaccine Ordering Process

All facilities register stock data in one ledger per vaccine. The stock data includes what they have used, what they have received, what is remaining, any losses or adjustments etc. These forms are collected by or delivered to the DIVO monthly. When asking about the routines for this, one informant at a district said that "it depends. Sometimes the health workers travel to the district, and sometimes the DIVO travels to the facilities". When the DIVO travels to the facility to collect the forms, he or she often combines this with supervising and giving them new vaccine supplies.

The DIVO types the stock data into the electronic system SMT (stock management tool). This is a web-solution (previously excel-based), used in Tanzania since 2014, for the ordering of vaccines from district level and up. After the facility data is entered, SMT will automatically calculate an order based on a combination of the stock information and data on the target population for the facility. The DIVO can also use SMT to monitor the stock information for all the facilities' storages. The calculated orders are sent through SMT quarterly to regional vaccine storages. The RIVO further sends the order to the IVD program, at national level, based on the orders from all their associated districts. The IVD program combines these orders with statistics on population data provided by the National Bureau of Statistics (NBS) to calculate how much they should supply to the regions. From this, they create a distribution list, which is sent to MSD.

It is also possible to place emergency orders through SMT. However, one informant from the IVD program was clear about the fact that an emergency order needs to include a very good reason for the emergency and the necessity for placing this order. The procedure for an emergency order is the same as for a routine order, but the emergency order is usually placed for one vaccine only. The IVD program also takes costs into consideration when assessing if it is necessary to fulfill the emergency order.

Vaccine procurement

The procurement of vaccines is done by either GAVI (Global Alliance for Vaccines and Immunization) or the government. Further, all procurement happens through UNICEF, so all vaccine manufacturers are decided by them. With each order sent by GAVI or the government, a pre-shipment notice is sent to MSD, UNICEF, and the IVD program. When MSD receive this notice, they start a clearance process, as they are the ones to distribute all vaccines to the regional vaccine storages. MSD picks up the vaccines at the airport, and transports them to their central warehouse in Dar es Salaam and waits for a distribution list from the IVD program before distributing to the regions.

5.5.4 Vaccine Distribution

When MSD receives a distribution list from the IVD program, they start distributing from the central warehouse to all regional vaccine storages. There is one vaccine storage in each region in Tanzania, making it 27 in total – counting one of them as MSD's central warehouse located in Dar es Salaam. MSD's central warehouse stores all vaccines, and distributes them quarterly to the 26 regional vaccine storages in special refrigerated vehicles, based on orders from the lower levels.

The DIVO from each district travels to the regional storages, also quarterly, to pick up their supplies. For transportation of the vaccines, the DIVO brings a cold box, to make sure that the vaccines are held in the right temperature range during the travel. There is one vaccine storage in each district storing a three-month stock of vaccines for all associated facilities. The DIVO is responsible for distributing vaccines to the facilities monthly. One informant at a facility told us that they do not always get the amount of vaccines that they have ordered. In one of the districts we visited, the facilities were also able to travel to the district storages to pick up supplies if they were out of stock. This will, however, necessarily depend on the distance between the district storage and the facility. In addition, in all the districts we visited, they redistribute vaccines between the facilities whenever they need more supplies.

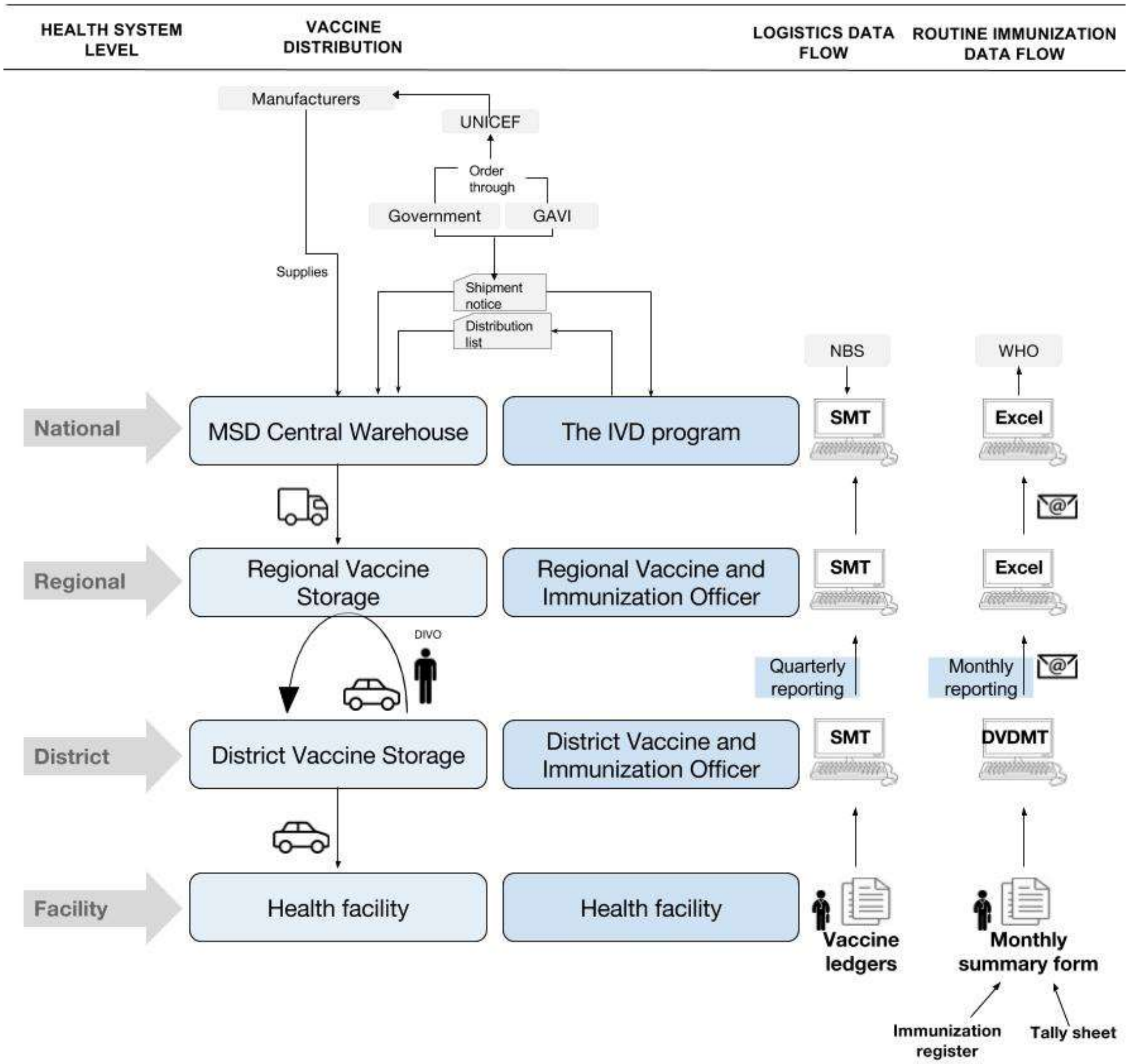


Figure 20 – Illustration of the vaccine ordering and distribution process together with the figure of routine immunization data flow.

5.5.5 Storage and Equipment

Each hierarchical level of the vaccine supply chain has a maximum stock capacity. The central MSD warehouse has a storage capacity up to 6 months of stock, the regional vaccine storages and district vaccine storages has a maximum capacity on 4 months of stock, and the facilities has a capacity up to 6 weeks of stock. All storages at all levels also have a minimum stock requirement, based on the target population for the area. The maximum and minimum stock capacity data are used when ordering and distributing the vaccines aiming to fill up to maximum stock each period. For monitoring the stock, SMT has a function with dashboards that visualize the stock status in colored bars. If the bar is green, the stock status is sufficient, if the bar is yellow, there might be a danger for running low, and careful monitoring or placing a new order is required. If the bar is red, they are out of stock and an order should be placed immediately. Because SMT is only used electronically from the district level and up, this function is not available for the facilities. In addition to update the stock status in the vaccine ledgers after receiving, distributing or using vaccines, some storages also do physical stock counts from time to time for cross-checking and controlling the inventory.

In some interviews at the facilities, the informants implied or said that vaccine stock outs are mainly a national problem: "if we are out of stock of some vaccine, and we are not able to get it from our district storage, this means that all other districts also are out of stock" (DIVO). However, the IVD-program said that higher level stock outs on vaccines are almost non-existent, and if they do happen, it rarely affects the lower levels because of the maximum and minimum stock solution. As an example, they mentioned that MSD had a stock out on BCG vaccines in 2013, but because the lower levels had their storages filled up to the maximum capacity, this was not a big problem at the facilities. Further, they said that "if a facility is missing some vaccines locally, this is often because of wastage caused by temperature or equipment issues". MSD are required to report their stock status on vaccines monthly to the IVD program, and whenever a stock out occurs. At one district vaccine storage, the DIVO said that there currently was a national stock out on tetanus vaccines (TT).

Figure 21 – Cold chain refrigerators/freezers

For cold chain storage, there are variations in the equipment used at the facilities. At most facilities, they have proper cold chain refrigerators with different types of temperature monitoring equipment. Some also use regular refrigerators, but mostly in addition to the cold chain refrigerators. All facilities have cold boxes for traveling and temporary storage of the vaccines. Each day, the health workers take out the estimated amount of vaccines needed for that particular day, put them in a cold box, and keep them there until all scheduled patients are vaccinated. When asking about how this affects the temperature and probability of vaccine wastage, the health workers said that it depends on the vaccines as they have different temperature sensitivity. If BCG or measles vaccines have been kept in a cold box for a whole day, and not been used, the health workers know that they have lost their efficacy and thus have to discard them. Also at the district level, they sometimes have to discard BCG vaccines because of its short expiration date

Figure 22 – Cold boxes for temporary storage and transportation of vaccines

All facilities we got to visit had access to electricity, and a backup solution with a generator in case of power outages. At one hospital we visited, they only had a regular refrigerator without any temperature monitoring system. Considering the frequent power outages in Tanzania, this can have consequences for the vaccines. If, for example, there is a power outage while no one is at work, and the power returns before the pharmacists are back at work, the pharmacists will not know that there has been a power outage. Depending on the length of power outages and on how long the refrigerator can keep the temperature without electricity, the vaccines can get damaged or lose their efficacy without anyone knowing this.

The health facilities use different types of temperature monitoring devices. Some use regular thermometers which they check regularly and write down the temperature on a paper either behind or on top of the refrigerator. Others have a more advanced electronic device, called a fridge tag, that can register and save all temperatures for the last 30 days. This device has a USB-stick connected to it, making the health workers able to save the temperature information on their computers and look at the temperature statistics for the last month.

A system called CCIT (cold chain inventory tool) is a monitoring tool for the cold chain equipment supposed to be used at the facility level. This information is based on information we got from the IVD program and the interviews we had with JSI. Further, on the MOH's websites about the IVD-program it says that in 2007, CCIT "was introduced to all regions in Tanzania to help monitor the status of cold chain equipment in health facilities" (MOHSW, 2017). The IVD program informed us that CCIT notifies the DIVO if there is a problem with the equipment or the power is out for more than a couple of hours. The DIVO then have to update the equipment status in the inventory tool, which will further send a notification to the IVD program. There are technicians at both national (central) and regional level which can travel to do reparations at the district and facility vaccine storages whenever there is an equipment failure. Workers at the vaccine storages can also get technical support by phone.

When asking informants at the facilities and districts about CCIT, it seemed like they did not know what it was. Furthermore, when asking questions about what type of systems they used, they only mentioned DVDMT and SMT. However, at one district located in Dar es Salaam, they had a system that would automatically notify the DIVO by SMS or email if there were any problems with the cold chain equipment. This system would also keep notifying the DIVO until he fixed the problem. We were also told that this cold storage, because it was located in one of the bigger, urban districts, worked as a regional storage. Here, they had a quite advanced cold chain storage with big cold rooms in additions to the refrigerators and a generator that kicks in automatically if there is a power outage.

Figure 23 – “Cold room” (left) and equipment for managing its power supply (right)

Figure 24 – How the vaccines are stored inside the cold room

5.5.6 VIMS (Vaccine Information Management System)

The informants from the IVD program told us that one of the biggest challenges they are facing is that they are using three uncoordinated systems for managing immunization services and the vaccine supply chain. In addition, they are using DHIS2, which collects duplicate routine immunization data with DVDMT. This is problematic because the health workers need to type in the same information multiple times. Further, the data often do not match. Therefore, the workers at the IVD program needs to do a lot of analysis and comparisons, because they "do not know what data to trust and not" (informant from IVD).

According to Village Reach (2016), eLMIS was developed to support all commodities for all health programs. However, on JSI's website for articles and blog posts, "The Pump", it says that:

> Because of IVD's unique needs, vaccines were not initially included in the eLMIS deployment, although the system was designed with vaccines in mind. Once eLMIS had proven its value and feasibility in the field, IVD was ready to engage with the eHealth strategy of greater integration and unified national technologies. (Wright, Alenga, & Mwencha, 2015)

Therefore, there is currently an ongoing project of implementing an integrated Vaccine Information Management System (VIMS) for the IVD program. VIMS is built on the existing openLMIS platform, and integrates the functionality of all three stand-alone information systems, namely DVDMT, SMT and CCIT. In this way, the higher levels can obtain information on both vaccine stocks, how the facilities are performing in their immunization service delivery, and monitor the cold chain inventory. When the higher levels can see the stock status and capacity for all facilities, the idea is that it can reduce stock outs. Another motivation JSI mentioned is that the district level can be able to take more informed decisions due to better availability of all immunization data in one integrated system.

The VIMS-project was initiated by CHAI (Clinton Health Access Initiative) in 2015, with one of the main developers being JSI. Now, the system is fully developed, and the implementation process has started with training in seven regions. In addition, all facilities have been oriented of the new forms they are going to use. One of the informants from JSI argued that "VIMS cannot be implemented if the new forms are not incorporated into the daily routine at the facility level". At the facility level, they will be able to report all information for DVDMT, SMT and CCIT into one single register. However, the information they report is not changed, so they will still report the same amount of information, and the monthly summary form will still be duplicate of the monthly summary form used for DHIS2.

During our interview with system developers from JSI, we got a demonstration of the VIMS where we were shown the main functions. In the demonstration, they logged in as a DIVO, to show a typical use case. When the DIVO logs in, the first he or she sees are dashboards similar to what is also used in DHIS2. These show statistics on the facilities' reporting (on time, late, expected), vaccine supplies (pending, received), cold chain equipment status, vaccine coverage for the target population, dropout rate and wastage of vaccines. Further, the DIVO can chose the functions *routine immunization* (representing DVDMT), *stock management* (representing SMT) and *equipments* (representing CCIT).

A colleague from HISP Tanzania, talking about the lack of communication between the initiators of VIMS and HISP said that "because they have enough funding, they can just create their own systems without collaborating with DHIS2". He argued that this lack of communication and coordination is mainly caused by funding, different interests and politics. However, the informants from the IVD program said that it would be beneficial to share data between their systems and DHIS2 to get more trustworthy data. Also, the developers from JSI argued that if VIMS could be integrated with DHIS2, "…we can improve the data quality in DHIS2". Additionally, on JSI's newest blog post about VIMS, it says that VIMS has been designed to enable data sharing with DHIS2 (Wright et al., 2015).

5.5.7 BID Initiative

As mentioned in section 2.2.2, the MOH believes that the key challenge related to ICT capabilities in the health care sector is that the HIS is fragmented with several ICT pilot projects and different sub-HIS, hindering the information sharing between the different actors within the HIS. In addition to the VIMS project, one other ICT project related to the vaccine sub-HIS, called the BID (Better Immunization Data) initiative, was identified in the research process. This has not been investigated in the field, but is nevertheless shortly mentioned here.

The BID initiative is a project led by PATH and funded by the Bill & Melinda Gates Foundation. Their aim is to improve data quality, collection and use with the goal of enhancing immunization services and the overall health service delivery in developing countries. They currently have test projects in Zambia and Tanzania where they are implementing solutions for collecting and managing immunization data. The purpose of the system is to provide more effective and automated data collection and support the immunization services for health workers at the facility level. In Tanzania, they are collaborating with the MOH and the IVD program, and currently, an electronic immunization register has been implemented at 180 facilities (BID Initiative, 2016, n.d.).

6 Discussion

In this chapter, the findings will be discussed in light of the research question (what are the potential benefits and challenges of integrating vaccine information systems with HMIS?), using the theoretical framework presented in chapter 4. The discussion is framed around four topics identified as important to approach the research question:

1) How the Tanzanian HIS is fragmented
2) Why the Tanzanian HIS is fragmented
3) The challenges created by fragmentation
4) The opportunities and challenges for integration of the information systems in the HIS in Tanzania

First, in section 6.1, a discussion of how Tanzania's HIS is fragmented is provided, framed on Carlile's integrative framework (2004) and the technical, data and organizational level. Building on this discussion, and drawing on II-theory, a discussion of *why* the HIS is fragmented is presented in section 6.2. Next, the challenges of fragmentation in Tanzania are discussed in section 6.3. In section 6.4, The integrative framework is again used to analyze the opportunities and challenges for integration in the HIS. The last two sections (6.5 and 6.6) discuss potential benefits and costs of integration, and critically assess if integration is the best solution to solve the fragmentation challenges in Tanzania.

6.1 How HIS is Fragmented in Tanzania

HIS in developing countries are best understood as socio-technical and heterogeneous, consisting of several institutions and components managed by different organizations and actors at different levels of the health system. The actors within an HIS, including the public and private health sector, international organizations and donors, often build their own information systems to meet their own particular information needs. These information systems are typically built in isolation, and the HIS ends up fragmented with multiple uncoordinated and overlapping sub-HIS running as silos (Braa et al., 2007; Braa & Sahay, 2012; Chilundo & Aanestad, 2004; Lippeveld et al., 2000; Sæbø et al., 2011).

Next, the three levels of the framework presented in chapter 4, based on Carlile's integrative framework (2004), will be used to analyze more thoroughly the fragmentation of the HIS in Tanzania. That is, *how* it is fragmented on the technical level, the data level, and the organizational level. This is discussed drawing on examples from not only the vaccine information systems, but also Tanzania's HMIS and LMIS.

6.1.1 Technical level

The technical level in Carlile's framework is about *how* to share knowledge (Carlile, 2004). In an HIS, this involves the technical means for data and information transfer. This will include the different tools used at all health system levels in the HIS, for e.g. data collection, analysis and management of the different information systems. The tools can be both paper-based and electronic in different formats (Braa & Sahay, 2012). In a country with challenging infrastructural conditions like Tanzania, paper systems are a necessary part of the HIS in places where electricity is partly or completely unavailable. All sub-HIS encountered in this research are paper-based at the facility level and electronic from the district level and up. One exception was found for the LMIS in an urban district of Dar es Salaam, where eLMIS also were used at the facility level.

The IVD program uses three separate information systems: DVDMT, SMT, and CCIT. These are not connected to each other. Two of them, DVDMT and SMT, are identified in the findings as parallel information flows running on different technologies. While DVDMT is an excel-based system with email reporting, SMT is a web-based system. In addition, DHIS2 has overlapping functionality with DVDMT, as they both collect routine immunization data. There are also different paper-based systems tied to these information systems. For SMT, one vaccine ledger per vaccine is used to collect logistics data. For DVDMT they are using an immunization register, a tally sheet and a monthly summary form. These three forms are also being used by DHIS2. The vaccine sub-HIS in Tanzania can be argued to be fragmented in itself, as the IVD program uses three separate information systems at the technical level, in addition to one of them being duplicate with DHIS2. A similar situation is presented by Chilundo & Aanestad (2004), showing that the HIS in Mozambique had four reporting channels for Malaria information alone with inconsistencies in the reporting frequencies and formats. The newly developed VIMS is a web-based system built on openLMIS and will include all functionality for DVDMT, SMT, and CCIT in one. VIMS will further combine the existing paper forms from DVDMT, SMT, and CCIT in one big register, but it will still have duplicate forms with DHIS2.

The findings also identified several systems connected to Tanzania's LMIS. eLMIS with the R&R forms is the national LMIS, but three other systems have also been identified. EPICOR9 is running as a stand-alone inventory system at MSD's warehouses. CTC2 is another system running locally at hospitals for keeping track of HIV/AIDS treatment and logistics related to this. In addition, ILS gateway is used for SMS-reporting on 20 health commodities.

Another aspect of fragmentation at the technical level identified is the differences in how data in the various systems are coded and defined. When participating in the comparison test of the data in DHIS2 and eLMIS, we found that the data elements were defined differently for some facilities and districts. Some facilities could, for example, have the same codes, but different names and some facilities had the same names but different codes. This was also found for EPICOR9 and eLMIS where commodity data were coded differently.

6.1.2 Data level

The data level in Carlile's framework involves the actors' understandings of what knowledge to be shared (Carlile, 2004). The data level in an HIS includes the health data to be collected, processed and shared in and between the different information systems. With independently developed information systems for separate actors, there can be different understandings of, for example, what is the most important data that should be collected (Braa & Sahay, 2012).

The data collection process has not focused on how the data is understood by the different actors. However, it is identified that DVDMT and DHIS2 are collecting duplicate data, from three similar forms (immunization register, tally sheet, and monthly immunization form). Even though they collect the same routine immunization data, there may also be some differences. That is, they use the same type of forms, but it has not been investigated to what extent the data is e*xactly* the same and if all three paper forms are complete duplicates of each other. Thus, there *may* be some differences in what they collect, as the data sets are developed by separate actors. For example, WHO demands a standardized data set for DVDMT, but these information demands may be different for DHIS2. With the introduction of VIMS, the same data will still be collected, so this is not going to change.

The findings also identified that some of the information systems require different reporting frequencies. While SMT requires quarterly reporting, DVDMT and DHIS2 require monthly reporting, and eLMIS runs a staggered quarterly reporting schedule in groups (ABC). Different requirements for reporting frequencies further makes the data sets being different.

6.1.3 Organizational level

The organizational level in Carlile's framework involves all actors with both common and domain-specific knowledge. The actors can have different, and possibly conflicting interests and requirements which hinder them in sharing knowledge (Carlile, 2004). An HIS involves multiple stakeholders and users both horizontally and vertically. Different actors within the various sub-HIS can have different interests, different procedures for e.g. data collection, as well as their own information flow and resources like staffing and economy (Braa & Sahay, 2012). The HIS in Tanzania is shared among multiple stakeholders with different roles, from the facility to the national level. This includes, for example, the MOH and the government, international organizations like JSI, CHAI, UNICEF and WHO, as well as national health programs and other actors like the IVD program, MSD and HISP Tanzania. Also, UNICEF and GAVI are involved in the procurement of vaccines. In addition to the organizational actors at the national and international, level there are also health workers, like nurses, doctors, and pharmacists at the facility level, as well as health managers at all levels connected to the HIS. Health managers include for example the DIVOs and the HMIS workers in the District Health Management Team.

Further, actors within the HIS have different interests and requirements. The health workers are interested in providing reliable health services for the patients and need good systems to keep track of patients and health commodities. The health managers at the district, regional and national level are interested in making good decisions and need reliable systems for monitoring e.g. the performance for all levels underneath them. Moving up to the international organizations, they have their own interests. For example, the initiators for VIMS have an interest of integrating all functionality related to immunization and vaccines into one big system. However, the IVD program also wants to integrate with DHIS2, as they find it hard to trust the data because of the discrepancies in DHIS2 and DVDMT.

While DVDMT is specific for immunization, DHIS2 collects not only immunization data, but all data related to routine health service delivery. Further, both systems require monthly reporting, but the two systems are also tied to different actors and routines. For example, WHO demands a monthly immunization report from the IVD program. Another example is that the DIVO is responsible for all immunization activities within the districts, and is therefore also responsible for entering data into DVDMT. For DHIS2, it is the HMIS workers at the District Health Management Team that are responsible for collecting HMIS forms and enter data into DHIS2.

Lack of communication between the organizational actors became evident when talking to one informant from HISP Tanzania, as he said that the initiators for VIMS (CHAI, JSI etc.) have the resources to simply develop a new system without communicating with HISP. However, when talking to JSI, the system developers said that they *want* to enable data sharing with DHIS2 and that this can improve data quality. Thus, the uttered interests from these actors seem to be somehow contradicting, and verifies that there is little communication between them. The different information systems tied to the various organizational actors also have different routines for reporting frequencies (monthly, quarterly and staggered quarterly).

To summarize, focusing on Tanzania's national HMIS and the vaccine information systems, in addition to parts of the LMIS, this thesis has shown that Tanzania has a heterogeneous HIS with a multitude of different, uncoordinated, overlapping and/or duplicate sub-HIS. The technical level in Tanzania's HIS consists of different systems in different formats running side by side. Some are paper-based, some are using excel and some are running on web. The vaccine sub-HIS in Tanzania can be argued to be fragmented in itself, as the IVD program uses three separate information systems at the technical level. In addition, DHIS2 is collecting duplicate data with DVDMT at the data level. Also, at the data level, differences in required reporting frequencies lead to the data sets having different reporting periods. Furthermore, the findings identified that the data collected for DVDMT and DHIS2 is similar, but there may also be differences because the data sets are developed by separate actors. At the organizational level, several actors with different interests and routines have been identified. Further, because of some contradicting information about their interests, it seems that there is little communication between some of the actors.

6.2 Why Fragmentation

While the previous section discussed *how* the Tanzanian HIS is fragmented, this section discusses *why* the HIS is fragmented. This discussion is not framed on the different levels in the integrative framework, but builds on the previous discussion and uses concepts from the II-theory presented in chapter 4.

An HIS, made up of information systems, technical components, humans and organizational actors, can be conceptualized as a socio-technical Health Information Infrastructure (HII). Using the definition of IIs by Hanseth & Lyytinen (2010), an HII is "a shared, open (and unbounded), heterogeneous and evolving socio-technical system (which we call installed base) consisting of a set of IT capabilities and their user, operations and design communities" (p.4). Seeing the HIS in Tanzania as an HII, it is heterogeneous in the way that it has a socio-technical installed base, consisting of different technologies, formats, organizational actors, sub-HIIs and different procedures. The information systems with different technologies, formats and data sets, are developed by separate actors with different information demands. For example, because DVDMT is developed by WHO, the requirements for this system is based on WHO's interests and demands. They require monthly reporting from the IVD program on a standardized immunization form, which is also used in several other countries. Based on this, it is reason to believe that this heterogeneity - the existence of vertical health programs and other actors with their own interests and demands at the organizational level, can be the reason for the use of different systems at the technical level, and the different understandings and definitions of data at the data level.

Drawing on II-theory, the sub-HIIs, like the vaccine information systems and the HMIS should not be seen as standalone information systems. They should rather be seen as parts of a bigger HII also involving other sub-HIIs, various technology, and other components, and shared between actors with different and/or overlapping interests. As mentioned in chapter 4, vertical information systems developed by, e.g. health programs are often considered as *silos* – separate and with little or no coordination with other parts of the HIS (Braa & Sahay, 2012). However, when seeing the sub-HIIs as parts of a bigger infrastructure, it is hard to argue that Tanzania's HII consists of silos, even though it is fragmented. There are vertical programs and other organizational actors running vertical information flows, but the information systems encountered in this research are also interconnected with one or more of the other information systems. For example, eLMIS is interconnected with ILS gateway and CTC2, because CTC2 also uses R&R forms and ILS gateway notifies the health facilities whenever they need to send reports (R&R forms) to the district. Further, VIMS is going to be built upon the openLMIS platform, and will, therefore, be interconnected with eLMIS. In addition to the electronic systems being interconnected with each other, they are also interconnected with the paper forms. Thus, instead of seeing the sub-HIIs as separate stand-alone silos, it may be more suited to see them as interconnected *ecologies of infrastructures* (Hanseth, 2000), or *interconnected system collectives* (Henfridsson & Bygstad 2013). The complexity of interconnected system collectives may lead to side-effects, as a change in one system can possibly require changing the other systems as well. Changing parts of the electronic systems, like the data fields, will also require a change in the paper forms. However, using paper systems limits the flexibility of the information systems within the HIS, as changing and modifying paper forms requires a substantial amount of work (Braa & Sahay, 2012). This became evident in the findings on Tanzania's LMIS where, instead of changing the paper forms whenever updates are made in eLMIS, an extra paper form has been added to close the information gap between eLMIS and the paper-based R&R forms.

When introducing new components, or changing the HII, this needs to fit with the installed base. In Tanzania's HII, the installed base consists of various actors, (health workers, MOH, donors, organizations etc.), organizational practices (vertical health programs, private health sector etc.) and their existing work procedures (e.g. data collection routines and reporting frequency), technology (DVDMT, SMT, eLMIS, DHIS2 etc.) and paper systems. The HII is also open to an unlimited number of new initiatives and components, including technical, human and organizational, and the installed base is constantly growing. Because of this, it gets more and more difficult to make changes and build systems from scratch. Thus, to satisfy new requirements for the HII, the different actors must extend what is already existing, and develop new systems on top of the complex and fragmented installed base. One example of this is the extra paper-form added to close the information gap between eLMIS and the R&R forms.

Having a heterogeneous HII with distributed control between separate actors and interconnected information systems, connecting and fitting to the installed base in not necessarily a straightforward process. With limited communication between the actors, his can lead to parallel initiatives trying to solve the same issues at the same time, which can further lead to fragmentation. One example of this from the findings is the implementation of electronic immunization registries at facilities initiated by the BID initiative, while JSI is, at the same time, working on the development of VIMS. Further, the development of VIMS is done partly in isolation. On one hand, it is a domain-specific system, only handling immunization-related information and running as a system for the vertical IVD program. In addition, the initiators have not collaborated with the developers from the HISP team, even though VIMS and DHIS2 are still going to collect duplicate data. On the other hand, even though VIMS is being built as a new system, it is not being built completely from scratch. First of all, the data included in the new paper forms, for instance, will be the exact same data that is already being collected. The difference is that the health workers can write all data in one big ledger, instead of separate ones, and the district level and up will have access to the functionality of DVDMT, SMT, and CCIT in one common, computerized system. The routines for data collection and processing will be almost the same, and WHO will still demand a monthly routine immunization summary from the IVD program. However, it is also being developed on the same platform as eLMIS, that is, openLMIS. Thus, it is being connected with the national LMIS, and therefore connecting with one part of the installed base.

To summarize, from an II perspective, the HII in Tanzania consists of a socio-technical, complex and heterogeneous installed base with multiple interconnected information systems, actors and other components. The existence of vertical programs has led to a distributed responsibility of parallel information flows within the HII. This, in addition to limited communication between the actors at the organizational level can be important factors for explaining why the HIS is fragmented. In addition, the installed base at the data and technical level consists of inflexible components, like paper-based systems, which are hard to change. Furthermore, because the installed base is open to an unlimited number of new components, it is constantly expanding, making it more difficult to build systems from scratch. Thus, new components get built on top of the already fragmented installed base, making it even more complex.

6.3 Challenges Created by Fragmentation

While the previous sections discussed how and why the Tanzanian HIS is fragmented, this section aims to discuss the challenges created by fragmentation. Previous research has shown that fragmented HIS can lead to multiple challenges (e.g. Braa & Sahay, 2012; Chilundo & Aanestad, 2004; Sæbø et al., 2011). Several, interconnected and overlapping silo systems mean duplication, overlaps and typically inconsistencies in the data and data formats. With different systems, formats and procedures, it can be hard for health managers to coordinate and collate the information to make good decisions. Duplication of data in the different systems can also lead to a lot of unnecessary work at the facility level, as the health workers need to fill in the same data in several paper forms. This can also be exhausting for the health workers and lead to increased probability of data errors, which again lowers the quality of the data. Low quality data, can further lead to the data not being used for decision-making (Braa & Sahay, 2012; Sæbø et al., 2011).

In Tanzania, the health workers at the facility level collect duplicate data. One example is the data collection of routine immunization data for DVDMT and DHIS2, where the health workers register the same data in three separate forms; immunization registers, tally sheets, and monthly summary forms twice. Then, it gets at the same time entered into the two separate systems at the district level by the DIVOs and the HMIS workers. Duplicate data collection will necessarily add to the already high work burden of health workers. This is particularly a challenge when the systems are paper-based and the same information must be filled in several forms by hand. The high work burden with all the manual work can further lead to data errors and the data having poor quality (Braa & Sahay, 2012; Chilundo & Aanestad, 2004; Sæbø et al., 2011). For example, the findings indicate that poor data quality is an issue in DHIS2. This became evident when talking to JSI, the IVD program, and with HMIS workers at the district level. Further, health managers at the IVD program find it hard to know what data to trust and not because the data in DHIS2 and DVDMT are different even though they collect the same information. Also, JSI and some DIVOs mentioned that this data does not match, and with low data quality, it can be hard to make good decisions for managers at all levels.

With the existing vaccine information systems, the IVD program currently needs to obtain data from three separate systems if they want to collate and coordinate all data related to immunization and vaccines. Thus, it may be hard to get a full picture of all immunization related activities. Further, with all the different technologies and reporting formats, including paper-based systems, stakeholders at all levels need to transfer a lot of data *manually*, both vertically and horizontally between the different sub-HIS. This needs to be done from paper systems to paper systems, from paper systems to electronic systems, and between different electronic systems. One example of transfer between paper systems, is the registering of routine immunization data, where the health workers fill in information in an immunization register and a tally sheet, and then compiles this information into a third form; the monthly summary form. In addition, some data is registered in the patients' immunization cards, and the data in these cards also need to be cross-checked and/or transferred between the card and the facility's immunization register.

Manual transfer of data from paper to electronic systems is done vertically for all the sub-HIS investigated in this thesis. That is, from R&R forms to eLMIS, from monthly summary forms to DHIS2, from vaccine ledgers to SMT and from another monthly summary form to DVDMT. Because of the equal monthly summary forms for DHIS2 and DVDMT, the DIVOs and the HMIS workers also do parallel work as they type in the same information at the district level in two different systems. This manual data transfer also requires traveling between the facility and the district level. For example, in one district, they said that they spend 2-3 days collecting HMIS forms from all facilities within the district. In other districts, the facilities often need to travel to the district office with the forms themselves. The time spent on this work could possibly, with an integrated system, be reduced, and the health workers could have spent more time on e.g. taking care of the patients. An example of horizontal, manual data transfer between electronic systems is that the workers at the MSD warehouses transfer data manually between eLMIS and EPICOR9. However, they are currently implementing an interface for data sharing between these two systems. Manual data transfer of R&R forms is also done from CTC2 to eLMIS.

To summarize, the fragmented HIS encountered in this thesis has led to duplicated data collection, as the health workers need to fill in three different paper forms twice for DVDMT and DHIS2. The problem with this is that it requires a lot of work, which could, potentially be avoided with integration of the systems. Further, manual data transfer is required from paper forms to paper forms, from the paper forms to electronic systems and between electronic systems. This also leads to a higher work burden, and unnecessary time spent on traveling between the levels for collecting or bringing the paper forms. High work burden and a lot of manual work can further increase the chance for making mistakes with the data, which can, again reduce the data quality. The challenge of poor data quality was found for DHIS2, and the IVD program finds it hard to use the immunization data to take good decisions because of the data discrepancies between DHIS2 and DVDMT. All these challenges may affect the overall health management in the country, and, according to the MOH, the fragmentation of the HIS in Tanzania is the key challenge related to the ICT capabilities in the country's health care sector as it hinders "…the effective sharing of information between healthcare participants" (MOHSW, 2013, p.iv).

Based on table 3 from section 4.2.1 with fragmentation challenges identified in related research, the table below summarizes the challenges created by HIS fragmentation identified in this thesis.

Table 4 - Fragmentation challenges in Tanzania's HIS

Fragmentation challenge	Example from empirical findings
Duplication of data and work	Health workers at the facilities need to fill in three different paper forms twice for DVDMT and DHIS2. This data is also entered in parallel into the two systems at the district level. This can lead to a high work burden, data errors and low data quality.
Hard to collate and coordinate information	With the existing vaccine information systems, the IVD program needs to obtain data from three separate systems, in addition to DHIS2 When data is available in different systems and formats (electronic and on paper), manual data transfer is required at all levels - from paper forms to paper forms, from paper forms to electronic systems and between electronic systems. Manual data transfer also requires a lot of traveling to physically bring or collect the forms. This can further lead to a high work burden, which can also affect the data quality.
Overburdened health workers	It is reasonable to believe that the duplication of work and manual data transfer adds to the already high work burden of the health workers.
Poor data quality	HMIS workers at the district level, JSI and the IVD program has mentioned poor data quality in DHIS2
Poor use of information to make decisions	Because of the different systems collecting the same data with different results, the IVD program finds it hard to know what data to trust and not, making it hard to take good decisions.

6.4 Opportunities and Challenges for Integration

As mentioned in the theoretical background, a commonly shared vision to solve the challenges of fragmentation is to move towards integrated HIS (Braa & Sahay, 2012; Health Metrics Network, 2008; Nielsen & Sæbø, 2016). Integration of an HIS will involve changing the different sub-HIS. Using a socio-technical perspective, not only technical, but also social and organizational factors need to be changed in an HIS integration process. The framework presented in chapter 4, based on Carlile's integrative framework (2004), is therefore used here to better understand the opportunities and challenges for integration at both the technical, data and organizational level in Tanzania's HIS. Using the terms from this framework, integration at the three levels would require three corresponding processes, namely transfer, translation and transformation.

The point of departure for investigating the vaccine information systems in this research was the identified issue of data discrepancies in the duplicate data collected by DHIS2 and DVDMT. The following discussion is therefore aiming to focus on opportunities and challenges for integrating DVDMT and DHIS2, as well as how these considerations change with the introduction of VIMS. Even though this is the main focus for approaching the research question, the discussion also draws on other examples from the findings, e.g. on the process of linking DHIS2 and eLMIS, and EPICOR9 and eLMIS. This is done to help shed a light on the opportunities and challenges for HIS integration in general. A complete assessment of a possible integration between DHIS2 and SMT is not included. This is mainly because SMT is handling another domain than DHIS2, namely logistics, and the most "obvious" vaccine information system to integrate with DHIS2 is DVDMT as they collect duplicate data.

6.4.1 Technical Level

Using Carlile's (2004) terms, integration at the technical level would require agreeing on a common lexicon that enables transfer of knowledge. Integration at the this level in an HIS involves agreeing on technical means for data and information transfer, that is, how health data can be transferred between different systems, and making the systems interoperable (Braa & Sahay, 2012).

Integration at the technical level can be constrained by the use of paper-based systems, both horizontally and vertically. Making standards for data transfer between software is one thing, but because paper forms are unchangeable "hardware", they will need to be replaced if changes are to be made. However, with the duplicate forms in DVDMT and DHIS2, a horizontal integration of these forms by removing eventual differences and agreeing on a shared set of forms could seem technically possible. At the same time, this will change with the introduction of VIMS. Even though the paper-forms going to be used for VIMS still will collect the same data as in DVDMT, it will also collect logistics data and cold chain inventory data in the same paper form. Integration with VIMS will therefore require new considerations on how to handle the paper forms.

With different technologies in the HIS, it can be hard to make systems interoperable, for example between an excel system like DVDMT, which is hard to modify and change, to a web system like DHIS2. If, for example, DHIS2 is updating or changing functionality in the system, like e.g. adding data fields for immunization data, this would require a manual change in the static excel-forms in DVDMT as well. However, with the introduction of VIMS, the inflexible excel-based DVDMT with email transfer of information will be removed. Further, both eLMIS and the vaccine information systems are going to run on openLMIS, which may possibly lead to opportunities for future interoperability between eLMIS and VIMS. On the other hand, it is not known how the data is coded in VIMS compared to DHIS2, and different coding or definitions of the same data challenges interoperability between systems. This challenge was encountered in the data linking of eLMIS and DHIS2, and for the interfacing between EPICOR9 and eLMIS.

6.4.2 Data Level

At Carlile's data level, the actors involved will have different interpretations and understandings of knowledge. Thus, a shared meaning, or common interpretation should be developed in a process of *translation* (Carlile, 2004). In an HIS, there can be different understandings on what data to be collected, processed and shared between the systems. Thus, integration at this level requires establishing agreement and shared understanding between the actors on *what* data to be shared. This can be done by e.g. standardizing data sets.

One challenge for integration at the data level is the reporting frequencies for the different actors at the organizational level making the reports include data from different periods. However, both DHIS2 and DVDMT collect monthly immunization data. Further, if there are no differences between the data sets in DVDMT and DHIS2, a shared agreement between the actors on *what* data to be collected and how to define them should require little negotiations. If there are some differences, the actors will need to agree on what data is most important to include in a standardized form for both systems. With the introduction of VIMS, a new data set is being introduced, and integration with DHIS2 will therefore require new agreements on this data set and extending to negotiate on new domains (logistics and inventory) not previously supported by DHIS2 in Tanzania.

6.4.3 Organizational Level

In Carlile's framework, the actors at the organizational level have different interests and requirements which may be in conflict and hinder them to share knowledge. Therefore, an alignment of interests and a *transformation* of the different actors' knowledge, both common and domain-specific, is required (Carlile, 2004). In an HIS, integration at the organizational level is about aligning interests between the different actors by transforming the social and organizational structures like routines, systems, responsibilities, information ownership, data sharing, management and so on (Braa & Sahay, 2012).

Integration at the organizational level will require an agreement between the involved stakeholders on what data collection routines should be followed and a change in the existing practices. For example, DHIS2 and eLMIS have different reporting frequency (monthly and staggered quarterly) which can be a challenge for integration. The reporting frequency for eLMIS is also tied to the commodity supply delivery schedule, so a change in the reporting frequency will require a change in the delivery schedule as well. However, the organizational stakeholders involved, HISP and JSI, have agreed to make an integrated dashboard, and they have already used it at the national level for almost a year. Thus, a process of making agreements and aligning interests is already ongoing at the organizational level for the integration of DHIS2 and eLMIS.

Routines and interests at all levels will have to be maintained in an eventual integration process. For example, if DVDMT should be integrated with DHIS2, the interests of HISP, WHO and the IVD program must be aligned. Further, the actors will have to agree on which system to use and delegate the responsibilities at the district level between the DIVOs and the HMIS workers. An opportunity for integration of DVDMT and DHIS2 at the organizational level, is that both systems require monthly reporting. In addition, they overlap in the domain of routine immunization data. However, DHIS2 is not only handling routine immunization data, but all routine health service delivery data, which is an interest that needs to be maintained.

With the initiative of integrating all functionality used for immunization related activities into VIMS, integration with DHIS2 becomes constrained by new factors. VIMS and DHIS2 will still have overlapping functionality and duplicate data collection, but there are also specific and individual requirements that need to be maintained. First, VIMS will handle other domains, namely logistics and cold chain inventory management. Therefore, integration of the vaccine information systems with DHIS2 would require extending the functionality and domain of DHIS2 to also include logistics and cold chain inventory management. Also, new actors will be involved in the negotiation process, like for example JSI which is developing VIMS, and MSD handling the procurement and distribution of vaccines, tied to the logistics functionality of the system. The findings also indicate that there is little communication between the initiators of VIMS and HISP. Further, the previously used paper-forms for DVDMT are being collated into one big immunization register with also logistics data and cold chain inventory data. Thus, negotiations for what paper-systems to be used (or how to integrate them) at the technical level, as well as what data to be collected (data level), will be required.

6.4.4 Summary of the Opportunities and Challenges

To summarize, integration at the technical level involves making the systems interoperable. Identified challenges for HIS integration at this level are the use of inflexible technology like excel, and paper systems, considered as unchangeable hardware. However, integration of the paper-systems used for DHIS2 and DVDMT seems possible because they are similar and a solution could, from a purely technical perspective, be to remove one set of the forms and bridging eventual differences. For electronic systems, different definitions or coding of the same data is a challenge for enabling data sharing. Ensuring interoperability between DVDMT and DHIS2 can be constrained by the fact that, while DHIS2 is a web-based software, DVDMT uses excel and email to transfer information, which is considered as quite inflexible. However, this challenge may turn into a possibility, as the excel-based DVDMT is being removed with the introduction of VIMS.

Integration at the data level requires agreeing on a shared understanding of *what* data should be collected, processed and shared. It is unclear exactly what data is collected in DHIS2 versus the vaccine information systems. However, with similar paper forms collecting duplicate data, an integration of DHIS2 and DVDMT would necessarily not require that much negotiation between the actors. However, with the introduction of VIMS, the previously DVDMT data is being collated into one big form with also data from SMT and CCIT, and the actors will need to negotiate on logistics data and cold chain inventory data, previously not supported by DHIS2 in Tanzania.

Integration at the organizational level requires an alignment of the different actors' interests, routines, responsibilities etc. Integrating DVDMT and DHIS2 would not require changing the reporting frequency. In addition, they have overlapping domains, namely routine immunization data. However, DHIS2 is not only handling routine immunization data, but all routine health service delivery data, which is an interest that needs to be maintained. There are also different actors at all levels tied to different routines for the two systems. All routines like the collection of forms, data transfer from paper forms to the computers at the district level, collation and analyzation of the data at the higher levels and so on, will thus need to be aligned. This will further involve agreeing on who will have the different responsibilities for what. The introduction of VIMS constrains the integration at the organizational level by new factors. This is mainly that the actors need to negotiate on new domains, that is, also logistics and cold chain inventory management. This will also involve new actors like e.g. MSD and JSI.

The opportunities and challenges for integrating DHIS2 with the vaccine information system used for routine immunization data on the technical, data and organizational level are further summarized in table 5 and 6 below. That is, opportunities and challenges for integration of DHIS2 with DVDMT in table 5, but also how this will change with the introduction of VIMS in table 6.

Table 5 - Opportunities and challenges for integration of DHIS2 and DVDMT

	Opportunities	Challenges
Technical	Similar paper forms	Inflexibility (excel and paper) makes it hard to interoperate, change and update systems
Data	The systems collect duplicate data in three similar forms. Monthly data set	Unclear if it is *exactly* the same data that is collected in the two systems, so some negotiations may be needed for a standardized data set.
Organizational	Same reporting frequency (monthly) Overlapping domains: routine immunization	Different actors with different routines and demands needs to be aligned DHIS2 and DVDMT have individual requirements in addition to the overlapping domains VIMS is going to be implemented

Table 6 - Opportunities and challenges for integration of DHIS2 and VIMS

	Opportunities	Challenges
Technical	Introducing VIMS will remove the inflexible excel-system (DVDMT)	The routine immunization data will be gathered in one big form with also logistics data and inventory data It is not known how the immunization data is coded in VIMS compared to DHIS2 – different coding of the same data challenges interoperability
Data	The same routine immunization data will still be collected	Introducing VIMS requires negotiations on new type of data: logistics and inventory data
Organizational	Still overlapping domains: routine immunization	Introducing VIMS involves new actors, new routines, new domains – more to align and negotiate on between an increased number of stakeholders Low communication between VIMS initiators and HISP

6.4.5 Iteration Between the Levels

In Carlile's framework, iteration between the different levels is an important part of an integration process, because changes develop iterative and evolutionary. Further, the organizational level will need solutions at the technical and data level to solve eventual issues (Carlile, 2004; Sæbø et al., 2011). This was for example shown in the example by Braa and Sahay (2012) from Malawi where the Ministry of Health and the Expanded Program on Immunization agreed to solve a data discrepancy issue. However, first after a solution at the technical level was established, they were able to agree on organizational issues like shared management of information and coordination of other processes. In Tanzania, the MOH has already developed an eHealth-strategy focusing on the integration and utilization of existing solutions. This might be the first step in an iterative process of incremental integration. After all, eLMIS and DHIS2 are already in an integration process, and the vaccine information systems are being integrated into one.

Integration at the technical level will require agreements at the organizational level as changing or adding systems would necessarily require establishing an agreement between the actors at the organizational level on how this can be achieved. This will also include agreeing on how to code and define the data to be shared, for ensuring interoperability. Establishing a new integrated system at the technical level also involves negotiations on issues at the data level, as the actors will need to *translate* their understandings and agree on *what* is important data to be collected by e.g. making a standardized data set.

In an iterative integration process, boundary objects can be used as means for the negotiations between the different actors (Braa & Sahay, 2012; Sæbø et al., 2011). Referring to the citation from JSI in section 5.5.6, it can be argued that eLMIS has worked as a kind of boundary object for the integration of the various logistics systems: "once eLMIS had proven its value and feasibility in the field, IVD was ready to engage with the eHealth strategy of greater integration and unified national technologies" (Wright, Alenga, & Mwencha, 2015). This can be summarized as follows: the MOH developed the eHealth strategy and led to eLMIS being developed and deployed as a national LMIS. Then, after eLMIS proved useful, the IVD program and JSI agreed on developing VIMS. DHIS2 has not been included in the process of developing VIMS. However, because VIMS is being developed on the OpenLMIS platform, and there is an ongoing project of linking data between DHIS2 and eLMIS, this can mean that a future integration or data sharing between VIMS and DHIS2 also may be possible. That is, if VIMS can work as a boundary object for new negotiations between the actors.

6.5 Potential Costs and Benefits of Integration

The motivation for integrating various sub-HIS with each other is to reduce the existing challenges created by a fragmented HIS which, in Tanzania, are e.g. data duplication, duplication of work and poor data quality. In this section, the challenges created by the fragmented HIS in Tanzania will be discussed together with the opportunities and challenges for integration discussed in the previous section, aiming to understand the potential costs and benefits of integration.

One fragmentation challenge discussed in section 6.3, is the manual data transfer between different formats and systems. This is a challenge that potentially can be solved with both horizontal and vertical integration. For example, MSD has developed an interface for data transfer from EPICOR9 to eLMIS, and a future ambition is to also enable data transfer the other way; from eLMIS to EPICOR9. With automatic data transfer from EPICOR9 to eLMIS, the workers will no longer have to manually transfer information from eLMIS to EPICOR9, which may both save time, and reduce the risk of data errors. This can also enable more effective management of health commodities at MSD. With integration, or automatic data transfer, the other way, the district offices will also be able to see all facilities' available budget in eLMIS. Thus, they will no longer be dependent on a printed form from MSD.

Manual data transfer from paper forms to electronic forms is done for all sub-HIS encountered in this thesis. *Horizontal* integration of the sub-HIS will probably not solve the issues of manual data transfer between paper and computers. However, *vertical* integration, or enabling a smooth flow of information between the facility level and the national level can solve this fragmentation issue. This can further reduce the time spent on bringing and collecting paper forms, and give the health workers more time to spend on other, more critical activities, like taking care of the patients. However, because of the infrastructural conditions in Tanzania, paper systems are currently necessary at the facility level for all sub-HIS. For the future, this can possibly be solved by tablets and phones with offline solutions and a long battery life. For example, this is currently being tested by the BID initiative implementing electronic immunization registers at the facility level.

The existing solution with DVDMT and DHIS2 having overlapping domains (routine immunization data) and parallel information flows has made the health workers at the facility level collect duplicate data in three different paper forms. Further, the IVD program do not know what data to trust, because of poor data quality and data discrepancies in the two systems. Thus, the motivation for integrating DVDMT and DHIS2 is to solve these issues. Integrating the vaccine information systems with DHIS2 could solve some fragmentation issues. If one could integrate DVDMT and DHIS2, one could remove the duplicated data collection at the facility level. One on hand, this could potentially enhance the data quality, as the health workers would only need to fill in one set of forms. On the other hand, duplicate data collection may not only be a challenge. It may be a burden for the health workers, but when the data can be obtained from two separate sources, it may also be possible to get more reliable data than what is possible from having only one system.

With one integrated system having all routine immunization data, the IVD program would not need to obtain data from two different systems. This could remove the issue of the IVD program not knowing what data to trust or not, because now they will only see one set of information. However, they will not know *if* this data is correct, because it is not known where the data errors in the existing solution appear. Another point is that, as mentioned in chapter 2, the vaccine coverage in Tanzania is over 90 percent for most vaccines, and the findings have not revealed any critical issues on national vaccine stock outs in the country. In addition, as mentioned by one informant from the IVD program: "if a facility is missing some vaccines locally, this is often because of wastage caused by temperature or equipment issues". Hence, it may be interpreted that potential vaccine wastage and stock outs are mainly caused by infrastructural issues tied to the cold chain management. To what extent the information systems affects this is not clear. Hence, it should also be considered how, and if, the current data discrepancies affect the overall decision-making and management of vaccines and immunization services.

This means that it is also unclear to what extent integration of DVDMT and DHIS2 can enhance data quality and decision-making. Further, the previous discussion showed that there are both enabling and constraining factors for integrating these two systems. On one hand, they collect the same data, they have overlapping functionality and they both have monthly reporting frequency. On the other hand, the inflexibility of excel in DVDMT can make it hard to make the systems interoperate at the technical level. Further, the various actors involved has their own interests and demands, like WHO requiring a monthly report, and DHIS2 not only collecting routine immunization data, but *all* routine health service delivery data. This will therefore require a process of negotiations and alignments of interests at the organizational level. The most important organizational challenge for integration with DVDMT is probably that VIMS is going to be introduced, replacing the existing vaccine information systems.

The introduction of a new system like VIMS might seem unnecessary. It can look like a typical example of a system developed in isolation to satisfy individual requirements, namely, for the IVD program and the VIMS initiators. That is, VIMS will still have a functional overlap with DHIS2 and they will require the same immunization forms. Thus, the health workers will still need to do duplicate data collection, and the same data will be typed into two separate systems at the district level. However, VIMS might, in fact, also solve some issues of fragmentation. With an integrated system, the IVD program will be able to obtain all information regarding immunization activities side by side, and it can be easier to compare the data and get a fuller picture of all immunization related activities. For example, one could look for correlations between the routine immunization data (e.g. how many patients have gotten a certain vaccine) and logistics data (e.g. how many vaccines of that type have been dispensed). One could also compare cold chain inventory data (e.g. if there has been a failure in the equipment) and logistics data (how many vaccines were wasted while there was an equipment failure) or routine immunization data (have there been registered any adverse effects of the vaccines given while, or after, there was an equipment failure). In addition, the inflexibility of the excel-based system DVDMT will be removed, which can make future data sharing with other systems easier. Further, because VIMS is built on the same platform as eLMIS, it is somehow connecting to one part of the installed base – it is not developed completely in isolation. Also, the process of linking data between eLMIS and DHIS2 has made JSI and HISP collaborate, and because JSI is the developer of VIMS as well, this may lead to future negotiations with HISP. That is, if VIMS are being well received, it may work as a boundary object for future negotiations between the organizational actors. Integration of VIMS and DHIS2 may solve the duplicate data collection, and it *may* solve the data quality issues experienced by the IVD program. However, also new issues will arise, like negotiation on new domains with new functionality not previously supported by DHIS2 (vaccine logistics and cold chain inventory management) and involving more actors (MSD, JSI etc.) with their own interests.

To summarize, integration may solve some existing fragmentation challenges. For example, there are different potential advantages of integrating DVDMT and DHIS2. If the health facilities could have one set of forms for collecting routine immunization data, the health workers would not have to spend time and effort on filling in the same information twice. This *may* also enhance the data quality, but this is unclear as it is not known where the data discrepancies appear and how this affects the decision-making and overall health management. However, the discussion in section 6.4 also revealed some challenges for integrating DHIS2 and DVDMT. For example, DVDMT is excel-based and thus highly inflexible and there are different actors at all levels with different routines which also have individual interests and requirements in addition to the overlapping domains. The most important challenge for integrating with DVDMT is the development of VIMS. VIMS can solve some fragmentation issues for the IVD program and it will remove the inflexible excel-based system, possibly making it easier to connect to other systems like DHIS2. Integrating VIMS and DHIS2 can solve the duplicated data collection, but it will also require new negotiations between even more actors and on new issues, as VIMS is extending to also the domains of logistics and inventory management. Thus, integration could also potentially be a highly complex process, and one should consider if the potential benefits is worth the effort and eventual resources needed to be spent.

6.6 Is integration the Solution?

There is a wide-spread consensus that countries need to work towards more integrated HIS, and that this will achieve more efficient information management and enable better decision-making and overall health management. However, Monteiro (2003) points out that "… the integration of health information systems is currently something of a truism, a taken for granted ambition" (p.428). The following discussion aims to not take integration for granted, but rather discuss alternative strategies for solving the challenges of fragmented HIS. Integration may potentially solve some fragmentation challenges, but there can also be various constraining factors for integration. Thus, integration may require a lot of resources and effort from the actors in order to be achieved. Considering this, is integration the best solution to solve the challenges of fragmentation?

What if one, instead of integrating the sub-HIS with each other, could replace all functionality in the different sub-HIS with one common system for all actors? In this way, one could remove all duplicate data, duplicate work and possibly enable a more coordinated information flow and achieve better quality data. For example, the IVD program could, in this way, also be more able to trust the data and use the information to take good decisions. However, within the HIS in Tanzania, there is a myriad of different actors involved, and they all have individual and overlapping requirements and interests which need to be maintained. One big, integrated system for the existing sub-HIS, like for both the national HMIS and the vaccine information systems would require an even more extensive amount of coordination and negotiation between the involved actors, including e.g. agreeing on information ownership and who is responsible for what (Nielsen & Sæbø, 2016). Who will, for example, be in charge of developing and maintaining the system? Another issue is that one big system may not be able to meet the different needs of all the different actors. That is, both horizontally and vertically. The national level for example requires advanced ERP and warehousing systems, like EPICOR9 at MSD, as well as systems for distribution management, while the facilities need basic inventory systems and patient-management systems like, e.g. the immunization registers and vaccine ledgers. In addition, the previous discussion has shown that the installed base is complex and that the existing sub-HIS are interconnected with each other. For example, VIMS is already developed and is going to run on openLMIS. It is therefore already interconnected with the LMIS-part of the installed base in Tanzania's HIS. In other words, the installed base of the HIS challenges a process of developing one big system, because it needs to be based on extensions and improvements to what already exists, rather than starting from scratch.

Considering the complex, existing, installed base, starting from scratch and integrating all functionality into one system would require a substantial amount of work. It may not be possible to keep the individual requirements with this type of integration. Maybe a more feasible solution is to, as the MOH called for in the eHealth strategy, integrate and utilize what already exists. Monteiro (2003) argues that instead of tightly integrating existing systems, "a more decentralized approach to integration is more likely to encourage robust, independent components that communicate through well-defined interfaces" (p.431). In general, an installed base cultivation, or integration of the fragmented parts of the installed base, may, as we have seen, solve some existing challenges and help the HIS towards the desired goal of being more integrated.

Another important question that arises when discussing the integration of DHIS2 and DVDMT is where data discrepancies appear. The data in the two systems do not match, but where does the data collection and processing fail? If one were to solve the data quality issue, maybe the first step in this process could be to keep the systems as they are, preserve their individual functions, and find out where the data errors appear. This would require the involved actors to first agree on solving the data discrepancy problem, and then to share their data. Then, one possible solution could be to share the duplicate and overlapping data between the systems, like what have been done for eLMIS and DHIS2. If one could enable data sharing between the new VIMS and DHIS2, on the data that was previously collected in DVDMT, one could identify why and where there are mismatches in the data. In this way, the individual functionality of the two systems will be preserved – DHIS2 can be focused on all routine health service delivery data, while VIMS can handle all data related to immunization and vaccine logistics. Further, the IVD program may be more able to trust the routine immunization data, and the overall management and decision-making within the vaccine sub-HIS can, if possible, be enhanced. At least, this could possibly be *one step* into further negotiations on how to enhance the immunization data quality.

7 Conclusion

The purpose of this chapter is to conclude the thesis. First, concluding remarks are drawn related to the research question and research objectives. Second, focusing on the vaccine information systems and HMIS, some implications for integration are presented. Third, reflections are made on the strengths and the weaknesses of Carlile's (2004) integrative framework and the limitations of this thesis.

7.1 Concluding Remarks

The research question addressed in this thesis was: *what are the potential benefits and challenges of integrating the vaccine information systems with HMIS?*

Four research objectives were identified as important for answering this research question, and the following section approaches these objectives before concluding on the research question. That is, how the Tanzanian HIS is fragmented, why the Tanzanian HIS is fragmented, the challenges of fragmentation in Tanzania, and the opportunities and challenges for integration of the information systems in the HIS.

Focusing on the national HMIS, LMIS and the vaccine information systems, the discussion in this thesis illustrated how Tanzania's HIS has various uncoordinated and overlapping sub-HIS. At the technical level, the HIS is fragmented with different systems in different formats and with different data de finitions and coding of the data. At the data level, the fragmentation is unclear, but with different actors developing the data sets for the various systems, there may also be differences in what data is collected. At the organizational level, several actors with different interests and routines (e.g. different reporting frequencies) were identified. Further, because of some contradicting information about their interests of integration, it seems that there is little communication between some of the actors.

The analysis on *why* Tanzania's HIS is fragmented illustrated that, based on an II-perspective, the HII consists of a socio-technical, complex and heterogeneous installed base with interconnected information systems, actors and other components. The existence of vertical programs has led to a distributed responsibility of parallel information flows within the HIS with limited communication between the actors at the organizational level. Further, because the installed base is open to an unlimited number of new components, it is constantly expanding.

Because this makes it more difficult to build systems from scratch, new components get built on top of the already fragmented installed base, making it even more complex.

Several challenges of the fragmented HIS were identified, like duplicate data collection, manual data transfer between different systems and formats and low data quality. There are also data discrepancies in the duplicate data collected by DVDMT and DHIS2. Because integration is a common suggestion for solving the fragmentation challenges, opportunities and challenges for integration were discussed. Some opportunities were mentioned, like using the same reporting frequencies, having overlapping domains, collecting similar data and using similar forms. However, several challenges related to achieving integration were also identified, for example the use of different system formats, inflexible systems and differences in the routines and interests of the various actors involved.

In conclusion, integration may solve some fragmentation challenges, like for example removing duplicate data collection at the facilities, facilitate the coordination of information and possibly enhance the data quality. However, it is not clear how the current data duplication actually affects the data quality, and if the discrepancies in the data affect the overall decision-making and immunization services. Integration will further require intricate negotiations and aligning of interests between different of actors on the organizational level. This makes it a potentially highly complex process, and the benefits should be carefully considered related to the effort and resources needed to achieve integration.

While integration is a common solution to solve the challenges of fragmented HIS, a critical perspective on integration was applied in this thesis. This was done by avoiding the presumption that integration can solve the fragmentation challenges. Instead, the approach was based on first assessing how and why HIS are fragmented, then identifying the challenges related to this, and finally discussing the possibilities and challenges for integration. Based on this, the potential benefits and challenges for integration, and on the possibilities for solving the fragmentation issues with alternative strategies, were discussed.

7.2 Implications for Integration

Because of the potential resources and effort required in an integration process, also possibilities for solving the fragmentation issues with alternative strategies were discussed in chapter 6. One alternative strategy is to tear down the independent sub-HIS and instead develop one big system. However, the complex installed base of the existing HIS involving multiple, interconnected information systems, will challenge the process of developing one big system. Starting from scratch will probably involve a substantial amount of work, and it may not be possible to maintain the individual requirements for the diverse actors. Thus, installed base cultivation, or integrating various fragmented parts in an iteratively way, may in fact, be a better solution.

If a decision is made to try integrating the vaccine information systems with the national HMIS in Tanzania, this thesis suggests, as a first step in an iterative process, to compare duplicate data and identify data discrepancies. Based on this, the involved actors can locate the problem and negotiate on how to solve it from there. This will require the actors at the organizational level first aligning their interests by agreeing on solving the data discrepancy problem and to share their data. Then, they will have to agree on what data to be shared for comparison at the data level. This will also require negotiations and figuring out how to enable the data sharing and compare the data at the technical level. For example, in the data sharing project between DHIS2 and eLMIS, this was done by inserting data from both systems into a dashboard in DHIS2 to visualize the data side by side. It is also possible to compare the collected data in the paper forms used at the facility level, but this will require a lot of manual work. If the actors can manage to identify where there are mismatches in the data, they can further negotiate on how to solve this problem and reassess if integration is beneficial and/or necessary to achieve this. This can further be the beginning of an iterative process of enhancing the immunization data quality.

7.3 Reflections on the Use of Carlile's Integrative Framework

Carlile's integrative framework (2004) was originally developed to understand the management and sharing of knowledge across boundaries within an organization. Various HIS researchers, like Braa and Sahay (2012) and Sæbø et al., (2011), have adapted and used the framework to understand different levels of standardization and interoperability within HIS and the interaction between these levels in integration processes.

The framework is used in this thesis to analyze how Tanzania's HIS is fragmented from the purely technical level to the organizational level with different actors. This has been helpful considering the existing theory and related research on the field understanding HIS as socio-technical infrastructures. Changing the HIS, like for example introducing new components or integrating existing parts, will also involve changing social and organizational factors.

The different levels have different features and involve different processes for integration. Thus, the framework has been useful to understand the possibilities and challenges for integration at the three different levels, and what a potential integration process will involve. Further, comparing how the HIS is fragmented at the three levels with the opportunities and challenges for integration at the same levels, has been useful as a foundation to critically discuss potential benefits and challenges for integration.

Beyond directing the focus towards and supporting the understanding of the different levels of fragmentation and integration separately, the framework is also useful for understanding the HIS as a whole, and how the different levels interact and are related to each other. For example, using the concept of iteration and boundary objects supported building an understanding that Tanzania may be in an iterative process of integrating the logistics part of the national HIS. That is, eLMIS can be conceptualized as a boundary object, which has iteratively led to negotiations between the actors and now enabled the development of VIMS.

7.4 Limitations

This thesis has achieved to approach the overall objectives for answering the research question. However, there are also some limitations.

One limitation of this thesis is that it is only parts of the HIS in parts of Tanzania that have been investigated. Within the timeframe and scope of this study, it was not possible to do research throughout the whole country. Only a limited set of stakeholders have been interviewed, mostly within Dar es Salaam, and in some of the nearest rural areas. Further, all facilities visited had access to electricity. However, the majority of people in Tanzania live in rural areas with low access to electricity, water and sanitation facilities, and there are big differences between the health status of the people living in rural and urban areas. Therefore, it would have been useful to visit other parts of the country to get a broader picture and better understanding the potential consequences of fragmented HIS.

Another limitation of the data collection is that only the national, district and facility levels were visited. We were for example not able to see regional vaccine storages and this part of the supply chain. However, we were told that the big district vaccine storage we visited within Dar es Salaam was similar to a regional storage. When studying information infrastructures, this is a common challenge due to their complexity and size.

Further, there are no clear empirical findings regarding the CCIT system. However, the district vaccine storage visited in Dar es Salam had a system with similar functionality to how CCIT was explained to work. Thus, one interpretation could be that the equipment we observed and discussed actually was CCIT, but that the workers did not know the name of the system.

According to the MOH, there are a lot of vertical health programs and ICT pilot projects running in parallel, leading to fragmentation and fragmentation challenges. Due to the focus and scope of this thesis, only parts of the HIS were investigated. It is thus not possible to say anything about the fragmentation of the whole HIS based on these findings. However, the parts of the HIS investigated can be used as examples from Tanzania's HIS and may shed a light on the fragmented HIS in general. Furthermore, to what extent the findings from this thesis are relevant also in other developing countries can be questioned. Even though the context in other countries are different, it may, however, be useful to apply a corresponding critical perspective and use Carlile's integrative framework (2004) to analyze fragmentation and the opportunities and challenges for integration. Considering the related research presented in chapter 4, it should also be noted that the fragmentation encountered in this study is quite similar to what is reported in other studies.

Furthermore, as discussed in section 3.1 and 3.4, I have aimed to understand the phenomenon and context through my own interpretation of the informants' interpretation. Hence, repeating this study may not lead to the same results as found in this thesis, but the study can contribute to an explanation and rich insight of the studied phenomenon.

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Appendices

Appendix A – Example of Interview Guide

<u>Interview guide for facilities – August 2016</u>

Immunization services

- What are the routines for providing immunization services?
- How do you reach out to the communities?
- How do you register the patients getting their immunization?
    - How do you track what vaccines have been given to which person?

Ordering process

- Can you describe the ordering process of vaccines?
    - Which tools are you using for this ordering?
    - How often do you place the orders?
    - What do you base the orders on?
- How often do you get supplies of vaccines?
    - How do you get your supplies? (By whom?)
    - Do you always get what you order?

Storage, equipment and stock management

- What equipment do you use for the storage of vaccines? *(Observation)*
- Do you have electricity at this facility?
    - Do you experience power outs?
        - How frequent?
        - What do you do when/if there is a power out?
- How do you monitor the temperature?
    - What do you do if the temperature has been too low for a longer time? (wastage)
- Are you experiencing any stock outs on the vaccines?
    - How frequent?
    - What do you do when/if there is a stock out? (Emergency orders? / Redistribution?)
- Are you experiencing any overstocks on the vaccines?
    - How frequent?
    - What do you do when/if you are over stock? (Redistribution?)
- Are you experiencing any wastage of the vaccines?
    - How frequent?
    - What are the main reason for this wastage? (e.g. out of date, temperature etc.)
- How do you manage the stock?
    - Physical counts? + How often?

Appendix B – Not Subject to Notification

NSD

Result of Notification Test: Not Subject to Notification

You have indicated that neither directly or indirectly identifiable personal data will be registered in the project.

If no personal data is to be registered, the project will not be subject to notification, and you will not have to submit a notification form.

Please note that this is a guidance based on information that you have given in the notification test and not a formal confirmation.

For your information: *In order for a project not to be subject to notification, we presuppose that all information processed using electronic equipment in the project remains anonymous.*

Anonymous information is defined as information that cannot identify individuals in the data set in any of the following ways:

- directly, through uniquely identifiable characteristic (such as name, social security number, email address, etc.)
- indirectly, through a combination of background variables (such as residence/institution, gender, age, etc.)
- through a list of names referring to an encryption formula or code, or
- through recognizable faces on photographs or video recordings.

Furthermore, we presuppose that names/consent forms are not linked to sensitive personal data.

Kind regards,
NSD Data Protection

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