Health commodity ordering in Uganda

Exploring DHIS2 Tracker as ordering tool in the antiretroviral health programme

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Abstract

Reliable Logistics Management Information Systems (LMIS) are needed to ensure access and availability of health commodities in developing countries. In Uganda, the Ministry of Health is currently undergoing strengthening efforts, aiming to move from paper-based ordering, towards ordering based on the DHIS2 software.

This thesis examines the current status of the ordering systems present in Uganda, in order to better understand what aspects shape the use and evolution of LMIS. Stock-outs were found to occur in almost every health facility visited, indicating that improvements to commodity distribution and access are needed. Other challenges were identified, such as the fragmentation strictly guiding the design and evolution of LMIS, and the generally low resources and poor infrastructures present. Still, several of the routines found in the strong installed base contribute to strengthening the overall LMIS, such as districts and warehouses functioning as paper-to-digital gateways, ultimately making data available in DHIS2.

As the DHIS2 Tracker module has gained recent attention in Uganda, this thesis further investigates its applicability as ordering system in the antiretroviral health programme. Through system development, Tracker was found to support commodity ordering processes and output requirements. Several workarounds resulted in an unnecessary complex software solution, indicating that the module seems somewhat immature to support large orders. Four needed functions in DHIS2 are proposed: performance improvements in Event Reports on large orders, support to display Tracker Data Elements on metadata groupings, support for the specific ordering periods in the logistics sector and support for easily storing information on facility warehouse-connections.
Acknowledgements

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Nicolai August Hagen
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Abbreviations

AR Action Research
ARV Antiretroviral
API Application Programming Interface
DHIS2 District Health Information Software 2
DHO District Health Office / District Health Officer
HIS Health Information System
HISP Health Information Systems Programme
HMIS Health Management Information System
II Information Infrastructure
IS Information Systems
IHIA Integrated Health Information Architecture
LMIS Logistics Management Information System
MIS Management Information System
MOH Ministry of Health
NMS National Medical Stores
TB Tuberculosis
WAOS Web based ARV Ordering and reporting System
WMS Warehouse Management System
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Chapter 1

Introduction

This thesis focuses on logistic processes and Information Systems (IS) of health commodity ordering in the Ugandan health system. Health commodities are products used in a country’s health care. Examples include medicines (e.g., HIV/AIDS pills), medicinal equipment (e.g., gloves and syringes) and preventive equipment (e.g., malaria bed nets). The topic for this thesis is the IS, ordering processes, and the creation of useful information from order data in the context of the Ugandan health sector.

1.1 Motivation

There are three main motivations for this thesis work.

First, Uganda suffers greatly from poor health status and deep-rooted challenges in the health system. Communicable diseases are the leading causes of death in the country, where HIV/AIDS is rated as the top killer. Improving the access and availability of life-saving commodities is crucial to combat these challenges. Here, information systems play an important role as a part of the overall health system strengthening process, ultimately leading to improvements in health. Better Logistics Management Information Systems (LMIS) are sought after, as several developing countries are struggling with issues related to medicine distribution, access and availability, with a typical problem being stock-
outs of medicines and medical equipment (Kraiselburd & Yadav, 2013; Jahre et al., 2012; Chindove & Mdege, 2012). The overall performance of health care supply chains in developing countries is often lower than in OECD nations (Kraiselburd & Yadav, 2013, p. 378). Even though Uganda is currently improving on access and availability of health commodities, around 36% of the country’s health units still experience stock-outs on important tracer drugs (Ministry Of Health, 2016). A motivation to research the Ugandan logistics and commodity ordering systems is to identify the possibilities of improving the information basis for health-enhancing decision making in the health logistics sector.

Second, the information system District Health Information Software 2 (DHIS2) is used to report on routine health statistics in Uganda, and its use is widespread. In more recent years, the Ministry of Health (MoH) has decided to use the software as a LMIS, dealing with the process of health commodities ordering and disseminating data from the orders in the health sector. Currently, DHIS2 is used for commodity ordering in the HIV/AIDS health programme, while the other programmes use paper-based systems. In the near future, Ugandan MoH aims at expanding the utilisation of DHIS2 to include ordering for even more health programmes. As a part of this digitalisation shift in the Ugandan LMIS, the aim is to explore how DHIS2 can be used to derive useful and reliable information from commodity orders. By this, national stakeholders can better be able to know where to focus resources and funding, and decision-makers at the local level can use the information for local planning. The overall goal is to improve the information basis, ultimately leading to better medicines distribution.

Third, a parallel initiative is ongoing in the development of the DHIS2 software itself. A fairly new software module, labelled the DHIS2 Tracker, extends the software by including support for registering event-based data, alongside applications for disseminating this data. For instance, the software is used for tracking patients through treatment processes. As health system stakeholders in Uganda are interested in using this module for commodity ordering, it would be beneficial to see whether orders can also be tracked through the supply chain. The motivation behind

\[1\] Numbers from 2014/15
examining the module is to understand whether or not it can be utilised to support health commodity ordering, aiming at improving the overall quality of information. Learnings from this work can be transferable to other strengthening processes in other developing countries in similar situations as Uganda.

1.2 Research context and domain

A case study has been carried out during two field visits to Uganda, as well as from Norway. This thesis work is a part of the research group Information Systems at University of Oslo, who is coordinating a research programme labelled the Health Information Systems Programme (HISP). This programme conducts research on Health Information Systems (HIS) in several developing countries, one of them being Uganda. Through the HISP network, I and a fellow student have established contact with the HISP node in Uganda. HISP Uganda is a local DHIS2 consultancy initiative, also facilitating research on the HIS in the country.

1.3 Scope

The overarching research field is HIS in developing countries. Further, the focus of my thesis is the Ugandan public health sector, specifically the health commodity ordering systems. Hereunder, the ordering of antiretroviral (ARV) medicines\textsuperscript{2} in the HIV/AIDS health programme has been targeted, as MoH in Uganda has partly digitalised the commodity ordering in this programme during the last years. This part of my scope is shared with one fellow master’s student. However, I have further narrowed my scope to focus on the technical aspects of health commodity ordering in the ARV health programme, and on understanding the requirements for information stemming from the order data. In terms of practical system development, the scope of my thesis is the DHIS2 software.

\textsuperscript{2} Medicines for treating HIV.
1.4 Research questions

The purpose of this thesis is twofold: to provide insight from understanding the current status of the Ugandan LMIS’ and health commodity ordering systems, and to better understand the applicability of the Tracker module for creating a commodity ordering system inside DHIS2. The two research questions therefore are:

1. What is the current status of the overall LMIS and health commodity ordering systems in Uganda?

2. What is the applicability of DHIS2 Tracker to support ARV logistics requirements?

In the former research question, the aim is to understand what characterises the current LMIS and commodity ordering systems in Uganda to better understand what aspects shape the use and overall strengthening processes. In the latter, the aim is to first understand the requirements for information output in the ARV programme, in order to assess the usefulness and applicability of DHIS2 Tracker as a commodity ordering tool through system development.

1.5 Chapter overview

Chapter 2 - Background describes the research context by giving an overview of the Ugandan health status, as well as the supply chain and HIS.

Chapter 3 - Research approach gives an overview of what has guided the data collection and how data has been collected and analysed. Moreover, methods of system development are described, and reflections on the research are given.

Chapter 4 - Theoretical background provides insight into the relevant literature on the typical challenges for health and logistics information systems in developing countries, alongside strengthening strategies to cope with such challenges.
Chapter 5 - Empirical findings describes the findings from the initial field trip, aimed at understanding LMIS in Uganda, and the second field trip, focusing on understanding requirements for a commodity ordering solution for the ARV programme.

Chapter 6 - System development introduces the technical environment for software, presents the different architectural designs considered, and presents the resulting software setup and information outputs created from this setup.

Chapter 7 - Discussion joins insight from the theoretical chapter, findings and development work, using the research questions as the basis.

Chapter 8 - Conclusion and future work concludes the main thesis contributions, and suggest future work.
Chapter 2

Background

As most of the research has been carried out in Uganda, this chapter presents this research context. This chapter will be useful to better understand the findings from data collection, as well as better understanding the rationale behind decisions made during systems development. A brief overview of Uganda is provided, following an elaboration on the statuses of health, infrastructure, and the current health information system. Moreover, descriptions of the role of the HISP network, the DHIS2 software, and an overview of the health information system is given.

2.1 Overview of Uganda

Uganda is an equatorial developing country located in the central-eastern part of the African continent. Hence, Uganda has stable temperatures and a well cultivable soil for farming (Haslie, 2016). The main export goods are coffee, tea and fish.

Uganda became independent from Britain in 1962 and is today a member of the British commonwealth of nations (Haslie, 2016). Unfortunately, the period of independence lead to a turbulent political and military landscape in the country (The World Factbook, 2016). Ugandan political history has been violent, and many hundred thousand lives were lost during the dictatorial regimes of Idi Amin and Milton Obote. After the last military coup in 1986, by the still reigning Yoweri Museveni, the country
has become more stable and secure (The World Factbook, 2016). However, Uganda still has challenges with a slowly moving economy, infrastructural problems and profound health related challenges.

Uganda is rated as a Least Developed Country (LDC), with around 29 percent of the population living below the international poverty line \(^1\) (Haslie, 2016). The country has a low GDP of 726.9 USD per capita (United Nations, n.d.-b). In contrast, Norway’s GDP per capita is 97 226.5 USD (United Nations, n.d.-a).

2.1.1 Infrastructure

Uganda faces infrastructural challenges, mostly prominent in the more rural areas of the country. This is where most of the population resides, as only 16.1% of the citizens reside in an urban environment (United Nations, n.d.-b). In contrast, Norway has 80.5% urban residing citizens (United Nations, n.d.-a).

Transport is mostly done by smaller trucks and motorbikes, as railroads are not widespread and the road conditions often poor. As the official road network in Uganda is not extensive, motorbikes are highly flexible to reach the more rural areas - where most people live. Even the main medical commodity providers use motorbikes in the distribution process. During transport of health commodities, there is a risk of the vehicle braking down, which in turn may lead to damaged or lost medicines.

Moreover, Uganda also suffers from frequent power outages. This makes it necessary for clinics, hospitals and offices to maintain a spare power grid and functioning UPS equipment. Power outages can last for hours, or even days. This was also experienced during our field trips to Uganda. Power outages have negative side-effects, such as for cold chain management of temperature sensitive commodities (e.g., vaccines).

In terms of communication, fixed lines are not heavily extended in the country. Very few use fixed telephone lines, but the use of mobile network technology is rapidly increasing (The World Factbook, 2016).

\(^1\)Below 1, 25 USD per day
Third generation mobile network (3G) is evolving, making it manageable to increase connection for Ugandans to Internet resources. This shift is positive for the health information system in the country, as it may contribute to increasing reporting rates, ultimately offering better and more complete health statistics. Interestingly, the Ugandan Ministry of Health (MoH) has signed a contract with one main telecom provider, giving health personnel access to the national reporting servers for free. This MoH strategy for increasing reporting rates will become important for health system strengthening.

Overall, the rapidly increasing mobile 3G connections in Uganda are promising for bettering health services in the country. Mobile technology is making it possible for developing countries such as Uganda to skip several generations of technology (Haugnes, 2016). Caused by this, it is possible to save substantial costs related to older technologies, such as wired networks.

2.1.2 Health Status

The country is densely populated, having an approximate of 39 million residents (World Health Organisation, n.d.-c). The population is under steady growth with an average annual growth rate of around 3.3 (United Nations, n.d.-b), compared to Norway’s 1.3 (United Nations, n.d.-a). This is one of the highest growth rates in the world, presumably linked to the fact that Uganda also has one of the highest fertility rates in the world (The World Factbook, 2016). Between 2010-2015, the fertility rate was 5.9 live births per woman (United Nations, n.d.-b).

The Ugandan age distribution is shown in figure 2.1 on the following page. The most salient characteristic is the high amount of young residents, with around 48% of the population being below 14 years, with a median age of only 15.7 years (The World Factbook, 2016). The median age is also indicative of the low life expectancy at birth of 57 years, compared to Norway’s 82 years (World Health Organisation, n.d.-c).

One major health related issue in Uganda is the prevalence of commu-
nicable diseases, with HIV/AIDS being the most prominent. Currently, around 1.5 million people are living with the illness in Uganda (World Health Organisation, n.d.-a). HIV/AIDS is the main cause of death in Uganda, responsible for around 61 400 deaths yearly\(^3\) (World Health Organisation, n.d.-c). Treatment with antiretroviral therapy\(^4\) is crucial to keep people infected healthy and prevent further infection between people. Also, Uganda is working on procedures in antenatal care to prevent HIV-infected mothers continue the disease onto the children. Other prominent health related challenges in Uganda include tuberculosis (TB) and malaria.

### 2.2 Health System

The health services in Uganda are delivered by both the public and private sector, where the public sector accounts for about 50% of the services provided (Ministry of Health, 2015, p. 12). Moreover, Uganda has divided the country’s health facilities (including hospitals) into seven levels, as shown in table 2.1 on the next page. The level categorisation is based on some key characteristics, such as facility size and patient numbers. Level one to three are the levels nearest to the community, providing primary health care. Level four and five are larger health units, often health centres or small hospitals. Level six and seven provides the special treatments often not available at local health units.

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\(^3\)Numbers from 2012.  
\(^4\)Medicinal treatment for slowing down an HIV infection. The treatment often consist of a combination of several medicines.
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Table 2.1: Uganda’s division of health system levels.

The private actors in Uganda are also of significant importance in improving the country’s public health. The private actors can be further divided into two different categories: (1) faith-based or non-faith-based, and (2) Private-For-Profit (PFP) or Private-Not-For-profit (PNFP).

The PNFP actors accounts for 20% of all of the health facilities in the country, and also consists of pharmaceutical warehouse suppliers such as Joint Medical Stores (JMS), as well as hospitals and smaller health facilities (Ministry of Health, 2015). This is the largest category of private medical organisations in Uganda.

The PFP actors accounts for 14% of all of the health facilities in the country, and includes a diversity of organisations from manufacturers, retailers, drug shops, and health facilities at different levels (Ministry of Health, 2015). Uganda is a highly religious country, where most of the inhabitants are Christian. As a result, considerable amounts of facilities are faith-based. They are typically founded and driven by Christian movements, or movements from other religions.

Uganda’s private health facilities differ markedly from the facilities in the public sector. They are different in terms of general organisation structure, logistics systems, reporting procedures, doctor-patient coverage and commodity ordering methods. The ordering methods used by facilities depends for example on whether the facility in question is for-profit or not, and who they currently have business relations with.
2.2.1 Health commodity providers

The health sector is primarily subsidised by external implementing partners, as a result of the slowly moving Ugandan economy. This includes resources from industrialised countries and NGOs. Uganda is heavily reliant on this financial help from international funders.

When commodities arrive, they are usually linked to a specific health programme (e.g., the ARV programme or the TB programme), because the external funding plans are organised in this manner. The commodities are shipped to private or public warehouses, according to the plans of implementing partners. The organisations have multiple warehouses throughout the country, to ensure coverage of medicines, vaccines and medical equipment for health units, ranging from small clinics to large regional and national hospitals.

2.2.2 Supply chain

National Medical Stores (NMS) was established in 1993 to effectively and efficiently supply health commodities to public Ugandan health facilities (National Medical Stores, n.d.). As the provider of medicines and medical equipment to public Ugandan facilities and hospitals, they are the first node in the health commodity supply chain. The two other warehouses are JMS and Medical Access Uganda Ltd (MAUL).

Facilities order health commodities from these providers through a bi-monthly ordering scheme. This is paper-based, except for ARV medicines which are only partly paper-based. To avoid major bottlenecks at the warehouse level, warehouses have divided the country’s facilities into five delivery zones. These zones guide when commodities are ordered, and when the commodities should arrive from the warehouses.

An important aspect of the health supply chain in Uganda is that even though facilities orders from one warehouse, ordering is done through one ordering form for each health programme. This is caused by funding being split into health programmes, and not planned as a whole. In practical terms, this means that the ARV programme has its own
ordering form. Further, this also means that facilities will have several
different forms caused by connections to different health programmes and
initiatives.

2.3 Health Information System in Uganda

The overall health information system in Uganda consists of both health-
and logistics-specific information systems. These are briefly introduced in
this section.

2.3.1 Role of the Health Information Systems Programme

In order to give a brief overview of the health information system in
Uganda, a description will first be given of the relation to the HISP, introduced in the previous chapter.

HISP is described as a global network made to strengthen health
information systems in developing countries (University of Oslo, n.d.),
researching on the development and deployment of the software DHIS
for over 15 years. The HISP project started in South Africa in 1996, where
the focus was on strengthening the HIS in the post-apartheid era (Braa,
Hanseth, Heywood, Mohammed & Shaw, 2007). The District Health
Information Software was used to provide useful and timely information
to decision makers at the district level. Moreover, the software was used
to collate and analyse data material in response to the need for integration
of multiple health data to create information needed to improve the
country’s health situation (Braa et al., 2007).

Today, DHIS is used at various levels in the health system in 47 countries
in the global south (DHIS2, n.d.-e), with the number of implementing
countries steadily growing each year. The second major distribution of the
software (named DHIS2) has come with useful new contributions, such as
more refined data management and analytics tools, visualisations and a
more interoperable and scalable infrastructure (DHIS2, n.d.-f).

HISP has autonomous networks in many countries, one of them being
Uganda. HISP Uganda is currently doing consultancy work on the DHIS2 software and can be considered as country experts on the software. HISP Uganda also supports HISP in other countries, such as Rwanda and other eastern African countries.

In relation to the Ugandan health commodity supply chain, HISP Uganda has been a central resource for MoH to set up digital collecting routine health data in DHIS2, and later commodity reporting data. During our field visits in Uganda, we lived at the HISP Uganda office in Kampala, closely collaborating with the consultants working there. They have supported us in our practical work and facilitated visits to clinics, hospitals and organisations.

2.3.2 Information Systems

The WHO-initiative Health Metrics Network (HMN) describes that the goal of a health information system is to “produce relevant information that health system stakeholders can use for making transparent and evidence-based decisions for health system interventions” (Health Metrics Network, 2008, p. 9). Systems are needed for handling the information used in both health and logistics systems. This is where Health Management Information Systems (HMIS) and LMIS are relevant. Firstly, Hurtubise (1984, p. 28) defines management information systems as “a system that provides specific information support to the decision-making process at each level of an organisation”. In other words, such systems are linked to the creation and use of data, in order to create meaningful information relevant for decision-making.

In Uganda, the health system consists of several such management systems. In these systems, the information is both paper-based and digital. For example, commodity orders are often first entered at a computer when delivered in paper at district, region or national level.
HMIS

An important part of the contribution made by HISP Uganda is the commissioning and support work performed to build and to maintain a national HMIS in Uganda, an information system assisting the management and planning of health programmes (World Health Organisation, 2004, p. 3).

Such systems aim at enhancing the national public health, by providing meaningful information for decision makers at the different levels of the health system. This is the intention of the DHIS2 software, giving countries such as Uganda an affordable and customisable open source software.

In Uganda, DHIS2 is currently being used for reporting on monthly routine health data, such as reporting on disease occurrences as well as on other quantifications (e.g., the prevalence of malaria preventives or the number of deaths related to a disease). For several years, this reporting has been successful even though facilities often deliver paper reports to the district level, ultimately entering it into DHIS2. Through the software features of DHIS2, useful outputs can be created for decision-making. Today, MoH experience improved reporting rates, and use the routine data from DHIS2 actively in decision-making. This has been possible because of data utilisation made possible with digital material combined with DHIS2 visualisation and reporting tools.

LMIS

In a country’s health system, a well-planned distribution and ordering system for commodities is also needed. Another part of a national HIS is therefore logistics information, thereunder also information from commodity orders (e.g., statistics). Similar to HMIS, LMIS aim at empowering decision-makers in the health system. LMIS is specialised on creating effective supply chain systems for commodity handling (World Health Organisation, n.d.-b). In more recent years, DHIS2 has also been used for commodity reporting in Uganda. Around two years ago, the commodity ordering in Uganda was done solely on paper-based forms.
After 2015, MoH started a digitalisation effort towards using DHIS2 as the platform for HIV/AIDS commodity ordering, through the ARV programme. This effort was labelled Web based ARV Ordering and Reporting System (WAOS), and has served as an important starting point for this thesis work.

2.4 Main takeaways

To summarise, the health status in Uganda is challenged by infectious diseases such as HIV/AIDS. To be able to further improve the public health, useful and reliable information systems are needed. As DHIS2 has been used as national HMIS for many years, and the WAOS-initiative is built on DHIS2, there is a potential in using DHIS2 for commodity ordering in general. The largest benefit is that stakeholders such as community health workers, MoH and warehouse managers, now has knowledge about the software.
Chapter 3

Research approach

In this chapter, a description of the conducted research is given. The purpose of this chapter is threefold, (1) to describe the philosophical assumptions guiding the research methodology and methods, account for the overarching methodology used, and give a description of how data collection has been carried out, (2) to describe how data have been structured and analysed, and lastly (3) to describe how practical system development has been carried out.

As health and logistics information systems are inherently socio-technical, merely looking at technical solutions would not be adequate for the purpose of the research, as they are a part of a larger picture. Through the socio-technical perspective, information systems are viewed as not only consisting of technical components, but also humans, their established routines and work practices, as well as the variety of social, cultural and environmental factors at play. This perspective is particularly useful when analysing the use of information systems in a developing country such as Uganda, as the perspective looks at the totality and context of the current situation rather than only considering how to solve issues using only technical solutions (Chilundo & Aanestad, 2005). The adoption of the socio-technical perspective acts as a guiding concept for data collection and analysis.
3.1 Philosophical foundation

Overall, ontological and epistemological assumptions have guided the research conducted in this thesis. The assumptions have guided the view of information systems, what type of data has been collected and the choosing of research methods, as well as how data from the research is pulled together and analysed.

The overall philosophical foundation in this thesis lies within the interpretive research paradigm, where researchers assume that access to reality is only given through social constructions (Myers, 1997). With this, access to both reality of and knowledge about information systems is gained through the thought and experiences of the people affiliated with the information systems. The interpretive paradigm focuses on understanding the process where the information system influences and is influenced by the context (Walsham, 1993, pp. 4-5). In understanding their organisations, work routines and thoughts on the work carried out, an understanding of the context of the information systems is sought after. Klein and Myers (1999, p. 67) emphasises that:

Interpretive research can help IS researchers to understand human thought and action in social and organizational contexts; it has the potential to produce deep insights into information systems phenomena including the management of information systems and information systems development.

These rich insights are important for understanding both the information systems and the information systems use, but will not provide formal proof as in the more positivist research traditions. Caused by this, the interpretive foundation can be considered as an opposition to generate truths or social laws, but rather offer a thick description in order to understand the complexities of information systems (Walsham, 1995).

3.2 Research methodology

In this thesis, two different methodologies have been used. An explorative case study has been conducted to understand more about the current
status of health commodity ordering and LMIS in Uganda. Throughout this process, needs in the current health system expressed by different actors were discovered and analysed. Further, these needs have been addressed by a technical system development process using the Tracker module of the DHIS2 software. Hence, this sub-chapter divides the methodologies into (1) the methodology used for empirical data collection, and (2) the methodology used for system development.

3.2.1 Case study

An explorative case study was chosen as the overarching research methodology in this thesis work, where the case can be considered as the Ugandan health commodity ordering systems in general, and for the ARV programme in particular.

To understand the process of commodity ordering in Uganda, an understanding of the current status of LMIS, the requirements, as well as the context of work, was needed. Hopefully, through understanding the case in Uganda, fruitful learning can be made also relevant for other developing countries in similar situations.

Case studies focus on activities, functioning’s and local meaning, aiming at understanding a complex phenomenon in their context (Stake, 2005; Baxter & Jack, 2008). In opposition to some positivist scholars, the aim of this case study is to pursue learning over proving, as emphasised by Flyvberg (2006). Generalisation from case studies is argued to function differently from positivistic studies, where case studies for example rather aim at contributing through rich insights or drawing on specific implications for further design and development (Walsham, 1995).

Insights from this thesis will hopefully lead to useful learnings for Ugandan stakeholders, as well as health and logistics system scholars, implementers and developers interested in the possibilities of improving LMIS in other developing countries. Moreover, the work may serve as useful input for actors interested in standardisation and integration processes in LMIS and HMIS.
3.3 Data collection

Qualitative data collection has been carried out in Norway and during two field trips to Uganda during the periods of January 2016 and mid-August through September 2016. Data collection has been carried out by me and a fellow master’s student during these trips. During the first field trip, data collection was done around the capital city Kampala, yet also in the more rural town Soroti, located in the more rural eastern part of the country. During the second field trip, data collection was performed in the greater Kampala area. The data collection was focused on understanding LMIS and health commodity ordering and distribution in the Ugandan health sector. Moreover, data collection was important to better understand the different needs and requirements from the different actors at the various health system levels in the Ugandan ARV health programme.

In this subchapter, the goals guiding the data collection are given. Moreover, a description of the data collection methods used is provided, alongside an overview of the participants involved in this process. Also, the typical facility field visits are described, alongside general elaborations on methodological concerns.

3.3.1 Goals

The goals for data collection in this thesis are threefold, seeking to (1) understand how the health sector in Uganda functions in general, and (2) understand the role of LMIS and health commodity ordering in the country, and finally (3) discover the needs and requirements for a commodity ordering information system in the ARV health programme specifically, in order to map out requirements, further informing technical design and development.

3.3.2 Data collection methods

Several complementary data collection methods have been used to enhance the total understanding. The different methods have often
been used together, combining observation of work routines at health facility workers with interviews, resembling the approach derived from ethnographical studies, labelled contextual inquiry (Rogers, Sharp, Preece & Tepper, 2011). This combination was found fruitful.

Throughout the data collection, participants have remained anonymous, as their identity was not deemed necessary in this thesis work. The result of NSD’s official notification test for research approvals is included in appendix A.

Overall, extensive notes were produced during and after field visits, meetings and discussions to structure the empirical data material gathered. The field note records were important not only to remember what has been discussed, but also to learn new insights after discussions.

The field notes produced also consisted of pictures taken at the site of the facilities. In these pictures, we tried to capture the environment around the facility, or the typical working situations of the logistics workers at the locations. The use of images in the field notes was particularly useful for remembering the situation and who we have talked to. An example is given in figure 3.1 on the following page. Oral consent was always given before pictures were taken, either of the work place, material or people.

**Interviews**

The most prominent method used for data collection in this thesis is interviews, performed both before, during, and after the field trips to Uganda. Walsham (1995, p. 78) argues that interviews are a primary data source in interpretive case studies, as the method gives good access to the interpretations of participants. Their interpretations are important to better understand the work routines and needs in the information systems used, through hearing their own reflections on the work.

Initially, two interviews were done with a professor of logistics at the BI Norwegian Business School and a professor of community health at University of Oslo. They provided useful information, and made us more prepared for carrying out field work in a developing country. Moreover,
we interviewed two logistics master’s students at Massachusetts Institute of Technology (MIT), to gain insight into the more practical concerns of conducting field studies. Before we left Oslo for our first field trip, we also interviewed a logistics officer at Akershus Universitetssykehus (AHUS) to understand more about health commodity ordering in Norway to get a wider perspective.

Further, during the field visits to Uganda, several formal and informal interviews were carried out. In the typical field visits, we interviewed around 1 or 2 people at a time (up to 6). Semi-structured interviews structured informally were favoured, as the interviewees often seemed somewhat reluctant to answer if the situation seemed formal. Therefore, we used time in the beginning of each interview to talk about ourselves and the research project, before embarking on the questions. The semi-structured interview structure, where the researcher has set some pre-defined topics to discuss (Crang & Cook, 2007c), was useful for us as we wanted the participants to feel more comfortable. An interview guide example is given in appendix B.
Observation

Another data collection used was observation, aiming at a more comprehensive understanding (Lazar, Feng & Hochheiser, 2010) of participants and work practices. Observation was important to not only listen to what participants say, but also to see the actual work being carried out. By asking them to elaborate on their work practices, we got the possibility to understand more about the practical implications of their work, as well as understanding more about the context of use for the commodity ordering process. The observations were especially important for us to understand the factual usage of the current logistics and commodity ordering systems, as stated use and actual use varied.

Through triangulating data collection methods, such as complementing interviews with observations, evidence was combined from multiple perspectives in order to increase validity and confidence in the collected empirical material (Lazar et al., 2010).

Meetings

Insightful input was also gathered through meetings with representatives from Ministry of Health (MoH) in Uganda, as well as meetings with non-governmental organisations and employees at other levels of Ugandan health sector. These meetings were particularly useful for understanding information requirements.

Literature review

Moreover, written material from the health and logistics sector in Uganda was studied. Through papers and presentations from Ugandan MoH, lessons have been made about the overall health status, prominent issues, health system characteristics, as well as the functioning and plans for LMIS in the country. Other sources from literature reviews are summarised in table 3.1 on the next page.
### Table 3.1: Overview of used material in the literature review process.

<table>
<thead>
<tr>
<th>Field</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMIS</td>
<td>Research, brochures and SOP’s</td>
</tr>
<tr>
<td>HMIS</td>
<td>Research and DHIS2 documentation</td>
</tr>
</tbody>
</table>

#### 3.3.3 Participants

As data collection has been carried out in both Norway and during two field trips to Uganda, this section structures all participants for empirical data collection in three different tables. In the tables, the number of participants for each data collection session is given. The word "level" is used to indicate the health system level in question.

During the first field trip in Uganda, the main focus was to understand more about the structure of the health system and to get an overview of how health commodity ordering functioned. Data collection sessions from the first trip is outlined in figure 3.2.

<table>
<thead>
<tr>
<th>Level</th>
<th>Method</th>
<th>Role</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>Interview + Observation</td>
<td>Pharmacy manager and clerk</td>
<td>2</td>
</tr>
<tr>
<td>National</td>
<td>Interview + Observation</td>
<td>Warehouse manager and officer</td>
<td>2</td>
</tr>
<tr>
<td>Regional</td>
<td>Interview + Observation</td>
<td>Logistics manager at large hospital</td>
<td>1</td>
</tr>
<tr>
<td>Regional</td>
<td>Interview + Observation</td>
<td>Logistics manager at large centre</td>
<td>1</td>
</tr>
<tr>
<td>Local</td>
<td>Interview + Observation</td>
<td>Doctor at private clinic</td>
<td>1</td>
</tr>
<tr>
<td>Local</td>
<td>Interview + Observation</td>
<td>Manager at private clinic</td>
<td>1</td>
</tr>
<tr>
<td>Local</td>
<td>Interview + Observation</td>
<td>Logistics manager</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3.2: Data collection sessions first trip to Uganda.

During the second field trip to Uganda, data collection was focused on the actual ordering procedures for commodities. By gaining an understanding of the ordering in general through interviews and discussions, the process of mapping out general needs and requirements for the ARV programme was better informed. The overall role of DHIS2 as commodity ordering and information system was also investigated in these data collection sessions.

Other data collection sources have been Skype calls, as well as interviews and discussions while in Norway. Some of these sources served the purpose of understanding more about the field of logistics and logistics.
<table>
<thead>
<tr>
<th>Level</th>
<th>Method</th>
<th>Role</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>Interview</td>
<td>Senior technical officer</td>
<td>1</td>
</tr>
<tr>
<td>National</td>
<td>Discussion</td>
<td>Monitoring &amp; evaluation associate</td>
<td>1</td>
</tr>
<tr>
<td>National</td>
<td>Presentation + discussion</td>
<td>MoH and CHAI</td>
<td>10</td>
</tr>
<tr>
<td>National</td>
<td>Presentation + discussion</td>
<td>CPHL and MoH Pharmacy division</td>
<td>13</td>
</tr>
<tr>
<td>National</td>
<td>Discussion</td>
<td>Program Director at NGO</td>
<td>2</td>
</tr>
<tr>
<td>National</td>
<td>Interview</td>
<td>Warehouse logistics officers</td>
<td>5</td>
</tr>
<tr>
<td>National</td>
<td>Interview + Observation</td>
<td>Logistics officers and MoH</td>
<td>6</td>
</tr>
<tr>
<td>Local</td>
<td>Interview</td>
<td>District manager</td>
<td>1</td>
</tr>
<tr>
<td>Local</td>
<td>Interview + Observation</td>
<td>Logistics officer and MoH</td>
<td>3</td>
</tr>
<tr>
<td>Local</td>
<td>Interview + Observation</td>
<td>Logistics officer medium centre</td>
<td>1</td>
</tr>
<tr>
<td>Local</td>
<td>Interview</td>
<td>Logistics officers and MoH</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3.3: Data collection sessions second trip to Uganda.

processes. As a part of this, dialogues has been carried out with other master’s students, logistics and public health professors, and others working on logistics initiatives. Examples of this are the stakeholders having connections to the open source project openLMIS.

Other data collection sessions are outlined in table 3.4. In addition to the sessions mentioned in table 3.4, data was also collected through informal discussions. Examples of this are various Skype meetings, Google Hangout and WhatsApp sessions, text messaging and emails. These tools were often used to clear up common misunderstandings from the other data collection sessions.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Role</th>
<th>Method</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistics</td>
<td>Professor BI</td>
<td>Interview</td>
<td>1</td>
</tr>
<tr>
<td>Public health</td>
<td>Professor UiO</td>
<td>Interview</td>
<td>1</td>
</tr>
<tr>
<td>Hospital logistics</td>
<td>Department manager AHUS</td>
<td>Interview</td>
<td>1</td>
</tr>
<tr>
<td>Logistics</td>
<td>MSc students at MIT</td>
<td>Interview</td>
<td>2</td>
</tr>
<tr>
<td>openLMIS</td>
<td>Manager</td>
<td>Discussion</td>
<td>1</td>
</tr>
<tr>
<td>HISP Bangladesh</td>
<td>DHIS2 country coordinator</td>
<td>Discussion</td>
<td>1</td>
</tr>
<tr>
<td>openLMIS</td>
<td>Managers</td>
<td>Discussion</td>
<td>2</td>
</tr>
<tr>
<td>DHIS2</td>
<td>Developer team</td>
<td>Discussion</td>
<td>5</td>
</tr>
<tr>
<td>MoH</td>
<td>M &amp; E associate</td>
<td>Demo+discussion</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3.4: Other data collection sessions.
3.3.4 Typical field visits in Uganda

Our visits to health facilities in Uganda followed a process of data collection and handling. This typical process is illustrated in figure 3.2.

![Figure 3.2: The iterative process of data collection from facility visits.](image)

The first part consisted of understanding more about the facility or organisation for the visits. This was done by talking to HISP Uganda consultants for information, reading relevant documents and searching for geographical information, and information on the organisation on the Internet. The typical aims of these searches were to find out more about what health facility level it was, what the ownership was (i.e., public or private) and other useful background information (e.g., the number of patients and the typical health services offered at the facility).

Moreover, the work consisted of writing down the main questions during the visit, as well as discussing with each other about what have been seen in previous field visits/meetings, and what we have read about in relevant material. Through this, we aimed at a more thorough understanding of the facility, to indicate to the interview participants that we had an interest in their work and workplace. Hopefully, this lead them to be more open and willing to share their views.

The fourth stage was performing the field visit itself. Here, time was often spent in the hectic Ugandan traffic to ponder about other questions to ask,
and how to focus the interviews for more useful data collection.

Discussions between me and the fellow master’s student were carried out after the visits. The discussions included pointing out what had been the most important findings, what implications the information gathered had for overall system requirements. In general, the discussions aimed to better understand the ordering process and requirements by organising and structuring the data collected.

After visits, the work consisted of writing up summary documents on each facility/organisation, creating simple flow charts. This analysis work is described in section 3.4 on page 29.

### 3.3.5 Methodological implications

As the practical part of the research is mainly based on doing interviews and observing information technology use, it is important to note that this has implications for the material generated. First of all, since the data gathered is based on humans communicating, it is important to note that the results are based on a common inter-subjective understanding. Accordingly, it were important for us to make sure that both us as researchers and the researched gained a common understanding (Crang & Cook, 2007b). It is important to note that interviews are not naturally occurring as a part of the informant’s workflow, and therefore cannot be seen to provide direct access to the experiences of the ones being studies (Silverman, 1998). In other words, complementing interviews with observation becomes more important to better understand the work practices. Regardless, a gap will be present between actual work practice and work practice under the presence of researchers.

Epistemologically, knowledge about how people make sense of and experience the world is accessed through their representations (Verne, 2016). In our sense, the understanding of work was gained through trying to make sense of spoken and written language of the participants. This was sometimes far from trivial, as some of our informants spoke at a low volume and generally wanted to show that they understood even if they did not.
Another important methodological aspect is regarding our own role as researchers. As we in this context were considered as researchers, hence also functioning as representatives of the industrialised country of Norway, it affects the informants in data collection. How researchers appear to the informants will influence how they relate to us as researchers (Verne, 2016a). The informants will behave differently than normal, even though this is not intended. Moreover, as being Norwegians in Uganda we also have interpreted things differently in contrast to native Ugandans. As both Walsham (2006) and Verne (2016) emphasises, our previous background, knowledge, experiences and prejudices will influence how we interpret what we encounter during research. It is important to acknowledge this reflexivity in the relationship between us as researchers, and the ones being researched as this has implications for the data collected.

In essence, the potential implication of using qualitative research methods including humans and human actions, is the reactivity and reflexivity present, as the information gathered is a result of us making ourselves understood, and at the same time understanding the participants. Our presence as researchers has undoubtedly affected the situation, as well as the answers given by the participants. For example, the interviewees may answer and behave differently because they are participating in the research project, so-called demand characteristics (Bordens & Abbott, 2002).

By not viewing ourselves as detached researchers or neutral observers, and not viewing the subjects as pure subjects (Crang & Cook, 2007a), it is important to note that we are, together with our informants, mutually constructing the data gathered. As such, the qualitative research methods used in this thesis cannot solely be viewed as data gathering, but rather as the collaborative co-construction of data as a result of establishing an inter-subjective understanding between researcher and the researched (Crang & Cook, 2007b).

Moreover, as data collection mostly has been carried out by two persons, this has had other methodological implications. First, this has some positive consequences, such as person 1 is able to give full focus towards the interviewee, and that person 2 is able to write notes, detect more from
the surrounding environment and ponder about follow-up questions. Still, this also offered a challenge, as it became more difficult for the interviewee to know which person to focus on when speaking. Therefore, we later on chose to divide the interviews into two sub-interviews, describing to interviewees when we were changing who will do the talking.

Lastly, the focus has been directed to not only collecting data, but also giving constructive feedback to participants in the research. For example, as a token of appreciation to HISP Uganda, consultants were offered training in practical web development. Walsham (2006) underlines the importance of giving feedback to research participants, both to give them something valuable in return, but also to maintain access, as access remains a key challenge in research projects (Crang & Cook, 2007b).

Also, discussions with technical developers from the DHIS2 team have given them useful feedback on the current status of the software. For example, technical issues faced during software development in this thesis work has been presented and discussed at a meeting for DHIS2 developers and stakeholders (see Appendix E), as well as in ongoing dialogues.

### 3.4 Data analysis

Walsham (2006, p. 325) emphasises that data analysis in interpretive case studies can be constructed out of the reflections of the researcher, supplemented by the minds and reflections of others. For each of the data collection methods mentioned above, discussing and analysing the collected material was important for gaining an understanding of the situation. This overall process can be summarised in figure 3.3.

The iterative cycle of enhancing understanding by continuous analysis describes how the knowledge has been gained using the collected material actively. In this thesis, different work processes have been followed, in order to structure the collected empirical material in various ways to better be able to interpret it. This structuring work is described in the below sections.
3.4.1 Summary documents

As mentioned briefly, summing up the notes, create drawings and specify thoughts on each facility visit or meeting in digital documents were important to analyze the data gathered. In the summary documents, main lessons learned from the visits were specified. Moreover, an overview of main challenges, and what to ask next was also described. An excerpt from a summary document is given in figure 3.4.

These documents often contained different types of information. First, general information such as facility type, size, a picture, and health system level was given in the top of the document. Second, keywords from the specific visit were provided, along with information on what other documents should also be visited to inform about this visit. Moreover, an overview was given over the most important aspects of the visit. This functioned as an abstract of the main findings, summing up only the
most relevant information from the visit. Further, a background section was given. Here, the facility-specific features were presented: Where is it located? How was the facility organised? Was it private or public? How was the overall infrastructure? What about human resources?

Consequently, the typical information systems were described. Central questions to be answered here were: How is health commodity procurement done? What systems do they use in their daily work, and how? After this followed a section for prominent challenges found during the visit: What do the informants express as their main concerns? Also, what are the main concerns in regards to current and future commodity procurement?

Lastly, two lists were provided. The first specified what need to be investigated in future data collection. The second was to summarise the main findings and learnings of greatest relevance to the research questions.

In the process of writing the summary documents, new questions often emerged from the analysis work. Writing these questions down after visits were found useful, as we then had the possibility of getting them answered at potentially new visits, or at the time of contact with representatives from MoH or HISP Uganda consultants.

### 3.4.2 Use of flow charts

The further structuring work consisted of creating two different types of flow charts, namely charts describing the information flow, and charts describing the commodity flow.

The flow charts were found highly useful to describe and better understand the situation and to convey findings to informants and other stakeholders. The flow charts were also useful in confirming the findings we had done together with the stakeholders, often resulting in additional findings. An example of a flow chart is given in figure 3.5.
3.4.3 Finding common denominators

Moreover, analysis work consisted of trying to map out what were the common denominators between the visits - working on establishing a common ground. As an example, consider figure 3.6 illustrating what was found to be the typical information needs after facility visits, discussions and meetings.

The further structuring work of finding common denominators after data collection consisted of formalising the findings into a tentative requirement specification. By doing this, it became easier to communicate the needs of a new commodity ordering system with other stakeholders, aiming to understand how DHIS2 can best be utilised as a commodity order and order data statistics tool.

Figure 3.5: Example flow chart of a facility commodity ordering process.

Figure 3.6: An example of finding common denominators.
3.4.4 Understanding requirements

Stemming from the work described in the preceding section, formalisations of requirements for a commodity ordering system in the ARV program has also been a part of analysis work. For this purpose, data collection has consisted of interviews and observation of actors at various levels in the health system.

The observations have also been important for the requirements understanding and eliciting differences between the answer given during interview, and actual work practice. For example, a logistics manager at a health facility showed a different use of output from the system than he answered in the interview. In the work of gathering requirements, efforts were put into structuring them into overarching requirements of data outputs. The result was a table of ten executive requirements needed for information outputs in the current solution, described in chapter five.

3.5 System development

The practical development of this thesis has been focused on DHIS2 as the platform for implementation. To learn about the software itself, experience has been gained from several types of work: Through two university courses, two DHIS2 academies, as well as individual learning. Through this work, learnings have been made on the software, usage and possibilities in order to technical develop on top of the DHIS2 platform. Also, as the general development of this software is done at the University of Oslo, I have had the privilege to collaborate closely with key DHIS2 developers and implementers. This was found to be useful as help through technical difficult issues and design decisions, aiming at solving concrete issues throughout the practical development. Fruitful discussions took place with several different developers, all having expertise on the different software components in DHIS2. Further, outputs created from the commodity ordering setup has been evaluated with a representative from Uganda MoH. A guide for this evaluation session is given in Appendix C.
Moreover, the technical development process has given insightful learnings. First, it has been useful to understand LMIS as the topic. As programming is itself a rigid undertaking, detailed descriptions of data models and attributes of objects in the real world (as commodity orders) needs to be strictly formalised. By doing this, the practical programming process clarified the structural attributes of logistics commodity orders. Through the practical work, an understanding of important characteristics of logistics as field and commodity orders in particular, has been gained. Second, showing results from practical development (e.g., web applications, screenshots and reports) were found to serve as a good basis and useful common ground for discussions. Through illustrating outputs of practical work, the path to a common understanding of requirements has been shorter.

### 3.6 A reflection on methodology

A case study is used as the overarching research methodology for data collection in this thesis. In the case study, a problem has been identified, and data has been collected through field trips to understand the problem. Moreover, the issues have been addressed practically in collaboration with stakeholders through evaluation sessions. Lastly, learnings have been specified from the practical work. This process resembles that of Action Research (AR), illustrated in figure 3.7.

![Figure 3.7: The action research cycle (Susman, 1983, as used by Baskerville & Wood-Haper, 2016).](image)
Over time, the thesis project has moved towards AR. However, the AR process consists of iterating over the different phases of the research. In my case, only one iteration was performed. Moreover, the processes inherent in AR has not been strictly followed. Rather, my work has consisted of studying the case of commodity ordering, followed by practical development and learnings. However, if this project would be continued, AR would be considered for further research.
Chapter 4

Theoretical background

This chapter introduces relevant theoretical background literature, and is divided into three main parts: (1) background on information systems as socio-technical systems, (2) literature on typical challenges and strengthening processes in health information systems, as well as (3) relevant literature on logistics management information systems (LMIS) as part of supply chain management.

4.1 Information Systems

In many developing countries, the information systems are predominantly analogous. Nonetheless, new technology drive digitalisation processes forward, enabling the proliferation of digital information systems for managing the large arrays of data collected.

Numerous scholars within information systems research have emphasised the need to view information systems not only as technical solutions, but also as tools to support social and organisational structures - in businesses as well as within health systems (Hanseth & Monteiro, 1997; Walsham & Sahay, 1999; Aanestad, Jolliffe, Mukherjee & Sahay, 2014; AbouZahr & Boerma, 2005; Ciborra, 2000). I support this view and believe it is important to acknowledge that information systems are built upon these non-technical structures. Development processes need to dynamically fit with these structures in order to become and remain
As “information technology has both restricting and enabling implications” (Orlikowski & Robey, 1991, p. 154), the current digitalisation efforts in developing countries generates both new possibilities, as well as new challenges. For example, digital information systems may enable better and more relevant information, but also require sufficient and correct training of personnel. In other words, both technical and social processes need to be addressed and catered.

### 4.1.1 Information Infrastructures (IIs)

Information Systems can be considered as complex socio-technical systems. A theoretical guiding concept for understanding complex socio-technical information systems is viewing them as heterogeneous Information Infrastructures (IIs). IIs are defined by Hanseth and Lyytinen 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 users, operations, and design communities.” (2010, p. 4).

The definition implies that IT-systems not only consists of technical artefacts, but also need to be seen as a part of a larger socio-technical ecosystem. Therefore, building IIs can never be seen as developing from scratch (Hanseth, 2000), but rather as an infinite evolution process (Hanseth & Lyytinen, 2010). Dependencies between system components are therefore being continued onto new development-projects. This indicates that IIs often are highly complex in nature, because they consist of multiple interacting heterogeneous elements. A key characteristic of IIs is that such infrastructures are shared by large audiences, user communities and developers. The use of such systems is diverse and heterogeneous, adding to its overall complexity. As IIs are shared and open, they are implicitly also vulnerable to changes.

A concept related to socio-technical systems is the installed base, a concept referring to the already existing configurations of heterogeneous II components (Hanseth & Lyytinen, 2010, p. 4), such as relevant technology, user communities, needs in the system, as well the associated work
practices. The installed base can itself be considered as an actor in the evolution of IIs, caused by their inherent inscriptions in information systems and on information systems use.

New additions to an II need to be integrated and be made compatible with this ever growing intricate system of the installed base (Hanseth & Lyytinen, 2010, p. 4). In other words, the installed base shape the overall development of the socio-technical infrastructure. This concept of path-dependant processes leads to strategies for the successful evolution of IIs, such as bootstrapping described later on.

Star and Ruhleder (1996) emphasises that the evolution of IIs is fixed in modular increments, and not all at once. One often seek to cultivate the installed base, instead of for example rip-and-replace strategies. Such installed base cultivation is seen as a strategy for managing ever-evolving IIs (Ciborra, 2000), and aims at adding new increments to information systems on the premise of cultivating the already-existing components of such systems (i.e., building on what is present).

To successfully grow information infrastructures, a development plan should seek support the current installed base. Scholars has found that technical solutions or standards can function as an attractor, a solution achieving a certain level of success and enabling the building of momentum (Sæbø, Kossi, Titlestad, Tohouri & Braa, 2011, p. 1). In essence, software additions needs to be successful and useful to current user communities. Such an attractor should emerge from a bottom-up development process, by identifying what characterises the current installed base of the II and seek to fit with these characteristics.

### 4.2 Health Information Systems (HIS)

Health Information Systems (HIS) are systems for information creation, exchange and utilisation of data related to the planning and provision of health services. Substantial efforts have been put into researching on HIS, and on how they can be utilised to improve public health in developing countries. If such a system contain helpful and relevant information of
high quality, one can be able to better detect where to allocate scarce health system resources, such as human resources (e.g., community health workers), as well as physical resources (e.g., health commodities).

4.2.1 Typical challenges in HIS

Some challenges has been found to be typical in HIS evolution and development in developing countries. Firstly, disease specific health initiatives maintain their own systems, leading to health information in developing countries’ HIS being fragmented into vertical information silos. This may result in erroneous and duplicate reporting. Such fragmentation, where health initiatives maintain their own system has been identified by a multitude of scholars as a major contributing factor to poor health information systems (Lippeveld, 2001; Braa & Sahay, 2012; Stansfield, Orobton, Lubinski, Uggowitzer & Mwanyika, 2008; Health Metrics Network, 2008; Sæbø et al., 2011).

The fragmentation of health information is often a result of multiple influencing factors, the most important ones being lack of information use, poor data quality, lack of training and feedback, as well as issues with reporting rates and timeliness. These highly interrelated factors have been identified as key factors contributing to fragmentation, and need to be addressed in a strengthening effort of the health information system. The reason for this is that the factors mentioned above leads to decreased trust in the HMIS, forcing programmes and donors to create their own systems (Sæbø, 2016). This interplay is illustrated in figure 4.1 on the facing page.

4.2.2 Strengthening HIS

To address the challenges faced by health information systems, an array of strategies and tools have been proposed by scholars in the field. Such strengthening efforts aim at solving common challenges faced in HIS, such as moving towards higher quality data, better reporting rates, and higher information usage. The overall vision for HIS strengthening is therefore to
address such issues, in order to improve the situation.

The tools and strategies believed to be most relevant for this thesis work is now presented, namely (1) increasing information usage, and (2) introducing the concept of the Integrated Health Information Architecture (IHIA), together with the operationalisation of this architecture, labelled the data warehouse approach to HIS development.

**Information use**

Theo Lippeveld (2001) points at lack of information use as a contributing factor to poor data quality in health information systems. Data collected through routine health information systems need to be utilised in order to remain relevant and useful. Data collected need to be useful for both community health workers, as well as managers and top-level decision-makers.

In moving from data-led data collection towards action-led data collection, one ensures that both community health workers and managers have an interest in the data. This will, in turn, lead to towards a better culture for information usage.

The move towards action-led data collection also aims at increasing the relevance of the information gathered, in order to better inform health system managers at various levels of the health system, such that
strategic managerial decisions can be made to save lives (Stansfield et al., 2008).

To improve the basis for rational and information-based decision-making, one will also need to identify the often different information needs at the various levels of the health system. For example, a manager in a primary health care clinic has different information needs than implementing partners or the programme director at MoH. The differing management functions (as well as concentration) levels in a health system are illustrated by Lippeveld and Sauerborn (2000), having three main management levels, namely the health system, the health unit, as well as the patient/client management. Such distinctions are applicable to logistics information systems discussed in this thesis.

![Figure 4.2: Different management functions and health information systems concentration levels (Lippeveld, Sauerborn, Bodart et al., 2000, p. 18).](image)

**Data warehouse strategy**

A key strategic element for increasing the utilisation of information in health information systems is the notion of the IHIA, as conceptualised by Braa and Sahay (2012). This architecture is based on the premise that information systems are socio-technical in nature.

The IHIA is an architecture trying to conceptualise the horizontal integration of vertical information flows in order to manage increasing com-
plexity in fragmented health information systems (Braa & Sahay, 2012), derived from 15 years of experience of strengthening HIS in developing countries. Moreover, the architecture is based on the concept of maintaining a central data repository for creating and using information for a multitude of user communities. An operationalisation of this architecture is the data warehouse approach as proposed by WHO through the Health Metrics Network initiative (2008).

The power of the central data repository lies in the endless possibilities for creating useful information for decision-makers. Information may come in the form of reports, visualisations or tables. In other words, the central data repository serves the purpose of creating a better foundation for more solid evidence-based decisions.

Another key aspect of the data warehouse approach lies in the fact that it is flexible in terms of supporting the various needs in the different management and health information system concentration levels (see figure 4.2 on the preceding page). For example, specific reports on data in the repository may be created for health facility managers (often more granular data) than for district managers (often more aggregate data).

The motivation for the data warehouse approach is that in order to improve the health outcomes of people in countries, an effective and well-functioning health information system is crucial (Stansfield et al., 2008). This is illustrated clearly in figure 4.3 on the following page showing that in order to improve health we need to know where people are experiencing problems and where the resources are low, in order to address them. In other words, the data warehouse approach focus on better utilisation of high-quality data in order to better support both local, regional and national managerial decisions.

These aspects are considered as transmissible also to logistics supply chains and the distribution of commodities within a country. In combining information from routine health data and commodity ordering data in a central data repository, possibilities arises for new information to be created (SIAPS, 2014a). This is further described in section 4.3.5 on page 51.
The DHIS2 software is an example of such a central data repository and is targeted in this thesis.

For the data warehouse to be successful, efforts need to be put into standardisation. This is not a straightforward task, requiring stakeholder coordination at different levels. Braa and Sahay (2012) argue that a standardisation process needs to be addressed at three different levels, namely the pragmatic, semantic and syntactical level.

The most complex task is often to coordinate the different actors at the organisational level, making sure the different organisations can find an agreement. At the syntactical level, the different actors need to agree on what kind of technological standard they will use, answering the question

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of how the data should be transferred and where to (Braa & Sahay, 2012). DHIS2 as an HMIS is an example of one such technical platform, at the syntactical level of standardisation. Such a platform can be used as a data warehouse, as it has been developed mainly for the purpose of efficient health information management, making it possible for different users to utilise the information it contains in meaningful ways (Health Metrics Network, 2008).

4.3 Logistics Information Systems

Logistics can be defined as the planning, development, organisation, coordination, governing and controlling the material flow from commodity suppliers to end-users (Persson & Virum, 2006, p. 16). Logistics information is a cornerstone in the overall HIS in developing countries. As most of the literature now reviewed has focused on health information systems in general, this section presents relevant research on LMIS and health commodity supply chains after giving definitions of them.

Supply chain management is an important part of health logistics. Supply chain research is an extensive field, enclosing the whole supply-line of commodities, from production to shipping, packing, distribution, dispensation to waste handling. To narrow the scope of this thesis, the focus will be directed towards issues related to collection and reporting on logistics data in the context of developing countries.

Supply chain is a broad term encompassing most aspects of the logistics field. Lalvani et al. (2010, p. 9) defines the supply chain as "a network for delivering drugs from manufacturers to patients – including such processes as product development, manufacturing, procurement, registration, and quality verification, with the associated information and finance flows”. In other words, logistics supply chains deals with the creation, control, and information related to goods in the chain: "supply chains/logistics is an essential function in getting the products to the end user” (Raja & Mohammad, 2005, p. 1). An example of a supply chain is shown in figure 4.5 on the following page (there labelled logistics chains).
Managing supply chains is far from trivial, caused by all its inherent complexities. As a result, multiple sub-systems are often developed to cover the diversity of needs, thereby managing the various parts of the supply chain. Using figure 4.5 as the example, different information systems are needed at the various levels and the different organisations have different needs in the system. For example, at the warehouse level, own systems are needed. Here, a Warehouse Management Systems (WMS) typically include commodity handling internally at the warehouses, administering the receiving, storage, picking, and other common warehousing operations (Tukai et al., 2016; Helo & Szekely, 2005).

4.3.1 Understanding LMIS

A different sub-system in supply chains is LMIS. The term LMIS has often been used by international agencies and other stakeholders to describe information systems used for supporting logistics decision making in developing countries. As USAID (2006, p. 1) emphasises, a LMIS collects, processes, and reports logistics data. Moreover, LMIS should facilitate informed decisions in the supply chain, striving for accurate, timely, and appropriate data (USAID, 2006, p. 1). Importantly, such a system is used
for gaining useful information for decisions made on all the different levels of the health system.

A well-functioning LMIS for health systems aims at answering some of the questions outlined in figure 4.3 on page 44. To improve health in developing countries, one needs good and reliable information on where to prioritise resources. This implies that a well-functioning LMIS should ensure that medical commodities are accessible for patients needing help, delivered at the right time and place (Raja & Mohammad, 2005).

A clarification of LMIS can, therefore, be made to include the fact that they handle the ordering process between health system levels, as well as information on stock levels at these levels. Forecasting is also needed in order to understand needs of commodity levels (Lalvani, Yadav, Curtis, Bernstein & Oomman, 2010). Overall, LMIS can be understood as a management information system used to support the flow of information and commodities between warehouses and patients. In the context of Uganda, this includes information handling at the facility, district and national level. Through such a system, collection, processing and reporting on commodity data are used to get an informative overview of where logistics resources are needed in the supply chain. The goal of a successful LMIS is to better facilitate well-informed decision making.

### 4.3.2 LMIS: Typical challenges in developing countries

In developing countries, several challenges are identified in the development of, and caused by, LMIS’. Some examples will be presented here: fragmentation resulting in vertical LMIS’, inefficiencies caused by this, paper-based systems and lack of standardisation.

As mentioned in above sections, health systems and HIS in developing countries often have a fragmented structure. This fragmentation is mirrored in the health commodity supply chains, as these are also a part of the health information system. For example, in supply chains, different LMIS’ are used for the various health programmes. Moreover, fragmentation is also present in commodity providers. Thus, a sometimes unmanageable complexity is present in developing countries supply
chains (Jahre et al., 2012; Lalvani et al., 2010). For example, figure 4.6 illustrates the multitude of stakeholders in procurement and distribution, leading to fragmentation into vertical LMIS’ and commodity providers, ultimately leading to supply chain complexity in Kenya.

Figure 4.6: Medicines supply chain for Kenya (Aronobich and Kinzett, 2001, as used by Lalvani et al., 2010).

The fragmentation causes major inefficiencies in health supply chains and LMIS’ (Kraiselburd & Yadav, 2013). This is caused by the fact that large international agencies are behind the various health programmes, and have widely divergent objectives.

Scholars researching on LMIS in developing countries has found that sometimes the vertical LMIS collects similar information in similar formats between programmes, present in several countries (Chindove & Mdege, 2012). This has implications for standardisation efforts, as this would make it less complicated to align stakeholders. This relates to another challenge in LMIS’ in developing countries, namely lack of standardisation in reporting formats (Chindove & Mdege, 2012). Overall, the lack of standardisation is influenced by different health initiatives maintaining their own ordering tools and methods, thereby resulting in differences in methods.

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Another issue prominent in LMIS in developing countries is that they are predominantly paper-based (Chindove & Mdege, 2012). This leads to a more demanding information handling process than in digitalised management systems and may cause delays in the overall information creation process (SIAPS, 2014b). Related to the HIV/AIDS health programme in particular, scholars has found that a lack of an effective and efficient antiretroviral supply chain is often present in low and middle-income countries (Lalvani et al., 2010).

4.3.3 Challenges derived from poor LMIS’

There are several challenges that are caused by poor LMIS’ in developing countries. The common denominator with the challenges mentioned above is that they all ultimately may lead to lowered access of commodities, such as life-saving drugs. Such challenges are caused by the prevalence of stock shortages and stock-outs, as well as over-stocking resulting in medicine and vaccine wastage (Kaufmann, Miller & Cheyne, 2011; Jahre et al., 2012; Zaffran et al., 2013; Chandani, Felling, Allers, Alt & Noguera, 2006).

These issues causes the more perilous risk of decreased availability of health commodities to the people. In turn, the lowered availability and access to life-saving medicines, vaccines and equipment pose a serious threat to the public health of developing countries (Kraiselburd & Yadav, 2013; Jahre et al., 2012; Zaffran et al., 2013).

In order to improve the access of important commodities, reliable information on where, when and what products are needed in order to help health program managers making decisions (Chandani et al., 2006). By utilising such information, wastage can be decreased and accountability enhanced (Chandani et al., 2006).

4.3.4 Standardising commodity ordering in LMIS

As a possible solution to typical challenges, Chindove and Mdege (2012) has found that standardising the collection and reporting on logistics
data seem to improve the availability of health commodities and essential medicines in developing countries through a document analysis study. Standardisation of commodity ordering systems will help make the comparison of data from vertical health programmes easier, and create a common ground for stakeholder alignment at the organisational level of standardisation (see figure 4.4 on page 44).

Further, Raja and Mohammad (2005, p. 6) emphasises that in order to move towards a full supply of drugs and supplies, one need to implement an automated LMIS for making supply chain data (i.e., stock levels and consumption patterns) more transparent. Chindove and Mdege (2012) further supports this view in their findings, indicating that an automated and standardised LMIS help decision-making processes, which ultimately may lead to enhanced availability and access to commodities.

Many countries are currently moving from paper-based LMIS to digital and more automated systems, Uganda being one of them. This is a positive shift, as paper-based systems often imply longer delays for information to arrive to decision makers (SIAPS, 2014b, p. 7). Uganda is currently undergoing digitalisation efforts on the field of commodity reporting, which enables enhanced information for decision making.

In Uganda, vertical LMIS’ collects similar information, and often in comparable formats (Chindove & Mdege, 2012, p. 402). This was also found as a part of data collection in this thesis project and will be further discussed in the next chapter. In short, similarities in commodity data collection between different health programmes serves as a motivation for moving towards a standardisation of commodity ordering in Uganda.

It is important to understand that standardisation processes, as well as digitalising and automating information systems are all highly demanding tasks. Heeks (2002) has discussed the failure to sustain information systems in developing countries over time. Heeks (2002) argue that this is partially caused by information systems often tending to be transferred from stakeholders coming from industrialised countries, ultimately enforcing a western design to developing country contexts and their organisations. The same concepts of technology transfer even apply in smaller-
scale contexts, such as between local developers implementing the systems and the actual uses of the software.

As a result, several scholars have focused on how such design actuality gaps can be minimised. Sahay, Sæbø and Braa (2013) argue that the processes of scaling a HIS are best done by making smaller increments fit an ongoing redefinition of a socio-technical configuration. Moreover, Braa, Monteiro and Reinert (1995) argue that technology has to be learnt and mastered, rather than solely being transferred.

### 4.3.5 The relationship between HMIS and LMIS

Commodity ordering systems often tend to live alongside HMIS’. However, they are inherently linked to each other. A central idea behind the IHIA presented in section 4.2.2 on page 42 is that it enables the combination of multiple data sources into a central data warehouse (Braa & Sahay, 2012). By moving towards an integrated data repository consisting of combined data from both the community health and logistics sector, new possibilities emerges, such as enabling the creation of compound indicators. For example, one can consider checking whether low vaccination numbers in the HMIS data may be caused by low stocks reported from the LMIS (SIAPS, 2014a). In turn, such indicators can give a more fine-grained image of the health system, indicating where resources are needed the most.

The combination and integration of HMIS and LMIS data have been discussed recently in several international initiatives. One of these initiatives is an effort led by the UN Commission on Life-Saving Commodities (SIAPS, 2014a). Here, positive effects of such integrations include identifying mismatches between availability and distribution of commodities, as in the indicator example given above.
4.4 Summarising remarks

Challenges seem similar in both HMIS and LMIS, and there are coinciding possible solutions to the issues present. A central data warehouse approach seems to better support information used for decision-making, as a strategy for HIS strengthening. Moreover, the digitalisation shift in developing countries towards digital management information systems enables possibilities for better overviews on where to put resources. A certain degree of standardisation is needed in order to make the comparison of data between health programmes, as well as between health and logistics sectors, possible. This process is complex, and need good strategies for coping with both organisational and technical challenges.

With this in mind, there can be many new possibilities of combining commodity ordering data with the routine data already gathered in HMIS’, ultimately aiming at the more long-term vision of integrating LMIS and HMIS. As more data is gathered into DHIS2 as a central data repository, access and availability of health commodities may potentially be enhanced if information can be made more meaningful.

The empirical data collection and system development in this thesis are both based upon viewing IT systems as socio-technical IIIs. This view has guided the overall work, acknowledging that the evolution of information systems is a complex and intricate process, building upon the already existing social and technical components of the installed base.
Chapter 5

Empirical findings

In this chapter, a description of the empirical findings is given. The initial section describes the empirical findings from the first field trip to Uganda, aimed at understanding the structure of the health system in general, and LMIS in Uganda specifically. The second section outlines empirical findings from the last field trip, focused on understanding the current information requirements for health commodity ordering in the Ugandan ARV health programme.

5.1 First trip: Understanding health logistics in Uganda

The overall goals of the first field visit to Uganda were to (1) understand more about the functioning of the Ugandan health system, and (2) understand more about the LMIS’ and health commodity ordering systems. Data collection was done over a one-month period, visiting several hospitals and clinics in Uganda, as well as attending meetings.

5.1.1 Health and logistics system structure

The Ugandan health system is divided into a private and public sector, both accounting for around half of the health care services in the country.
The divide is illustrated through the three health commodity distributors. As a result, facilities order from different warehouses, having their own ordering schemes.

More importantly, the overall structure of the health system was found to be organised around vertical health programmes and initiatives. The programmes have substantial international organisations and agencies backing them up with both human and monetary resources. Therefore, the Ugandan MoH is bound to cooperate on work and align their plans with these stakeholders. These collaborations are strictly needed for a good functioning of the Ugandan health care.

The fragmented structure of the health system is reflected in the information systems present in the country. Health and logistics information systems, as well as information systems for health commodity distribution, are all based on the different health initiatives. Because of this, the data collection and dissemination of information is also fragmented in the country, leading to a less comprehensive health system. Commodity ordering is done through one ordering form for each health programme. For example, the HIV/AIDS, TB and essential medicines health programmes all maintain their own order forms, and creates information from them in different ways, leading to several LMIS’ being present in Uganda.

### 5.1.2 LMIS-related challenges

In addition to the overall fragmentation presented, other challenges were also found related to the Ugandan LMIS’.

The visits to clinics and hospitals showed that almost every facility had experienced stock-outs recently. Only the private clinics did not experience significant issues with stock-outs. Further, the public facilities had different routines when stocked out. For example, one health centre stated that when stock-outs occurred, they borrow medicines from another facility or hospital. There, they maintained a list of what was borrowed, and from whom. Another place, patients were referred to local pharmacies with the medicine in-stock.

Moreover, representatives from MoH explained several other challenges,
as well as indicating areas of improvement for LMIS’. First, personnel are entering data for facilities into DHIS2, there is a significant risk of erroneous data entry. Therefore, MoH uttered a need to integrate DHIS2 with the WMS’. By doing this, the employees at the warehouses could spare time to focus on their primary work. Second, the representatives stated that information use in the current information systems needs to be improved. By focusing on this, decision-makers (e.g., district health officers) can make better decisions on for example where to best re-allocate medicines and equipment. Third, they uttered a need that when facilities report stock-out on commodities, stock-out alerts are needed for DHOs to respond.

Two issues were found to affect the use of logistics information systems, namely infrastructural shortcomings and the lack of human resources. For example, several of the health clinics and hospitals visited had experienced frequent power-outages. Outages, and facilities often not having a backup solution such as USPs to provide electricity when the main power grid was down for maintenance, was an issue. Moreover, several did not have access to the Internet and available computers for stock handling and ordering.

Yet another issue found was the lack of human resources. Every facility or hospital visited was understaffed, and the persons responsible for ordering equipment and medicines seemed to have too much on their agenda. One place, the logistics manager even supported health personnel in between his own primary work.

5.1.3 The commodity ordering processes

In general, the commodity ordering systems in the health programmes were all based on paper-based ordering methods, except ARVs. Moreover, three overall characteristics of the current commodity orders in Uganda were found: (1) the multiplicity of ordering forms present, (2) the multiplicity of ordering methods present, and (3) the fact that commodity orders were structured as reports rather than orders.

As a result of fragmentation caused by vertical health programmes, a
A multitude of ordering forms is present in Uganda. This structure is shown in figure 5.1. Nonetheless, health facilities often order from only one place. For example, one public facility visited ordered every item from the largest public distributor. Each time ordering routines began, there were up to a double-digit number of different forms. This is caused by the Ugandan health system structure being organised around the various health programmes and initiatives. Thus, ARV medicines are ordered through the ARV programme form, and TB medicines are ordered through the TB programme form.

![Figure 5.1: Multiplicity of ordering forms present at the facility level.](image)

A multiplicity of ordering methods was also found, shown in table 5.1. As many of the health facilities experienced a general lack of technical equipment, training and human resources, several sent scanned paper forms or reported in person to a District Health Officer (DHO). The lower level facilities (i.e., level 3 and 4 facilities) tended to seek recognition or approval at the district level. More interestingly, organisations at national and regional level did not, and tended to order directly to the warehouse, not going through formal approval processes.

The two private clinics visited had more pragmatically methods of retrieving commodities. For example, one private facility manager used phone calls to a large network of pharmacies to identify places having available stocks. A doctor at another smaller private clinic had even outsourced this part, only calling to let a helper know what medicines and medical equipment he needed.

Last, the commodity orders were found to have a somewhat different
<table>
<thead>
<tr>
<th>Ownership</th>
<th>Organisation</th>
<th>Ordering method used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>National referral hospital</td>
<td>Paper –&gt; scanning/email</td>
</tr>
<tr>
<td>Private</td>
<td>National warehouse</td>
<td>None (warehouse)</td>
</tr>
<tr>
<td>Public</td>
<td>Regional referral hospital</td>
<td>Paper –&gt; scanning/email</td>
</tr>
<tr>
<td>Public</td>
<td>Health centre</td>
<td>In person to DHO (paper)</td>
</tr>
<tr>
<td>Private</td>
<td>Small clinic</td>
<td>By phone</td>
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<tr>
<td>Private</td>
<td>Small clinic</td>
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<tr>
<td>Public</td>
<td>Health centre</td>
<td>Using DHIS2</td>
</tr>
</tbody>
</table>

Table 5.1: Multiplicity of ordering methods present in Uganda.

function than expected. Uganda has a commodity distribution model which can be categorised as a smart push system, where facilities typically report on consumption for the previous two months, rather than simply specify how many packs to be ordered. This information is further used by the DHO and warehouses to calculate how much can and will be distributed in the future, based on aspects such as commodity availability. An important aspect of the order forms was that they structurally resembled reports rather than simple orders. For example, health facilities reported on what quantity of commodities they had consumed, rather than simply requesting the number of packs needed. Most of the commodity order forms in the country seemed to be divided into two main parts: (1) consumption data on formulations, and (2) general patient statistics on the number of patients actually receiving treatment of groups of formulations (e.g., total numbers of each formulation group given to children).

An integral part of this method of commodity “ordering” is the patient reports. In the ARV programme, the patient reports contain fields for specifying how many patients have been treated with different formulations and formulation groups. An example is shown in figure 5.2 on the following page. According to a representative from the MoH pharmacy division, these reports can be separated out in a software solution for commodity ordering if needed.

The patient reports (i.e., patient statistics) is an especially important part of the approvals of the orders at the district level, where the numbers in the patient statistics are cross-referenced with the reported numbers for each commodity/medicine, to ensure that the number of packs actually are
needed based on the patient numbers. Several of the health programmes had patient statistics as a part of their order forms.

Moreover, almost all of the order forms found during facility visits were also found to collect almost the same data: (1) opening balance, (2) quantity received, (3) consumption during last two-month cycle, (4) losses/adjustments, (5) days out-of-stock, (6) adjusted AMC, (7) closing balance, (8) months of stock on-hand, and (9) quantity required. Some of the order forms used slightly different words (e.g., using "dispensed" instead of "consumption during last two-month cycle"). However, the semantic of the naming was identical.

Another important aspect was that some of the order forms contain large amounts of data. Several logistics-managers interviewed saw this as a major issue, as this made it easy to do mistakes on data entry. This was discussed with representatives from MoH, who confirmed data quality as an issue in the current order forms. Therefore, efforts are needed to improve the DHIS2 forms in order to increase overall data quality, thereby improving the information received from data collected from the forms.

Further, the commodity orders in a facility were all based upon ordering from one warehouse. Overall, all the warehouses had a similar reporting scheme, where facilities were divided into different order zones, having their own order deadlines. For example, the data collection period for a commodity order for cycle 2 for one warehouse ranges from June 18th -
July 29th. Another facility may order from a different warehouse, where cycle 2 is specified as the period between November 22th and December 28th.

All warehouses had bi-monthly reporting, where facilities order six times a year. Each warehouse had divided facilities into five ordering zones.

5.1.4 The role of DHIS2

For several years, the DHIS2 software has been used in various ways in Uganda. The use was found to be widespread by both MoH, public hospitals and facilities, some private clinics and hospitals, as well as international agencies such as Clinton Health Access Initiative and U.S. Agency for International Development.

As a national reporting and system for health statistics, DHIS2 has been used in the public sector for many years now. The sector has several HMIS reports created for the different health system levels, as well as for the various health system stakeholders. This reporting on routine data is often performed by facilities on a monthly basis, as an integral part of the country’s health information system.

Moreover, the public health sector in Uganda has a short time ago started using DHIS2 for registering visits of mothers for antenatal care \[1\]. The setup for registration of ANC-visits for mothers has utilised the DHIS2 Tracker module to register this event-based data, where HISP Uganda is currently facilitating this roll-out.

As routines are in place for routinely collecting HMIS data, and new efforts use DHIS2 for tracking mothers, health workers in the Ugandan public sector were found to have generally good knowledge about the system.

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1Health care received in relation to a pregnancy. In developing countries, this often includes HIV/AIDS transmission tests, medicine distribution to the mother, and body scans.
The ARV Programme and the WAOS initiative

More recently, DHIS2 have been utilised for commodity ordering in the ARV health programme. The commodity ordering is based on the part of the DHIS2 software for aggregate health statistics, not the Events/Tracker module. This means that ordering is based on the standard Data Entry application in the DHIS2 software. Figure 5.3 illustrates this, showing a screenshot of the current digitalised ordering solution. Recent interest at HISP Uganda and MoH has been directed towards the possibility to use DHIS2 Tracker for commodity ordering for several of the country’s health programmes.

Figure 5.3: A small excerpt from the current digital ARV order in the aggregate part of DHIS2.

According to MoH representatives, the digitalised commodity ordering initiative for ARVs, labelled WAOS (see section 2.3.2 on page 15), is addressing current challenges in the LMIS for the ARV programme. The ARV health programme is the only programme ordering through DHIS2. Ordering in the other health programmes remains paper-based. Interestingly, Uganda MoH is currently planning a roll-out of DHIS2 ordering also for the tuberculosis programme.

WAOS was rolled-out in 2014/15 and was found to be the preferred data collection method in larger health centres, hospitals and in several of the public health facilities visited. The facilities not using DHIS2 are using a paper-based version of the digital form. To ultimately be able to use DHIS2 for order data statistics, District Health Offices (DHOs) and national warehouses were found to function as paper-to-digital gateways. For example, at one of the large private warehouses visited, paper orders
for the ARV programme were punched in at, resulting in a high work load for the warehouse clerks.

Out of the eight organisations visited, half of them were found to use DHIS2. This included a private warehouse, a national referral hospital, a district hospital and a level three health centre (the only one using DHIS2 for ordering in the ARV programme). The rest of them did not use DHIS2, including a level four health centre, a national referral hospital, and two private clinics. As only one of the facilities visited actually used DHIS2 for commodity ordering, the second field trip focused on visiting more of them.

During facility visits, different routines for commodity ordering for the ARV health programme were found. These are summarised in table 5.2 on the next page. The private facilities had no routines as they ordered per phone. Moreover, the one clinic using DHIS2 for commodity ordering was centrally located in the capital Kampala. This clinic had a computer connected to the Internet, and used DHIS2 for ordering ARVs through WAOS. Furthermore, the two referral hospitals both scanned the ARV paper forms and delivered them via mail. Even though one of them had access to a computer with Internet connection, they did not use WAOS for ordering. One of the logistics managers explained that they wanted to use DHIS2 for ordering, but if one them leaves for training in Kampala, the person staying behind cannot handle the pressure. During the visit at this health unit, nearly 100 patients were queued up outside of the office where the interviews were performed. The statement being from a logistics officer in a large regional referral hospital, illustrates that even at large health units, human resource issues are prominent.

5.2 Second trip: Understanding information requirements from health commodity orders in the ARV programme

As HISP Uganda and representatives from MoH showed interest in using DHIS2 Tracker for commodity ordering, this was a main focus for me
<table>
<thead>
<tr>
<th>Ownership</th>
<th>Organisation</th>
<th>ARV Ordering Routine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>National referral hospital</td>
<td>Email to warehouse directly</td>
</tr>
<tr>
<td>Private</td>
<td>National warehouse</td>
<td>Enters facilities orders</td>
</tr>
<tr>
<td>Public</td>
<td>Regional referral hospital</td>
<td>Email to warehouse directly</td>
</tr>
<tr>
<td>Public</td>
<td>Health centre</td>
<td>Paper form to DHO</td>
</tr>
<tr>
<td>Private</td>
<td>Small clinic</td>
<td>No formalised routine present</td>
</tr>
<tr>
<td>Private</td>
<td>Small clinic</td>
<td>No formalised routine present</td>
</tr>
<tr>
<td>Public</td>
<td>Health centre</td>
<td>Using DHIS2</td>
</tr>
</tbody>
</table>

Table 5.2: Routines for commodity ordering in the ARV health programme.

during the second field trip. In order to assess the applicability of DHIS2 Tracker as commodity ordering tool in the ARV programme, the second field trip to Uganda aimed to better understand the requirements for output from such a system. After attending a DHIS2 Tracker Academy in Rwanda to learn the possibilities and limitations of the tracker module in the DHIS2 software, the following five weeks in Uganda were focused on understanding requirements for a commodity ordering application in DHIS2, using the Tracker module.

In this subchapter, empirical findings will be presented from this field trip to Uganda. Findings from the empirical material will be structured around three different levels, namely the requirements associated with the local, district, and national level in the current DHIS2 order setup (WAOS). Within each of the sections, the text will present the level, what it consists of, and the data collected at the respective stage. Then, an elaboration on what the relation to the commodity ordering is at this level is given, and a summary of the requirements is specified at the level in question.

To clarify, requirements means what they wanted to preserve from the current solution (WAOS), as well as indications from the interviewee on what should be supported in future solutions. Also, the approval processes are described.

More importantly, the requirements are functional and are focused on the requirements for output from DHIS2, meaning the information from order data. In essence, the requirements come in the form of reports needed in the system. Non-functional requirements (e.g., latencies in data entry, the design of the ordering forms) is not part of this thesis, and will not be
discussed.

5.2.1 Local level

This level consists of health facilities and clinics, providing local health care in the communities, villages, and in towns. These are typically located in levels 2-4 in the Ugandan health system (see section 2.1 on page 11 for a specification of the Ugandan health system levels). Health facilities order commodities for internal use, and this is the level where the actual ordering is done. 2 out of 3 visited health facilities used DHIS2 for commodity ordering, and all had a dedicated health facility logistics-manager. At the local level, the main part of using DHIS2 is for actually entering the commodity orders. Of the places visited, other system requirements in addition to pure data entry were found. The requirements are listed in table 5.3.

<table>
<thead>
<tr>
<th>NO.</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reporting rate summaries</td>
</tr>
<tr>
<td>2</td>
<td>Report showing previously entered orders (Data Set Reports)</td>
</tr>
<tr>
<td>3</td>
<td>(Possibility to aggregate on singular commodities)</td>
</tr>
</tbody>
</table>

Table 5.3: System output requirements in DHIS2 at the local level.

Parenthesis around a requirement indicates that it was rather unclear if it was really used, due to difficulties in communication during the interview. One logistics-manager stated that he found the reporting rate summaries (a built-in part of DHIS2) to be useful for evaluating his own facilities commitment to the reporting deadlines. Moreover, in all the facilities the interviewed emphasised that they needed a report showing previously entered orders, as they often used data previously entered when making new orders.

Approvals

As facilities at the local level are those who actually enter the orders, there is a need present for approval from higher authorities. For the facilities we visited, this higher authority was the DHO. The ways the DHO actually
approved the forms varied. One facility got approval within DHIS2 from the DHIS2 for all health programmes, except the ARV program. For ARVs, the order went directly to the national warehouse. At the other health centre, the ARV forms were approved by the DHO before being sent to the national warehouse.

This seemingly optional approval stage was discussed with MoH officials. They acknowledged that approval seemed optional in some facilities, but clarified that they wanted this approval stage to be mandatory in the near future.

5.2.2 District level

The district is a decentralised decision-making unit, with the DHO being the management unit. At the DHO, managerial decisions are made on the facilities in the district. These decisions includes re-allocation of medicines, personnel, as well as general facility guidance. For example, district health supervisors guide facilities and health centres on how they should fill out the commodity orders for the different health programmes. This is done both at the district office, and in visiting facilities and logistics managers in-person.

At this requirement level, one DHO was visited. In this district, all facilities delivered orders by paper. They got approval from a district health supervisor. After approval, the ordering form was delivered to the DHO before the deadline, and then sent to the national warehouse (on paper or digitally). The approval process is illustrated in figure 5.4 on the facing page.
As system output requirements, the DHO needed DHIS2 for retrieving an informative overview of the facilities in their responsibility. First, they need reports for retrieving the facility stock statuses (e.g., how many month-of-stock a facility has for each commodity). Second, they need reports to see what has been entered at all the facilities (e.g., for the last ordering period). A key question addressed at the district level is: “How can I redistribute commodities in my district the best way?” This was further substantiated by two MoH representatives, as well as the district manager.

<table>
<thead>
<tr>
<th>NO.</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Report for facility stock statuses</td>
</tr>
<tr>
<td>2</td>
<td>Report for what has been entered for each facility in the district</td>
</tr>
</tbody>
</table>

Table 5.4: System output requirements in DHIS2 at the district level.

### 5.2.3 National level

At the national level of requirements, various actors are present: (1) top-level decision-makers at Ministry of Health, (2) warehouse managers, (3) funders and implementing partners, and (4) supportive stakeholders. These actors have quite differing needs in a commodity ordering system, and these will be structured in the below sections.
Ministry of Health

Employees at MoH have quite dissimilar needs in the system than for example the local level. At MoH, the employees make top level decisions based on data aggregated on clinics, districts, regions and delivery zones. At this level, we attended meetings where two of them were together with aid from a MoH representative. The other two were a combination of presentations and group discussions with the pharmacy division of MoH and Clinton Health Access Initiative.

Requirements found at this level are listed in table 5.5 below. The word aggregated is used to indicate that the highlighted reports should be possible to aggregate for facilities, districts, zonal and regional levels of the health system. This indicates that top level decision makers need an overview of the full health system.

<table>
<thead>
<tr>
<th>NO.</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reporting rate summaries (who has not been reporting)</td>
</tr>
<tr>
<td>2</td>
<td>Allocation lists (picking lists) for warehouses</td>
</tr>
<tr>
<td>3</td>
<td><strong>Aggregated</strong> report for stock status</td>
</tr>
<tr>
<td>4</td>
<td><strong>Aggregated</strong> completeness reports</td>
</tr>
<tr>
<td>5</td>
<td><strong>Aggregated</strong> timeliness reports</td>
</tr>
<tr>
<td>6</td>
<td><strong>Aggregated</strong> patient summary reports for the whole country</td>
</tr>
</tbody>
</table>

Table 5.5: System output requirements in DHIS2 at MoH.

In requirement three, MoH should be able to retrieve stock statuses for different levels in order to perform commodity re-distribution analysis for making sure access to medicines. This is similar to the requirement found at the district level.

Requirement four aims at giving information on the facilities or districts actually submitted reports at all, indicating where orders are missing. Moreover, a report for requirement five shows how many delivered orders has been submitted on-time. For example, MoH wants to retrieve information on this timeliness for districts before sharing it to implementing partners.

Further, requirement six is important for capturing the total status in the health commodity supply chain. Such a report should be capable of
aggregating total patient numbers for the ARV programme, answering the question of “What is the total number of patients in Uganda currently receiving ARV-medicines in June 2017?”. Such information is used as the basis for national budgeting. The Pharmacy division of the Ugandan MoH will, for example, use this information for engaging new and existing funders for the health sector.

In general regards, MoH had the highest number and highest granularity of system requirements through the data collection done during the field visit. As a senior technical officer at MoH stated: "Information use is really the most important aspect of a new system". The representative further explained that it is crucial for a new solution, using DHIS2 Tracker, that the analytical features support these information needs in the system. The requirements summarised in table 5.5 on the facing page are all needed for better evidence-based decisions in the ARV commodity supply chain.

However, the current dissemination of information from DHIS2 was not without shortcomings. For example, through several meetings with MoH representatives, several additional adjustments to the "raw" data retrieved from DHIS2 was done. They often used much time re-arranging and performing a deeper analysis of the data in Excel. One example of this is stipulating the total costs of ARV supplies for a fiscal year, using the data from requirement six. Budgeting and planning is an integral part of their daily work, and they need Excel for further analysis. Moreover, they use Excel documents and PDFs to share with other health system stakeholders.

Warehouses

Also present as important stakeholders at the national level are the warehouses. This includes private and public warehouses, both using DHIS2 for commodity ordering. The warehouse level is the endpoint, where orders are received (paper or in DHIS2) from the facilities for processing and picking. At this requirement level, two large warehouses were visited: one private, and one public.
Since all the warehouses visited during this thesis work also functioned as paper-to-digital gateways for ARV orders, they need to have the possibility for also entering the orders in DHIS2 to view previously entered orders for facilities. This was especially emphasised by the private warehouse. That requirement, in particular, is coinciding with the facilities requirements at the local level, described earlier in section 5.2.1 on page 63.

In addition to the local level requirements, a description of one addition to functional requirements at the warehouse level will be given. Both the public and private warehouses maintained their own WMS. The public warehouse used the MACS software, and the private used the IFS software as the WMS. To enter data into their WMS, they are dependent on a specialised report from DHIS2, today labelled the Stock distribution report. This report consists of only three values for each commodity, which is (1) a unique drug code, (2) the name of the regimen ordered, and lastly (3) the number of packs ordered. Moreover, these values are also used for the picking of commodities from the warehouse's shelves. It was unclear whether they also needed reports for showing previously entered orders from each facility, as the various employees had different opinions.

<table>
<thead>
<tr>
<th>NO.</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stock distribution report / allocation reports</td>
</tr>
<tr>
<td>2</td>
<td>(Report showing previously entered orders)</td>
</tr>
</tbody>
</table>

Table 5.6: System output requirements in DHIS2 at the warehouse level.

**Funders, implementing partners and supportive stakeholders**

Both national and several international stakeholders are present on this requirement level. This includes funders and health programme implementing partners, with examples being Baylor, UNICEF, PHS and so forth. At this level, a meeting with a health programme director for one such IP was attended. A joint meeting with MoH and CHAI, as well as the interviews with MoH representatives also guided these requirements.

Through thesis meetings and interviews, the requirements were found
to a large extent coinciding with the ones described for MoH. The MoH representatives were found to be responsible for generating reports and other information on behalf of funders, IPs and supportive stakeholders. One reason for this is that MoH does not want too many having access to sensitive data from DHIS2. However, some of the stakeholders had restricted access to DHIS2. From the data warehouse, they seemed more interested in reporting rates, timeliness and completeness.

### 5.2.4 Similarities and summary

<table>
<thead>
<tr>
<th>NO.</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Report showing previously entered orders (Data Set Reports)</td>
</tr>
<tr>
<td>2</td>
<td>Reporting rate summaries (who has not been reporting)</td>
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</tr>
<tr>
<td>6</td>
<td>(Possibility to aggregate on singular commodities)</td>
</tr>
<tr>
<td>7</td>
<td><strong>Aggregated</strong> report for stock status</td>
</tr>
<tr>
<td>8</td>
<td><strong>Aggregated</strong> completeness reports</td>
</tr>
<tr>
<td>9</td>
<td><strong>Aggregated</strong> timeliness reports</td>
</tr>
<tr>
<td>10</td>
<td><strong>Aggregated</strong> patient summary reports for the whole country</td>
</tr>
</tbody>
</table>

Table 5.7: Summary of all system output requirements found during the second field visit.

Throughout the second field trip to Uganda, a better understanding of the functional requirements for commodity ordering in the Ugandan ARV programme was gained. The findings show that requirements are different at the various levels in the Ugandan supply chain, ranging from the local, district and national level.

Nonetheless, the output needed from the LMIS in the ARV programme have similarities. Often, the data presented in the reports are hand-picked attributes from the actually entered orders. Also, several system stakeholders wish for quite similar reports, such as the stock status report. The actual differences are often a result of aggregating the data collected or not. Some actors have their own needs in the system: facilities need to view the orders or see order rate summaries, districts need overviews of facilities in order to re-distribute stock, warehouses need picking lists for
internal use, and other national stakeholders need highly aggregated data for budgeting and planning. The 10 unique requirements found during data collecting is listed in table 5.7 on the preceding page. Moreover, typical use cases for outputs in the system is summarised in figure 5.5 to illustrate system requirements.

Figure 5.5: Illustrating system requirements: Typical use cases for information use in the ARV health programme.
Chapter 6

System development

As shown in the preceding chapter, there are two overarching requirements for a new commodity ordering system for ARV logistics, namely to (1) create meaningful reports for the logistics system actors at various levels, and (2) improve the commodity data entry process user interface in order to reduce errors and improve the overall data quality. The first is addressed here in this chapter, and the latter is done by a fellow master’s student and is not a part of this thesis.

First, the Ugandan MoH is currently moving towards extending the use of DHIS2 as LMIS, also using it for ordering in the TB health programme. Moreover, the emergence of the Tracker module in the DHIS2 software has gained recent attention also in Uganda. Therefore, the practical contribution of this thesis is to understand the applicability of the Tracker module for ARV logistics requirements found. The software development process is described in this chapter.

The focus for technical development has been twofold: to set up an environment for commodity ordering using Tracker, and to explore the various ways to create outputs from this environment. Initially, key concepts from the DHIS2 software relevant for understanding the technical work is given. Moreover, a description of the design and implementation of a standalone web application made for automating the setup process for new health programs in DHIS2 is provided. Lastly, processes around the creation of outputs are described, and six resulting
reports presented. Links to the source code of all the software created, described in this chapter, is provided in Appendix D.

6.1 Technical background

6.1.1 DHIS2 and the Tracker module

DHIS2 is not mainly intended for the logistics sector. Rather, it is used to collect aggregate health statistics on a routine basis. Thus, in today’s software, there are no obvious solutions to logistics use cases such as supporting commodity ordering.

The DHIS2 Tracker is a module in the DHIS2 software. The module is used for managing event-based (transactional) data, originally designed for tracking individuals over time (DHIS2, n.d.-g). Tracking is organised through creating Programs and Program Stages (DHIS2, n.d.-g), which follows the specific routines of the health programs.

A key motivation for choosing the DHIS2 Tracker as the underlying infrastructure for supporting commodity ordering can be summarised as follows: If you can track individuals through a total patient cycle, you should also be able to track commodity orders through the total ordering cycle in the logistics supply chain. This structure is simplified in figure 6.1 on the next page, comparing the tracking of ANC-visits for pregnant mothers to the potential of commodity ordering for the ARV program.

As shown in the figure, the DHIS2 Tracker can give better support for processes rather than pure data collection at a specific time. The latter has been the prominent use for DHIS2 up until now. As commodity ordering and the logistics sector follows a different rationale, possibilities seem to be present for using the Tracker module for this purpose. This includes the possibility to incrementally add more data to the orders through the different stages in a commodity ordering process (e.g., adding additional information in the approval stage of orders).

The Tracker module revolves around two main constituting elements, the
Figure 6.1: The general idea of how DHIS2 Tracker can support stages in the logistics process: comparing the ANC-visits program and the ARV ordering program.

Programs and Program Stages. The Program specifies what data entry and data outputs are for. In this case, the ARV commodity ordering Program. In Programs, one can have multiple Program Stages for entering and disseminating different data - in this case for the different stages in the ordering process. In the practical work of this thesis, the first stage in the ordering process was modelled, the registering of actual orders (shown in the bottom-left corner of figure 6.1), as well as the creation of information from this stage.

6.1.2 DHIS2 and the web API

Throughout the evolution of the DHIS2 software, the architectural characteristics have changed over time. The overall architecture of DHIS2 is today built as a modular and more flexible system than in the earlier software versions (Staring & Titlestad, 2008). The core of the new architectural strategy is modularity, meaning that new components will be attached to the central software core. This implies that new software additions will not be integrated into the system, but rather be interoperable with the system. This core-periphery architecture is illustrated in figure 6.2 on the next page.
Moreover, the modularity shown is operationalised by using stand-alone web applications, web apps in short, for adding functionality to the software. These applications may be generic system applications, such as the Tracker module. Or, the applications may come in the form of third-party applications, also adding functionality to the software. This is done without modifying central parts of the software, but rather use its resources for specialised purposes. This makes it easier to make new adaptations to DHIS2.

A central aspect of the modularised architecture is the web-based Application Programming Interface (API). The API provides system resources (i.e., a connection to the database) in several data formats through standardised URL endpoints (DHIS2, n.d.-d). This software structure is also utilised by major technology companies (e.g., Facebook, Amazon and Twitter), making the software more modular and scalable. The API offers a simpler interface for web applications to access database resources in DHIS2. Communication is formalised through HTTP calls. An example, retrieving all DHIS2 Data Elements in the JSON data format, is given below:

https://SERVER_NAME/dhis/api/dataElements.json
With these architectural characteristics, the software DHIS2 aim to enable developers to create and implement their own additions to the software, making it possible for third-parties to address the more local needs in the system (Staring & Titlestad, 2008). Here, the DHIS2 web API has been utilised in almost all practical work.

Pivotal tools in central DHIS2 applications, and in the application described in this chapter, are the Analytics resources. The Analytics resources are enabled through the web API and is “powerful as it lets you query and retrieves data aggregated along all available data dimensions” (DHIS2, n.d.-a). The resources available through this interface is performance-enhanced, hence being more robust. An illustration of the power of the Analytics API is given in table 6.1, showing some key specifications one can utilise to retrieve data.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>dimension=dx</td>
<td>Actual data resources to retrieve (e.g., Data Elements)</td>
</tr>
<tr>
<td>dimension=pe</td>
<td>Period for the data (e.g., ’20170209’ for date or ’2017’ for year)</td>
</tr>
<tr>
<td>filter=ou</td>
<td>Filter on organisation units for the output.</td>
</tr>
<tr>
<td>skipMeta=false</td>
<td>Retrieve more data on the outputs</td>
</tr>
</tbody>
</table>

Table 6.1: Examples of specifications for data output from the Analytics web API in DHIS2.

### 6.1.3 Relevant applications

One application using the Analytics resource is the DHIS2-internal Pivot Table application. The Pivot table app is “a dynamic tool for data analysis which lets you summarise and arrange data according to its dimensions” (DHIS2, n.d.-c). It allows users to specify what kind of data they need in the tables; the what, the where and the when. The Pivot Table application uses the Analytics API described above. A similar application in DHIS2 is Event Reports. Internally, this application uses Event Analytics, slightly different but similar to Analytics.

Further, DHIS2 has many other applications and tools to make sense of data entered (e.g., information dashboard, graphical presentations and graphs). Of these, the application most important for the practical work...
of this thesis was Standard Reports, as the reports were an important part of the requirements for a commodity ordering solution. A HTML-based version of Standard Reports was used, offering full flexibility with JavaScript-enabled website reports (DHIS2, n.d.-b).

6.2 Creating a web application for automated setup using DHIS2 Tracker as infrastructure

This part describes the processes for setting up for commodity ordering in a new health programme using Tracker. Initially, a description of three different architectural designs considered for the Tracker setup is given. Moreover, an elaboration on the initial Tracker Program setup is given, along with a description of a general web application made for the purpose of creating new commodity ordering setups, with DHIS2 Tracker as the underlying infrastructure.

6.2.1 Architectural design proposals

Initially, an exploration process found place to find a suitable solution for a technical setup in Tracker, illustrated through three different architectural designs. In the process, an analysis of how the different design models could fit the output requirements was done. Practically, this involved setting up proposals, followed by discussions with DHIS2 implementers and developers at HISP Uganda and the University of Oslo. Illustrations show the data structures of the three proposals, where the most important part of the proposal is highlighted in bold.

To analyse what data was available through the different setups, a web application was developed in order to understand more about the implications of the different setups. An excerpt from this application, showing data structures of different setups, is shown in figure 6.3 on the next page.
Figure 6.3: A small excerpt from debugger web application for initial testing of architectural design ideas.

**First design proposal**

The initial design proposal is illustrated in figure 6.4. In this design, all commodities for ordering in the ARV programme was operationalised as own Program Stages, using Events in the Program Stage as the actual orders. The stages were set up as repeatable.

![Diagram of architectural design proposal: Design 1.]

The benefit of this structure lied in the possibility to aggregate on individual commodities, drilling down to the more atomic constituents of the ARV ordering forms.

However, some issues were identified with this approach. First, the need to drill down to singular commodities was not needed. Second, this architectural design contains much data-structural overhead. This was indicated in the data structures application, showing that in order to create meaningful outputs from such a system, large overheads will be present.
to create useful information. Caused by these shortcomings, this design was discontinued.

**Second design proposal**

The second design proposal aimed at addressing the overhead issue emphasised in the first design. Minor changes were made to the architectural model, shown in figure 6.5. Here, the individual Program Stages were left out, and the ARV program now consisted of only one repeatable Program Stage. Every commodity had an enclosing Event - the "generic" LMIS Order Event. This structure seemed was the preferred choice by the consultants at HISP Uganda.

![Figure 6.5: Architectural design proposal: Design 2.](image)

One of the reasons the HISP Uganda consultants favoured this approach, was that having each commodity as a singular Event would make it more flexible and granular, providing more powerful tools when using the data for analysis. Another more obvious benefit of this approach is that by removing a Program Stage for each commodity, the data structure overheads are reduced.

However, through discussion with several developers and co-students, we concluded that this design still is too complex. It would be a more cumbersome process to create meaningful outputs of the system using this design. For example, to be able to create the same report they have today (as well as new ones), several special adjustments in addition to the built-in functionalities in DHIS2 are needed.
Moreover, as technical resources are low in the Ugandan health facilities, this architectural model will produce higher loads of data to be transmitted to the server. Hence, efforts were put into making the data model simpler and easier to maintain and scale.

**Final design proposal**

Through learning from the issues from the first two architectural design proposals, a third design proposal was made. This model, eventually landed on for the further development, is shown in figure 6.6. The figure depicts the structure of this architectural design for the Tracker setup.

![Figure 6.6: Architectural design proposal: Design 3 (final).](image)

In the proposed model, the emphasis has been to make the overall design simpler. As shown, there is only one Program (the ARV program). Further, the actual orders are implemented as Events in the Program. This makes it possible to identify one order through one Event. The order events will contain all the actual data to be collected (i.e., the DHIS2 Data Elements) in each order.

The less complicated structure of the data has several benefits. First, this structure enables easier-to-create analysis. For example, as data structure overhead is reduced, there is a decreased need for special adjustments when creating information, in terms of for example reports, visualisations and tables. Eventually, this makes it simpler for stakeholders as health programme managers, DHOs and LMIS implementers to create new...
outputs based on the ever-changing demands in the health programmes. Outputs will be described in greater detail in section 6.2.4 on page 84.

Moreover, as the requirements found during the field visits show that the information needs at the different health system levels often is to show full or partial parts of the whole orders - it makes sense to structure the data into orders. This better mirrors the requirements and makes the data readily available in the needed format.

The overall structure of how Events can be utilised in the final design proposal is depicted in figure 6.7 below:

![Figure 6.7: Overview of the final architectural design proposed.](image)

### 6.2.2 Initial Tracker Program setup

To set up the architectures described in the above sections, tools were needed for creating the Program and its constituting elements. For example, a computer program was needed in order to automatically generate several hundred Data Elements.

DHIS2 already contain good support for large-scale imports of data in several formats. DHIS2 has a dedicated import/export web application for the purpose of importing for example metadata in large batches. In the initial setup, a flat CSV file containing the structure needed to set up all the Data Elements at once was created. As the ARV program order contained 31 commodities, a bulk-import of the 279 Data Elements was needed, as each of the commodities has 9 commodity operations (if every commodity used the same operations). For this purpose, a simple Python
script expanding the CSV with all these commodity operation suffixes using regular expressions (regex), was developed.

After being able to successfully import the CSV data creating all Data Elements, another issue emerged. As sufficient demo-data for 279 Data Elements were needed, development of more software was needed - manually entering only three ARV orders would result in needing to manually enter 837 data fields. Therefore, a web application for automatically generating and adding random test data to the DHIS2 instance was created. This tool was later included into the overall Tracker Program setup, and will, therefore, be described in detail in the next section.

### 6.2.3 JavaScript Tracker Program setup

To simplify the creation of new commodity ordering schemes, a setup wizard for setting up in DHIS2 Tracker for new health programs was developed. The application was developed as a standalone DHIS2 web application, created with JavaScript, HTML and CSS.

**User interface for adding commodities**

As many elements were to be entered through the graphical user interface (GUI), experimentation with several ways of adding commodities was done. The first is illustrated in figure 6.8.

![Figure 6.8: Initial setup scheme (discarded).](image)

Here, the layout was structured as forms, as implementers are used to such layouts from the paper-based ordering forms. However, some issues were present in this layout. As only the row and column names were the fields actually being modifiable, data entry became somewhat confusing. Further, one needed to be able to add different commodity operations (e.g.,
"Opening balance") for each commodity in the setup. Caused by these issues, another user interface was chosen. The full setup page is shown figure 6.9.

Figure 6.9: Screenshot of the chosen commodity entering scheme.

This setup offered more flexibility, as users can (1) add new commodities with different operations, (2) clone the previous commodity as they often use the same, and (3) adding sections dynamically at the website. All the fields (i.e., section names, formulation names and commodity operation names) can be changed by the user. The users are able to declare the desired format for the commodity orders, specifying what sections the forms should contain, and what commodities and associated operations they need. The automated setup prevents the potential issue that users (i.e., LMIS implementers) set up wrongly, as all data structures will be created as intended for the ordering system.

When pressing the finished-button, all the necessary structure is generated through API-calls, extracting all sections and the name of the program. After submit, it is possible to enter test data.
Sending user-generated metadata to the DHIS2 server

On submit, data structures were created in a format accepted by the DHIS2 web API. Before being sent to the server, metadata was created, grouping the data alongside several dimensions: (1) Groups for each commodity, (2) Groups for each distinct commodity operation, (3) a Group Set containing all commodity groups, (4) A Group Set for all commodity operations, and (5) creating Program Sections for the form in DHIS2. This was done by running eight JavaScript files, communicating with the DHIS2 server instance through the web API. The metadata was created server-side through the scripts, important for the further utilisation of the data.

Automating test data entering

After creating the program through the setup wizard application, the user gets the option to add randomised test data sets for the chosen program. This part of the setup wizard is solely for testing purposes. The site is illustrated in figure 6.10.

Post randomized events for the program

<table>
<thead>
<tr>
<th>Program ID</th>
<th>Program Stage ID</th>
<th>Posting Orgunit ID</th>
<th>Order date</th>
<th>Abacavir (ABC) 60mg ___Adjusted AMC</th>
<th>Abacavir (ABC) 60mg ___ART &amp; PMTCT Consumption</th>
<th>Abacavir (ABC) 60mg ___Closing Balance</th>
<th>Abacavir (ABC) 60mg ___Days out of stock</th>
<th>Abacavir (ABC) 60mg ___Losses / Adjustments</th>
<th>Abacavir (ABC) 60mg ___Months of stock on-hand</th>
<th>Abacavir (ABC) 60mg ___Opening balance</th>
<th>Abacavir (ABC) 60mg ___Quantity received</th>
<th>Abacavir (ABC) 60mg ___Quantity Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2011-03-02</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 6.10: Part of the application for automatically generating test data for the created program.

At the site, users are able to see all the Data Elements and what data will be sent to the server. At the end of the site (not shown in the excerpt), users are given the option to post one or 10 orders to the server at the time. Moreover, users can choose what facility (here through the organisation
6.2.4 Exploring outputs from the setup in internal DHIS2 modules

The previous sections have focused on technically setting up for commodity ordering in the Tracker module. In this section, the focus is to explore how the DHIS2 Tracker module can be used as underlying infrastructure to create meaningful outputs for information use by system users. This part of the development is closely linked to the information needs and requirements discussed in the preceding chapter. Here, a description of the work done on possible data disseminations in internal DHIS2 modules is given, as derived from the last design model shown in section 6.2.1 on page 79.

DHIS2 has an internal application for disseminating Tracker and Event data, named Event Reports. It contains possibilities for creating tables, both for depicting individual Events and for showing aggregate statistics. The Event Reports module is technically based on the fairly new Event Analytics API. In the typical use cases for Tracker, an Event consists of around 2-8 data elements for collection. A typical example here is registering singular Malaria cases, where countries often tend to need collecting a few, but important characteristics of the malaria case occurrence (e.g., where did an incident happen, what was the age of the person affected). For such use cases containing only a few Data Elements for collection, creating information in Event Reports is relatively flawless.

However, commodity order registrations contain large amounts of data for collection, as each Event can contain hundreds of Data Elements. The Event Reports module was tested as a tool for creating information, but it did not perform well with large analytical queries caused by performance issues. Some large queries in Event Reports, such as retrieving one full commodity order, take up to six minutes for Event Analytics to respond with data. During this time, web browser error messages are shown
informing that the operations take too long to respond.

Caused by these issues, Event Reports could not be used as a tool for exploring the test data in the new setup. Currently, it seems that Event Analytics is not suited to support large queries. In Appendix E, a document is attached prepared for a DHIS2 meeting with stakeholders for identifying possible improvements to Analytics, where the issues were discussed.

The Pivot Table application in DHIS2 is one of the internal applications that has undergone major performance enhancements, especially in the latest releases of the DHIS2 software. Internally, this application uses the powerful Analytics API. When using this application instead, retrieval of the same data from Event Reports was possible in only around one second.

Caused by these satisfactory performance results, viewing the test data in Pivot Table was successful. However, caused by the flat Data Element structure shown in figure 6.11, moving towards the two-dimensional (2D) structure needed was in order to be similar to today’s ARV reports.

![Figure 6.11: Output from Pivot Table: the flat structure of Data Elements.](image)

To move away from the flat structure, a re-arrangement of the output form was done using the metadata earlier described (Data Element Groups and Group Sets). By doing this, the needed layout was retrieved, shown in figure 6.12 on the next page. By using the groupings, one actually do not need to specify what Data Elements to show. Rather, they are inferred from the created Groups and Group Sets. This serves as a useful abstraction layer to end-users of the system, hiding the complexity of the underlying data structures.

A major issue was identified with the grouped output. As illustrated in figure 6.12 on the following page, no data is present. After discussion this with several core developers behind the DHIS2 software, we identified
this as a present lack of functionality. The problem was related to the fact that the Groups and Group Sets stored Data Elements as having a different data type ("Tracker", and not the default value type "Aggregate"). This was caused by the fact that they have been registered as data elements specific for the Tracker module, labelled Program Stage Data Elements. As one of the developers stated, this should be a small addition to the current Pivot Table application but was not listed as a top priority for future development.

6.3 Creating reports as system outputs

Through understanding requirements in Uganda, stakeholders were found to often utilise Standard Reports to make sense of the entered commodity ordering data. Thus, it was important that they could preserve this way of presenting the order data in a new solution based on Tracker. As a result, six reports were created. Screenshots of every report created are included in Appendix F. Three of them were reconstructions of the existing reports in WAOS, while the other three were new reports based

Figure 6.12: Output from Pivot Table: the two-dimensional structure of Data Elements using the created Groups and Group Sets.

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1 In the Pivot Table user interface, they are named *event data items.*
on requirements found during empirical data collection. This section describes these reports, and give a summary of an evaluation session done with a MoH representative.

In terms of technical development, all the reports were enabled through the flexibility of Standard Reports in DHIS2, created using JavaScript, HTML and CSS. Data retrieval was based on the same data retrieval strategy as the internal Pivot Table application, namely, API calls to Analytics. As this resulted in the flat structure mentioned above, several technical special adjustments were needed, dynamically rendering HTML tables.

### 6.3.1 Reconstructions of three WAOS reports

As a new system need to successfully create the old reports from WAOS, three of these reports were created for the new setup. The Facility Stock Status Report is given as an example of such a report in figure 6.13. The figure shows a small excerpt of the report, containing stock status information for one ordering bi-month for all health facilities in the Kampala district (based on test-data).

![Facility Stock Status Report](image)

**Figure 6.13:** Screenshot of a reconstructed WAOS report: the Facility Stock Status Report.

A similar report reconstructed was the Allocation List for warehouses, including different attributes from the orders. In this report, only the
regimen name, drug code and packs ordered was supplied as information for each of the commodities.

The last report reconstructed, labelled the Consumption Data report, is shown in figure 6.14. Here, all the order information, except the patient statistics, is shown for every facility in the district, making the report far more complex than the others.

Overall, technical development showed that it was possible to create three of the WAOS reports in the Tracker module setup, indicating that the system structure can support the creation of the reports found during requirements gathering. However, it is important to note that the reconstructions are not warehouse-specific as in the original WAOS reports, and do not contain the patient statistics.

### 6.3.2 New reports created based on requirement findings

Through understanding requirements for outputs from the ARV health programme in Uganda, ideas for new reports emerged. A process of exploration resulted in three new reports in the system, described below.
The first report was based on an important need at the level of the district and MoH, namely stock re-distribution to reduce stock-outs. Today, reports such as the Facility Stock Status Report mentioned in the previous section is used for this purpose. In this new report, efforts were put into creating a report to show information directed for concrete action taking. The report is shown in figure 6.15 (based on test-data).

![Figure 6.15: Screenshot of the new Re-distribution List Report.](image)

In the report, tables are created for each commodity in the ARV programme, showing what facilities are below and above recommended stock threshold levels. Through this, stakeholders such as district managers can quickly identify how to re-distribute to re-balance stock levels in the district.

The second report created addresses the needs for concrete information for resource planning and budgeting for stakeholders at the national level (typically MoH). As they today make extensive use of Excel for such purposes, an alternative report was proposed, shown in figure 6.16 on the following page.

Here, aggregated consumption data for a district (or even the national level) will be shown for each commodity for a year. The total yearly expenditure is dynamically calculated based on the pricing input field.
The level of aggregation can be chosen when creating the report (e.g., a district or whole country) to create expenditure based on different health system levels.

The last report was made to address the need facilities had to view the orders they had entered. In WAOS, this functionality is available through automatically created reports (Data Set Reports). However, the Tracker data structure does not support this automatically creation of data set reports, which resulted in the need for manually creating the report as a Standard Report instead. The functionality of this report is largely similar to Consumption Data Report, and this will therefore not be described in detail. However, if the organisation unit chosen is of higher level, the report structure is somewhat different. Figure 6.17 on the next page shows an example of this alternative version of the report, where the average values in all orders in a district are shown.

Here, if the average months of stock for all facilities in the district are especially low or high, this will be indicated through colouring it green or red. Other possible data aggregation types provided are the sum (default) and count, as well as the statistical measures standard deviation and variance.
6.3.3 Feedback on the created reports

The reports created were evaluated over a Skype demonstration and discussion with a Monitoring and Evaluation representative from MoH in Uganda. The overall impression of the reports was good, but several improvements were suggested. The new reports created were generally considered as useful additions to output from the ARV ordering system. The functionality of the Re-distribution List was considered as much needed in order to ease the process of stock balancing at district and health facility level. The MoH representative suggested adding average monthly consumption and closing balance into the tables, as this would contribute to managers being able to make more informed decisions in the re-distribution processes of health commodities.

The representative further suggested that adding patient statistics as a part of the aggregated Order Summary Report would be beneficial. Through this, one can generate aggregated patient numbers for districts, or even for all facilities in Uganda. The Expenditure Report was perceived as a good idea for disseminating aggregated data from the orders. However, it seemed to be more relevant for the essential medicines programme rather than ARVs, as resource planning is done somewhat differently than presented in the report.

In general, the dynamic features of the reports were well received, in particular the feature to change the threshold levels in the Re-distribution
List, enabling users to drill-down to the information relevant at the local level of context. Also, the idea of more specialised and action based reports was found useful. Three reconstructions of the WAOS reports were found to show the same data as the current reports. Still, a missing aspect of the reports was warehouse specificity. In today’s system, three similar reports are created for each of the ARV distributors. This need to be catered for in future development.

The possibility to export the tables was an important requirement in the reports according to the representative. This includes the formats of CSV, Excel documents and PDFs so that the reports can be shared amongst health system stakeholders. The latter was found to be supported in the reports. However, there is a large need for Excel document and CSV export to be supported in a final solution. The Excel export feature was expressed as especially important at the national level, as users there often need to do additional analysis of the data.
Chapter 7

Discussion

This chapter discusses the empirical findings in light of the literature and reflects upon the learnings and contributions from the thesis work. The first two sections are structured after the two research question presented in the thesis introduction. In the last section, reflections on the overall research are given.

As presented in the previous chapters, the LMIS' and their use is shaped by multiple factors, such as the overall health system structure, the actors and stakeholders present, technologies, use practices, available resources and infrastructure. This chapter discuss the implications of the findings and learnings from the system development process.

7.1 Status of LMIS

Several factors were found important to describe the current status of LMIS and health commodity ordering systems in Uganda: stock-outs, fragmentation, the commodity orders, the role of DHIS2, infrastructure and human resources. How these factors shape the use and strengthening processes in Ugandan LMIS' are discussed below.
7.1.1 Stock-outs

A prominent challenge in the Ugandan health system is the high prevalence of communicable diseases in the population, such as HIV/AIDS. In order for it to reduce, increasing the availability of and access to essential medicines is crucial for improving the overall health status (Kraiselburd & Yadav, 2013; Jahre et al., 2012; Zaffran et al., 2013). A pivotal part of ensuring country-wide coverage of life-saving medicines is to reduce overall stock-out occurrences, emphasised by literature as a prominent issue in developing country’s health systems (Kaufmann et al., 2011; Chandani et al., 2006; Zaffran et al., 2013). Through visiting several health clinics and hospitals, both in public and private sector, stock-out occurrence was found to remain a large problem in Uganda, as almost every health unit visited reported high stock-out occurrence. A MoH report indicates that around 36% of the Ugandan health units experience stock-outs on important tracer drugs (Ministry Of Health, 2016). The occurrence of stock-outs illustrates that facilities often seem to not receive the number of commodities needed.

Many factors may contribute to this. Examples include a general lack of resources at the national level to order enough medicines, overall delays in procurement at national, regional or local level, drug expiration, or even losses/waste during distribution and transportation. This is substantiated by Jahre et al. (2012), pointing at a general lack of funding, storage space and capacity to procure and handle large order amounts at a large national health commodity provider.

However, the fact that the health facilities were found to re-distribute health commodities between themselves supports the finding that overall distribution is sub-optimal and that improvements are still needed in the Ugandan LMIS’. For example, drug expiration may be nearly eliminated by evening out stock levels, making sure that some facilities do not maintain large stocks while others have critically low stocks. An effective LMIS can make sure that the stocks are more evenly distributed at regional, district and local level. As stated by MoH representatives, they are currently looking into how to improve the information stemming from the current health commodity ordering systems, in order to strengthen the
decision making processes. An integral part of a strategy to combat stock-out occurrences is to improve the overall information in the country’s health logistics system.

The findings indicate that improvements to the usefulness and reliability of information from health commodity logistics are needed in the supply chain, to ultimately reduce the high level of stock-outs. Interestingly, even though stock-outs remains a considerable issue in Ugandan health units, both formal and informal routines were found present for handling them at the level of health units. Examples include facilities re-distributing between each other or referring patients to private pharmacies in nearby areas. This indicates that medicines still may be available through informal networks, even though the reporting facilities themselves may be out of stock. In the order forms, the field “losses and adjustments” is present to account for such internal stock re-distributions. Nevertheless, patients being referred to private pharmacies will not be a part of the information present in the national LMIS. Such out-of-system routines may eventually disrupt the overall order statistics, as controlling whether people actually have access to medicines or not will be complicated.

7.1.2 Fragmentation

Good information about the health system is important to be able to improve overall health status. Research on health information systems in developing countries has shown that disease-specific health initiatives cause fragmentation of health information into vertical information silos (Lippeveld, 2001; Stansfield et al., 2008; Sæbø et al., 2011). In the Ugandan health commodity supply chain, various forms of fragmentation were found.

First, multiple LMIS’ are present in Uganda. Each of the different health programmes in the country maintains their own commodity orders, resulting in a myriad of order forms for health logistics workers to handle. Practically, this complexity is illustrated through the fact that logistics managers do not fill in one commodity order when ordering. Rather, they filled out up to a two-digit number of ordering forms, even though orders
often arrive at the same warehouse. If they had access to DHIS2, only the commodity orders for the ARV health programme would be entered there. Hence, this increases the number of tools in use for the health worker.

Second, consistent with what Chindove and Mdege found in 2012, the LMIS in Uganda is continuing to be predominantly paper-based. This makes data dissemination processes more cumbersome, as additional manual work is required. The manual processes will potentially lead to delays in information for timely and pro-active decision-making. The process of creating information seem more complex when some LMIS are paper-based and others are digital, as information need to be assembled from both paper-based and non-paper-based orders.

Third, commodity distribution is fragmented in the country. Three providers are responsible for different facilities and health programmes. The fact that the different suppliers do not have similar ordering cycles makes comparison across warehouses more difficult. The different warehousing schemes also have implications for creating software when digitalising orders, discussed in a later section. Nonetheless, a positive aspect is that all warehouses have structured their commodity distribution the same way, dividing all their facilities into ordering zones with five cycles.

Lastly, Ugandan health services provision is divided amongst the public and private sector. This split has effects for the overall health information systems. For example, private facilities visited were found to not report on health commodity usage, as they tended to have more pragmatic methods of retrieving needed medicines. As these methods do not include reporting on health commodity data (e.g., consumption, average months of stock), data from these clinics will not be a part of the national logistics statistics. This has implications for the overall information available in the logistics system, as information from these facilities will not be a part of national planning and estimations of the need for commodities. In other words, the fact that public and private order statistics are separated into two overall logistics information systems leads to a less comprehensive health system.
To summarise, the various forms of fragmentation present are contributing to the overall complexity in the Ugandan health commodity supply chain, resembling the intricate structures found by others (Lalvani et al., 2010). The silo structure of the logistics systems present has important implications for data collection and dissemination and is actively guiding the further design and evolution of information systems in the Ugandan context. For example, reporting specifically for the different health programmes is still a need.

### 7.1.3 Commodity orders

The health commodity order forms were found to be the main data sources for the Ugandan LMIS, hence being crucial for the decision-making processes around health commodity distribution in the country. Therefore, improving the usefulness and quality of the information created from the orders will be important to better inform decision-making in the health logistics supply chain.

One strategy to strengthen the overall information in the LMIS is to standardise commodity ordering, aiming at improving the access and availability to health commodities (Chindove & Mdege, 2012). For example, standardised commodity orders will make the comparison of data from the vertical health programmes achievable. Furthermore, standardised ordering formats support the development of more generic solutions, aiming to decrease the fragmentation often found in health information systems (Lippeveld, 2001), and eases the burden for logistics workers. In Uganda, the order forms used for health commodity ordering were found to exhibit both opportunities and challenges in terms of supporting standardisation processes.

First, the fact that standardisation efforts are currently ongoing in the Ugandan logistics sector is positive. The orders in the different health programmes were found to have a highly similar structure, as well as having similar ordering routines. Each facility ordered from the same supplier and had the same order deadlines for all their reports. Further, almost all of the order forms collected the same commodity data (e.g.,
opening balance, AMC and losses/adjustments).

The structure of commodity orders was also found seemingly similar through initial discussions with other student’s research in Tanzania, and with a DHIS2 country coordinator in Bangladesh. This indicates that software for supporting health commodity ordering may be applicable not only in Uganda but also somewhat transferrable to similar countries. Through this, the creation of a more generic commodity order system should be in reach.

Some challenges were also found in terms of standardisation of commodity orders. First, the structure of the collection of patient statistics was found different in the various health programmes. The forms themselves often tended to contain health programme specific information, which will have implications for the standardising of commodity orders. The powerful agencies behind the different health programmes will complicate standardisation efforts, as they will try to keep the patient statistics specific for the programme. Nonetheless, a MoH representative was positive for the possibility to separate the patient statistics part from the order forms. If this plan will be realised, it would help standardisation processes as health programmes needing specific patient statistics can manage health statistics reporting internally. However, this will also increase the total number of reports for health and logistics workers.

To summarise, characteristics of the commodity orders in Uganda exhibit both challenges and possibilities in terms of standardising commodity ordering in the country. The order part of the commodity reports is highly similar across health programmes in Uganda. This may also be transferrable to other countries. However, the patient statistics seem to contain more health programme specific information. By splitting up these two parts, a more generic health commodity ordering solution in DHIS2 should be in reach.

In addition to reflections on standardisation, two general challenges were found with the orders. Firstly, in all health programmes except the ARV programme, the ordering process remained paper-based. Still, at the facility level, even reporting for the ARV health programme was found mostly to be paper-based. Scholars have found that paper-based
systems lead to a more demanding information handling process than digitalised management systems, and may cause delays in the overall process of creating information (SIAPS, 2014b). Another general issue found prominent with commodity orders in the Ugandan LMIS was the large size of the order forms, leading to a more error-prone data entry process. For example, logistics workers emphasised that it was fairly easy to enter data in the wrong fields. This has implications for the overall data quality, ultimately leading to confusions and miscalculations when the order data ultimately is used for decision making. Errors at the time of data entry will eventually lead to errors in the aggregated information derived from the orders. The error-prone data entry was an important motivation for creating a stand-alone commodity ordering system in Tracker in the first place, having higher flexibility for design than the core data entry modules in DHIS2.

7.1.4 The role of DHIS2

DHIS2 play an important role in decision-making in the Ugandan health sector, being an important part of the country’s installed base. For several years, the software has been used to collect and disseminate health statistics. Recently, DHIS2 has also been utilised for collecting commodity order data for the ARV health programme. The extensive use of DHIS2 is positive, as an increasing amount of health and logistics workers now are familiar with the software.

Despite this, only a few of the facilities visited actually used DHIS2 for ordering ARVs. Different routines seem to exist for ordering ARVs, ranging from delivering orders in person, scanning and sending via email or actually entering in DHIS2. The fact that actual use of digital or paper-based LMIS is shaped by the current installed base (Hanseth & Lyytinen, 2010), illustrates that strengthening efforts should bear this in mind. In Uganda, several informal arrangements are present, with the DHIS2 software mainly supporting the higher levels of the health system, as access to DHIS2 was found to be low at the facility level.

Nonetheless, the WAOS initiative can be considered as a partial success
despite the fact that several facilities not being able to enter orders directly into DHIS2, as warehouses and DHOs were found to function as paper-to-digital gateways. In the ARV health programme, data is ultimately entered for public health facilities and hospitals into DHIS2 caused by these paper-to-digital gateways. Derived from this data, automated statistics on the commodity orders and patient reports can be created and used for decision making. These statistics has been used by several actors to create important information to overcome stock-outs and other issues. For example, district managers can use the reports generated from DHIS2 to get an overview of where commodity stocks are low and high, in order to re-distribute.

In summary, the widespread knowledge about and usage of DHIS2 in Uganda indicate that the software may serve as a powerful attractor (Sæbø et al., 2011) bringing new health programmes on board, and in aligning the different stakeholders in the health and logistics system. Relevant data from commodity orders now becoming available inside DHIS2 creates new possibilities to create compound indicators in DHIS2 as the central data warehouse, in order to better inform the health information system in total. This follows the strategy of IHIA, to support the need for a more comprehensive health information system (Braa & Sahay, 2012). Through entering data for both the logistics and health sector, Uganda is one step further towards the overall goals of combining HMIS and LMIS data (SIAPS, 2014a), hopefully leading to a more integrated HIS.

7.1.5 Infrastructure and human resources

New efforts to strengthen the HIS in Uganda need to acknowledge that the further evolution of the health information system in Uganda is ultimately shaped by the country’s large installed base. Human actors, formal and informal routines, tools, technology and resources described in the above sections all shape how technological innovations will be used (Hanseth, 2000; Hanseth & Lyytinen, 2010). In Uganda, physical infrastructures were found to be fragile and the resources low.

Several issues with resources complicate both commodity ordering and
health service provision. Based on low funding, lack of tools and equipment such as computers, internet routers and USPs, makes it necessary to maintain paper-based systems in the country’s health facilities. Also, the facilities visited were heavily understaffed, nicely illustrated through the situation where a logistics officer actually having access to a computer with internet, but were not able to spare work hours going for DHIS2 training. This shows that challenges in the Ugandan health system are deep-rooted and interwoven.

7.1.6 Thoughts on LMIS use and strengthening

To summarise, automating and standardising LMIS is one strategy to enhance availability and access to health commodities (Chindove & Mdege, 2012). This will not be a simple task, as the LMIS’ in Uganda will be based on fragile infrastructures and low resources in general. The inherent complexities of the large installed base in the Ugandan health sector discussed all indicate that a rapid roll-out of a digitalised and automated LMIS in all Ugandan health facilities is overly optimistic.

This substantiates the point made by Heeks (2002), in that simply transferring new technology into a local context will not be adequate for successfully evolving information systems, as information systems are built upon the heterogeneous components of the installed base (Hanseth & Lyytinen, 2010). The national roll-out of commodity ordering in DHIS2 for the ARV health programme has seemingly worked, even though most facilities still use paper-based systems. A strong installed base is illustrated through well established formal and informal routines. Examples include paper-to-digital gateways in order to make information accessible in DHIS2, and facilities managing stock re-distribution internally to ensure better medicines coverage. A summary of challenges and opportunities for improving LMIS in Uganda are given in table 7.1 on the following page.

As a part of ongoing strengthening efforts in Uganda, the next section will discuss the applicability of the DHIS2 Tracker module.
<table>
<thead>
<tr>
<th>Challenge</th>
<th>Opportunity for improving LMIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock-outs</td>
<td>DHIS2 knowledge and use</td>
</tr>
<tr>
<td>Fragmentation</td>
<td>DHIS2 as gateway</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Order forms similar</td>
</tr>
<tr>
<td>Resources</td>
<td>Standardisation efforts ongoing</td>
</tr>
<tr>
<td>DHIS2 access</td>
<td>Strengthening process ongoing</td>
</tr>
<tr>
<td>Poor data quality</td>
<td></td>
</tr>
<tr>
<td>Patient reports</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.1: Summary of challenges and opportunities for improvements in Ugandan LMIS.

7.2 The applicability of DHIS2 Tracker to support ARV logistics requirements

The Tracker module has gained recent attention in Uganda as a part of the national digitalisation efforts of logistics order information, thus serving as a motivation for understanding the applicability of the module to support requirements for the ARV health programme. As ordering in the different health programmes was found similar, this work may be transferable to other health programmes in Uganda.

Initially, a discussion of technical opportunities and challenges is provided, including concrete recommendations for future development. Further, reflections on whether the requirements for outputs can be supported in Tracker follows. Finally, learnings from the overall development process itself are described.

7.2.1 Technical applicability

Through examining the commodity orders from different health programmes, and implementing support for ordering in the ARV programme, it became evident that the time aspect is different than in the typical use of DHIS2 for collecting health statistics. There, order periods are often same, where health workers for example report for a specific month. However, in the commodity orders, periods follow dissimilar reporting intervals, caused by the warehouses maintaining their specific order deadlines.
These specific reporting intervals are different than in health statistics reporting and is not internally supported in DHIS2. This creates additional workarounds in software development.

Moreover, health commodity orders seem to contain much larger amounts of data for collection than in traditional health statistics reporting. This has implications for both the visual design of the orders themselves, as data entry is more complicated, as well as for technically handling large data outputs in the information system.

Also, several of the commodity orders (e.g., ARVs and TB) found in Uganda also contain patient statistics. This creates a duality in reporting, as commodity reporting contains both order information and aggregated patient statistics. This duality seems somewhat different than in the usual health statistics reporting in DHIS2.

Several opportunities were found during the technical development process, listed in table 7.2. In the relatively short history of the Tracker module, it has mainly been used for smaller reporting cases related to following up patients, and not health commodity ordering. Setting up commodity ordering for the Ugandan ARV health program was found to be possible in the Tracker module of DHIS2. As discussed in the next section, the module also seems to support the output requirements found in Uganda.

<table>
<thead>
<tr>
<th>NO.</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Setup is possible</td>
</tr>
<tr>
<td>2</td>
<td>Supporting requirements seem possible</td>
</tr>
<tr>
<td>3</td>
<td>Better supports processes</td>
</tr>
</tbody>
</table>

Table 7.2: Summary of software opportunities in the commodity order setup for ARVs.

Representatives from MoH in Uganda wanted approval to be an integrated part of a future software-based solution for health commodity ordering. In order to manage approvals of orders inside the software, and not in person, a software structure fitting this is needed. Through gaining technical experience with the Tracker module, storing of additional information at different stages was found to be possible. Through this, it can better support the logistics processes inherent in supply chain manage-
ment, such as order approvals. However, as the system development done
as part of this thesis focused on the first stage in the commodity ordering
process, further practical work is needed.

Setting up commodity ordering for the Ugandan ARV health programme
and supporting functional needs from information stakeholders in the
system was possible. However, the software development itself was not
a straight forward task, illustrated by the many challenges faced during
development. These are summarised in table 7.3 on the facing page.

Workarounds were needed to handle the large amounts of data, which was
not well handled by DHIS2 components such as Event Reports. On large
data queries, performance issues challenged the development. Caused by
this, a need for using other DHIS2 data dissemination applications such
as Pivot Table emerged. As they did not natively support the needs for
system output, new workarounds were needed.

Retrieval of data in a flat structure from the Pivot Table application was
found possible, although this would not be adequate. The metadata
created in the Tracker setup proved to be less useful to structure the
data correctly in the Pivot Table, as the Tracker data structure was not
supported in the underlying analytical queries. Further, this issue needed
to be addressed in terms of further software development.

Moreover, to create the desired reports from the system, new and
cumbersome workarounds were necessary. As the tables could not be
retrieved simply from the internal DHIS2 components, generation of large
URLs for the underlying Analytics API was needed. This was error-prone,
making the reports more intricate than necessary. If table retrieval would
have been supported internally in DHIS2 for the Tracker data structures,
the creation of the reports would be simpler and much less error-prone.
Also, the need to render HTML tables from scratch inside the reports has
implications for the scalability of the reports: to change the structure of the
reports, extensive software changes and the technical expertise to change
them are needed.

Overall, the support for requirements in the ARV programme was only
possible because of the great flexibility offered by the modular architecture
used in the newer DHIS2 software generations (Staring & Titlestad,
<table>
<thead>
<tr>
<th>NO.</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Several workarounds needed</td>
</tr>
<tr>
<td>2</td>
<td>High data amounts of data</td>
</tr>
<tr>
<td>3</td>
<td>Performance issues with DHIS2 components</td>
</tr>
<tr>
<td>4</td>
<td>Supporting warehouse-specific periods and cycles</td>
</tr>
<tr>
<td>5</td>
<td>Comparing data will be difficult</td>
</tr>
<tr>
<td>6</td>
<td>Implementing patient reports in the forms</td>
</tr>
<tr>
<td>7</td>
<td>Data not shown on grouping</td>
</tr>
</tbody>
</table>

Table 7.3: Summary of software challenges in the commodity order setup for ARVs.

According to Staring and Titlestad (2008), system reports can be created by externally accessing system resources. The possibility to create third-party applications on top of DHIS2 (Staring & Titlestad, 2008) is both a strength and weakness at the same time: it makes special adjustments to a specific context possible (such as using it as LMIS in the ARV programme), but also makes changing the software dependent on higher skills required for the further evolution of the software.

Moreover, as the commodity orders follow a different rationality than in the typical health statistics reporting, this also created issues for the systems setup. For example, to support data entry for facilities, the warehouse-specific data, such as restricting data entry for one specific warehouse, is needed. Also, the ordering zones and cycles for the different warehouses need to be stored in DHIS2. However, as the current requirement for the reports is to view order data bi-monthly, this data is not needed for correctly displaying the information in the reports.

Overall, the process of circumventing issues mentioned above was cumbersome, showing that the Tracker module seems somewhat premature in supporting commodity orders out-of-the-box. Through system development, important characteristics of commodity orders need to be supported internally in the DHIS2 software to make commodity order setups less complex and error-prone.

Functions needed in DHIS2 to give better support commodity ordering for health programmes, includes (1) performance improvements in Event Reports on large orders, (2) support for displaying Tracker Data Elements on metadata groupings, (3) support for the specific ordering periods in
the logistics sector, and lastly (4) support for easily storing information on facility warehouse-connections.

7.2.2 Applicability of output requirements

Tightly connected to the technical applicability of Tracker is the support for output requirements in the system setup. The diversity in functional requirements underlines that various actors in the logistics sector also have widely different information needs. Moreover, it emphasises that DHIS2, as the LMIS, need to support quite different organisations and usage: facilities need to view orders or see order rate summaries, districts need overviews of facilities in order to re-distribute stock, warehouses need picking lists, and other national stakeholders use highly aggregated data for budgeting and planning.

This clearly illustrates the need for a central data warehouse making information available in several formats (Health Metrics Network, 2008), also applies for LMIS’. The power of the data warehouse lies in the endless possibilities for tailoring information from the orders to be useful for the diversity of user needs found in the health logistics system.

Initially, MoH provided four examples of reports used in WAOS, where three of them were implemented. DHIS2 Tracker as technical infrastructure was found to support data analysis from the order information in the ARV programme, even though several software-based workarounds were needed. As three out of four reports were created, the last report should also be possible to create from the Tracker data structure. Still, through evaluating the reports with a MoH representative, the warehouse-specificity still need to be catered for in a future development process.

In addition, three new reports were created, based on the information needs derived from the empirical data collection in Uganda. For example, the Re-distribution List was created out of the need to balance stocks at district and national level. The report was intended to elicit concrete actions to be made. As pointed out by Lippeveld (2001), a HIS need to be focused towards action-taking in order to maintain its
relevance. By the MoH representative, the new reports were considered as needed and wanted functions in the Ugandan ARV ordering system. Several suggestions for improving the relevance of the reports were also provided, indicating that the process of understanding requirements for a commodity ordering system is an ongoing process rather than having a fixed endpoint. The evaluation session indicated that there are still design-reality gaps present and that further evaluation of the outputs is needed, not only at MoH level, but also facility, district and other national stakeholders in order to remain useful.

As a technical note, a positive effect of the JavaScript-enabled Standard Reports was the great flexibility offered. This flexibility makes it possible to respond to diverse needs.

7.2.3 Learnings from the development process

In this section, an illustration of the complexities of developing software in DHIS2 for a Ugandan health programme is given through two concrete examples.

Improvements are often being made to the order forms for the ARV health programme. In the fall of 2016, we were given access to the current ARV order form. Months later, a new revision was administered. In the mid-spring of 2017, yet another order form came to our knowledge, where major alterations to the patient statistics largely changed the overall structure of the order form.

Through such rapid changes in order form characteristics, especially two factors are leading to complexity. The re-organisation of the patient statistics section in the newest version has great implications for the software solution. An altered software structure is needed to support the new forms.

Also, issues of backwards-compatibility arose for each new alteration of the order form: how do one compare data from different versions of the form, and for how long should old versions of the form be supported in the software before final detachment. In other words, the software development process became more complex for each new
revision, making it difficult to know what to implement, and when to implement it.

Another issue emerged during software development in DHIS2. The DHIS2 software has since its initial version been rapidly evolving, creating several generations of the software. The current public sector server runs one version of the software, the test server another, and the test server used for this thesis work yet another version. In the development process, the used test server was presumably hacked, thus requiring a re-installation. However, a side-effect of the re-installation caused a system breakdown for the commodity ordering setup, as a new version of the software was pushed to the test server. In this version, some of the software operations made were no longer supported in the system.

After discussions with DHIS2 developers, we concluded that the operations used in the web application probably will not be a part of newer versions of the software. As a result, reverting to an older version of the software was needed in order to finish development. However, this is not a sustainable solution. In other words, a restructuring of the application is needed, supporting the upcoming versions of the software.

Hanseth and Lyytinen’s (2010) characterisation of IIIs as an open and ever-evolving heterogeneous socio-technical system is a useful language to describe these two experiences from the software development process. As the examples indicate, the installed base can itself be considered as an influential actor in the evolution of IIIs. Actors with ever-changing needs, the multiplicity of software versions, and the myriad of different usages of the II, shows that multiple interacting heterogeneous elements have here made software development processes more complex and less manageable.

Hanseth and Lyytinen (2010, p. 4) points at the need for new additions to an II to be integrated and be made compatible with this ever growing intricate system. As new additions are made, such as a new commodity ordering system, one need to be careful not to disrupt other heterogeneous elements of the installed base. The inherent complexities of overlapping health system strengthening processes and large software bases, lead to challenges and delays in the development of information systems.
7.3 Reflections on the research conducted

The process of software development has required strict formalisations to be made. The formalisation resulted in a deeper understanding of logistics processes and the core structural characteristics of commodity orders.

In the methods chapter, our role as researchers from an industrialised country was briefly discussed. In the theoretical background, Heeks’ (2002) view on design-reality gaps was presented, where information system developers often tend to have a different vision of software and system than the actual users in the local context.

To minimise such gaps, understanding LMIS in the Ugandan context and understanding requirements have been done in participation with several primary users of the software, local and global HISP implementers, and in discussions with stakeholders in the health and logistics system of Uganda. Through this work, requirements were found different than first believed. We found that ordering commodities are not a process of specifying what is needed, but rather a thorough report on usage and needs, then used for planning distribution at the various levels.

Moreover, through visiting stakeholders at the different levels of the health system, output requirements were found to be more fine-grained than initially perceived. Hopefully, the empirical data collection in the multiple contexts in Uganda (urban areas, rural areas, warehouses etc.) has contributed to reducing the design-reality gaps between us as researchers and software developers and the Ugandan health logistics system actors.

However, such gaps are believed to still be present and need to be addressed as a part of future development. The reports evaluation session showed that software demonstrations and discussions with actual system users revealed that unresolved design-reality gaps still are present. Further evaluation sessions are needed at the different health system levels, and for the multiplicity of stakeholders in a health commodity ordering system. The crucial feedback from all system stakeholders is needed to further decrease the gaps between design and reality, and to
ensure that the information systems developed remain useful in the local context of use.
Chapter 8

Conclusion and future work

The purpose of this chapter is to summarise and conclude the findings and contributions of this research through answering the research questions, and present suggestions for future work.

Research question 1: What is the current status of the overall LMIS and health commodity ordering systems in Uganda?

The stock-outs occurrence of health commodities remains a large issue in the Ugandan health facilities. Health facilities were found to redistribute health commodities between themselves, indicating that overall distribution is not optimal and that improvements are needed in the overall Ugandan LMIS'. However, ad-hoc stock-out routines, such as referring patients to private pharmacies nearby, were found to increase access to medicines even though facilities report stock-outs. Overall, health system fragmentation was also found in the Ugandan logistics sector, creating a complex supply chain where multiple LMIS', commodity distributors and a public/private split, have negative effects for creating more comprehensive information in the health system. These structures are strictly guiding the further design and evolution of information systems in the country.

Logistics workers stated that the large commodity order forms were error-prone, potentially having detrimental effects on the overall data quality in the information system. The multiplicity of order forms has
also created complicated ordering processes for health logistics workers. Moreover, characteristics of the commodity orders in Uganda exhibit both possibilities and challenges in terms of standardising commodity ordering in the country. The order part was highly similar in most health programmes, while the part gathering patient statistics varied to a significant extent across programmes. Splitting up these two parts was therefore proposed as an improvement to support standardisation efforts.

Overall, the inherent complexities of the large installed base in the Ugandan health sector, all point at a rapid roll-out of digitalised and automated LMIS’ in all Ugandan health facilities as overly optimistic. This because it will depend on good coordination across strengthening efforts, and improvements to infrastructure and human resources. Nevertheless, a strong installed base is illustrated through the formal and informal routines found, all strengthening the health system. Examples include the warehouses and DHOs functioning as paper-to-digital gateways, and facilities managing stock re-distribution internally.

In Uganda, the widespread use and knowledge of DHIS2 in traditional health statistics, and now in the ARV programme, indicates that the software may function as an attractor bringing new stakeholders on board to create a more powerful data warehouse in the country. Still, several health facilities need to order health commodities using paper due to the limitations of poor infrastructure and low human resources, illustrating that challenges in the Ugandan health system are deep-rooted and interwoven. Nonetheless, the successful digitalisation of ARV order information has been possible in Uganda due to good routines, ultimately making data from facilities available in DHIS2 for creating more complete information in the LMIS. This illustrates that DHIS2 can be built upon for future development in the country.

**Research question 2: What is the applicability of DHIS2 Tracker to support ARV logistics requirements?**

The HMIS-software DHIS2 was found useful to function as commodity ordering system, and as a data warehouse for deriving useful information
from health commodity orders. DHIS2 Tracker was used as the underlying infrastructure for commodity orders, and to create reports as outputs from the system. Through this, the module was found to support the requirements found for the ARV health programme. However, several intricate workarounds were needed in the system development process, indicating that the module is premature to support large commodity order use cases. To give better support for commodity ordering in Tracker, four needed functions in DHIS2 have been proposed, to inform the future development:

2. Support to display Tracker Data Elements on metadata groupings.
3. Support for the specific ordering periods in the logistics sector.
4. Support for easily storing information on facility warehouse-connections.

DHIS2 Tracker shows promising characteristics of supporting the processes inherent in the logistics sector, as more data can be added in the different stages in Tracker. Moreover, the output requirements of a commodity ordering system for the ARV programme were found to not be final, as an evaluation of newly created reports showed that the outputs still can be improved to better support the decision-making processes in the logistics sector. This also illustrates that design-reality gaps are present not only in the proposed solution but also show that requirements gathering for the LMIS not necessarily will have a fixed end-point.

Lastly, the overall software development process showed that overlapping health system strengthening initiatives complicates strengthening processes in Uganda. It also showed that side-effects of the rapidly evolving DHIS2 software can emerge during development, such as compatibility issues across DHIS2 software generations, introducing challenges to the development process. In sum, the examples indicate that the heterogeneous components of the information system make software development processes more intricate.
Future work

Health commodity order forms were found similar across the Ugandan health programmes. Initial discussions indicate similar forms in use in Tanzania and Bangladesh, and a possible transferability of the proposed technical solutions to other countries would be valuable areas of research. The further examination and comparison of order form structures across other developing countries will create important insight, to greater inform standardisation processes. This will also be advantageous for creating more generic LMIS software, moving beyond a single country use case. Also interesting is that existing software applications such as openLMIS are intended to function exactly as a generic platform for commodity ordering processes. It would be fruitful to discuss in more detail whether DHIS2 as HMIS should be expanded to the field of LMIS, or rather be integrated with "pure" logistics software such as openLMIS. Similar strategies for functional architecting are also discussed in the work of Nielsen and Sæbø (2016).

Moreover, since several countries are working on digitising their LMIS, it is important to investigate different strategies for this. In Uganda, the chosen strategy has been to use DHIS2 as a digitalisation tool for health commodity ordering. An examination of whether other low and middle-income countries are currently undergoing similar processes of combining LMIS and HMIS in the same software would be intriguing. A comparison of different strategies to merge LMIS and HMIS would generate valuable insights for countries aiming at the same strategic goals of combining the two. It would also be beneficial to understand why countries have not combined these two.

Further, as data is available from both aggregate health statistics reporting and commodity reporting in the Ugandan DHIS2 data warehouse, understanding how to combine this data will be useful for potentially improving the information in the health information system as a whole. By looking into what compound indicators can be useful, the information basis for decision-making at the different levels in the health system can be improved.
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Appendices
RESULTAT AV MELDEPLIKTTEST: IKKE MELDEPLIKTIG

Du har oppgitt at hverken direkte eller indirekte personopplysninger skal registreres i forbindelse med prosjektet.

Når det ikke registreres personopplysninger, omfattes ikke prosjektet av meldeplikt, og du trenger ikke sende inn meldeskjema til oss.

Vi gjør oppmerksom på at dette er en veiledning basert på hvilke svar du selv har gitt i meldeplikttesten og ikke en formell vurdering.

*Til info: For at prosjektet ikke skal være meldepliktig, forutsetter vi at alle opplysninger som registreres elektronisk i forbindelse med prosjektet er anonyme.*

*Med anonyme opplysninger forstås opplysninger som ikke på noe vis kan identifisere enkeltpersoner i et datamateriale, hverken:*

- direkte via personentydige kjennetegn (som navn, personnummer, epostadresse el.)
- indirekte via kombinasjon av bakgrunnsvariabler (som bosted/institusjon, kjønn, alder osv.)
- via kode og koblingsnøkkel som viser til personopplysninger (f.eks. en navneliste)
- eller via gjenkjenning av ansikter e.l. på bilde eller videooptak.

*Vi forutsetter videre at navn/samtykkeerklæringer ikke knyttes til sensitive opplysninger.*

Med vennlig hilsen,

NSD Personvern
Interview guide

- understanding LMIS and commodity ordering at facility level

Introduction

• Presenting who we are, and why we are here.
• Who are you?
• What is your position/role at this facility?
• What does your typical workday look like?

Tools in use, ordering process and issues

• What tools do you use in your work?
  • How often do you use them?
  • Is DHIS2 a part of this? If not; why?

• Where do you order commodities from?
  • Do you follow a schedule for ordering? How does this look like?

  • Are there any differences in ordering methods for different health programmes?
  • How do you order ARVs for the HIV / AIDS health programme?
    • Would you like to show us the process for ordering commodities?
  • Do you get approval for your commodities? If this is the case; where do you get approval from, and how does this work in practice?

• In the current situation of commodity ordering: what is easy? what is difficult? what can be improved?
Appendix C - Evaluation guide

Plan for Reports evaluation session 10 / 04

Show reports as today

(1) Consumption Data Report
(2) Allocation Report
(3) Facility Stock Status Report

Discussion (for each report)

1. What is the essence in this report?
2. Who uses this report?
3. Is anything missing from this report?
4. Is the month-chooser necessary?

Show new reports based on requirements

(4) Order Summary Report

- Explain the underlying requirement behind this report
- Show for a facility, then the aggregations for districts
- Show colouring on aggregation type “average”

Discussion

1. Who would use such a report?
2. Is aggregation useful here?
3. Is colouring on average months of stock useful? Are the other aggregation types useful?
   1. Will colouring based on thresholds be useful at other fields in the orders?

(5) Re-Distribution List

- Explain the underlying requirement behind this report

Discussion

1. Who would use such a report?
2. Is the report useful for re-distribution of stocks? At district? At higher levels?
3. Are other parts of the orders also relevant for re-distribution (e.g., average monthly consumption) ?

(6) Expenditure Report

- Explain the underlying requirement behind this report

Discussion

1. Who would use such a report?
2. Is the report useful for planning at higher levels? Is it useful also at lower levels?
Tracker commodity order setup application

https://github.com/lmisuganda/ConfigurationLMIS

Debugger application for analysing Tracker design

https://github.com/lmisuganda/debuggingtool

Other resources (e.g., Standard Reports, scripts)

https://github.com/lmisuganda/Other-resources
Use case

LMIS: commodity ordering in Uganda using DHIS2 Tracker

Nicolai Hagen, UiO

Context
During the last year, two master thesis projects has focused on the development of a DHIS2 webapp for commodity ordering in Uganda, using the underlying DHIS2 Tracker logic. The webapp will consist of an own GUI communicating with the DHIS2 server.

Throughout this development, I have in my work used requirements from the current ordering in the ARV health programme (using Aggregate) to explore how Tracker can support these requirements. The ARV orders are quite large, containing 31 different formulations with 9 different data elements for each formulation — resulting in 279 data elements for collection. Further, patient reports are also a part of the ordering process in Uganda. As a result of this, I wish to point out two possible improvements for roadmap, for DHIS2 to better support this use case and similar ones. The issues identified are related to the outputs from DHIS2 after entering test-data through the new commodity ordering setup using Tracker.

Issues

<table>
<thead>
<tr>
<th>Issue NO.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Performance issues when generating tables in Event Reports (using Event Analytics) when total number of data elements are above around 50 elements</td>
</tr>
<tr>
<td>2</td>
<td>Data not present in Pivot Table when grouping Data Elements by Groups and Group Sets</td>
</tr>
</tbody>
</table>
**Issue 1**

As there are 279 data elements in total for each ARV order, I have experienced performance issues in Event Reports when trying to generate tables. Some large queries, such as retrieving the full orders, take up to 6 minutes for Event Analytics to respond. During the waiting period, the following error message occurs:

In Pivot table, the same query seem to have much better performance, taking approximately 1 second for it to finish. A performance improvement in Event Reports would be helpful for larger Tracker use cases, such as this one.

**Issue 2**

As a part of the development process, Groups and Group Sets has been created to structure the data so that the wanted tables can be created easily in Pivot Table. The tables are correctly shown, as illustrated below, but no data is present (even though the API and database shows that data is persisted). After discussions with developers, this seem to be caused by the fact that these are not ordinary data elements, but rather *event data items*. Analytics do not respond with the actual inputted data from this query. An excerpt for illustrating these tables is shown below:

![Table Example](image)

The current master thesis project solution is utilising the HTML Standard Reports alongside JavaScript, making several Analytics-queries to retrieve the data and show them in generated HTML tables to mimic the structure shown above. If the functionality was supported natively from the Pivot Table App, almost no special adjustment in JavaScript would be necessary in order to generate Standard Reports from Tables (other than actually retrieving the table from the API). This would make the Standard Reports needed for the ARV use case in Uganda much simpler to make.
### Allocation List -- All facility types

Select month (includes previous):

**2017 - February**

**District: Kampala**

<table>
<thead>
<tr>
<th>Drug code</th>
<th>Regimen</th>
<th>Packs ordered</th>
</tr>
</thead>
<tbody>
<tr>
<td>4161</td>
<td>Abacavir (ABC) 600mg</td>
<td>4</td>
</tr>
<tr>
<td>4093</td>
<td>Abacavir/Lamivudine (ABC/3TC) 800mg/300mg</td>
<td>3</td>
</tr>
<tr>
<td>4197</td>
<td>Abacavir/Lamivudine (ABC/3TC) 800mg/300mg</td>
<td>7</td>
</tr>
<tr>
<td>4089</td>
<td>Atazanavir/Ritonavir (ATV/r) 300mg/100mg</td>
<td>7</td>
</tr>
<tr>
<td>4242</td>
<td>Cotrimoxazole 1200mg</td>
<td>6</td>
</tr>
<tr>
<td>4233</td>
<td>Cotrimoxazole 400mg</td>
<td>3</td>
</tr>
<tr>
<td>4224</td>
<td>Cotrimoxazole 900mg</td>
<td>2</td>
</tr>
<tr>
<td>4278</td>
<td>Dapson 100mg</td>
<td>7</td>
</tr>
<tr>
<td>4188</td>
<td>Darunavir (DRV) 150mg</td>
<td>7</td>
</tr>
<tr>
<td>4179</td>
<td>Darunavir (DRV) 600mg</td>
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</tr>
<tr>
<td>4125</td>
<td>Efavirenz (EFV) 200mg</td>
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</tr>
<tr>
<td>4062</td>
<td>Efavirenz (EFV) 600mg</td>
<td>3</td>
</tr>
</tbody>
</table>
## Facility Stock Status Report -- All facility types

Select month (includes previous):

2017-02-03

### District: Kampala

<table>
<thead>
<tr>
<th>Drug code</th>
<th>Regimen</th>
<th>AMC</th>
<th>Months of stock</th>
<th>Packs Ordered</th>
</tr>
</thead>
<tbody>
<tr>
<td>4158</td>
<td>Abacavir (ABC) 600mg</td>
<td>5</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>4069</td>
<td>Abacavir/Lamivudine (ABC/3TC) 600mg/300mg</td>
<td>6</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>4104</td>
<td>Abacavir/Lamivudine (ABC/3TC) 600mg/300mg</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4077</td>
<td>Atazanavir/Ritonavir (ATV/r) 300mg/100mg</td>
<td>4</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>4239</td>
<td>Cotrimoxazole 120mg</td>
<td>2</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>4239</td>
<td>Cotrimoxazole 480mg</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>4221</td>
<td>Cotrimoxazole 960mg</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>4275</td>
<td>Diprosone 100mg</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>4185</td>
<td>Darunavir (DRV) 150mg</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4178</td>
<td>Darunavir (DRV) 600mg</td>
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<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4122</td>
<td>Etelviren (EFV) 200mg</td>
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<td>7</td>
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<tr>
<td>4059</td>
<td>Etelviren (EFV) 600mg</td>
<td>6</td>
<td>7</td>
<td>3</td>
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</table>
## Consumption Data Report

Select month (includes previous):

**2017 - February**

<table>
<thead>
<tr>
<th>District</th>
<th>Facility</th>
<th>Drug code</th>
<th>Regimen</th>
<th>Adjusted AMC</th>
<th>ART &amp; PMTCT Consumption</th>
<th>Closing Balance</th>
<th>Days out of stock</th>
<th>Losses / Adjustments</th>
<th>Months of stock on-hand</th>
<th>Opening balance</th>
<th>Quantity received</th>
<th>Quantity Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4158</td>
<td>Abacavir (ABC) 300mg</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4090</td>
<td>Abacavir/Lamivudine (ABC3TC) 300mg/300mg</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4104</td>
<td>Abacavir/Lamivudine (ABC3TC) 300mg/300mg</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4077</td>
<td>Abacavir/Ritonavir (ATR) 300mg/100mg</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4229</td>
<td>Cotrimoxazole 120mg</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4230</td>
<td>Cotrimoxazole 480mg</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4221</td>
<td>Cotrimoxazole 960mg</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4275</td>
<td>Dapsone 100mg</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Kampala</td>
<td>Example Facility 1</td>
<td>4185</td>
<td>Darunavir (DRV) 150mg</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>
ARV stock re-distribution list for Kampala

<table>
<thead>
<tr>
<th>Abacavir (ABC) 60mg</th>
<th>Facilities with months-of-stocks below 2 months of stock</th>
<th>Facilities with months-of-stock above 4 months of stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example Health Facility 1 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Example Health Facility 2 (5)</td>
<td>Example Health Facility 3 (6)</td>
<td>Example Health Facility 4 (8)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abacavir/Lamivudine (ABC/3TC) 600mg/300mg</th>
<th>Facilities with months-of-stocks below 2 months of stock</th>
<th>Facilities with months-of-stock above 4 months of stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example Health Facility 3 (1)</td>
<td>Example Health Facility 1 (2)</td>
<td>Example Health Facility 2 (7)</td>
</tr>
<tr>
<td>Example Health Facility 4 (1)</td>
<td></td>
<td>Example Health Facility 5 (6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abacavir/Lamivudine (ABC/3TC) 60mg/30mg</th>
<th>Facilities with months-of-stocks below 2 months of stock</th>
<th>Facilities with months-of-stock above 4 months of stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example Health Facility 4 (1)</td>
<td>Example Health Facility 1 (2)</td>
<td></td>
</tr>
</tbody>
</table>
2017 Expenditure Report for Kampala

<table>
<thead>
<tr>
<th>Regimen</th>
<th>Consumption (aggregated)</th>
<th>Price in USD</th>
<th>Total Expenditure 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abacavir (ABC) 60mg</td>
<td>45</td>
<td>3.75</td>
<td>168.75 USD</td>
</tr>
<tr>
<td>Abacavir/Lamivudine: (ABC/3TC) 600mg/300mg</td>
<td>57</td>
<td>3.75</td>
<td>213.75 USD</td>
</tr>
<tr>
<td>Abacavir/Lamivudine: (ABC/3TC) 60mg/30mg</td>
<td>50</td>
<td>3.75</td>
<td>187.50 USD</td>
</tr>
<tr>
<td>Atazanavir/Tipranavir (ATV/r) 300mg/100mg</td>
<td>50</td>
<td>3.75</td>
<td>187.50 USD</td>
</tr>
<tr>
<td>Cotrimoxazole 480mg</td>
<td>47</td>
<td>3.75</td>
<td>176.25 USD</td>
</tr>
<tr>
<td>Tenofovir/Lamivudine/Efavirenz (TDF/3TC/EFV) 300mg/300mg/600mg</td>
<td>40</td>
<td>3.75</td>
<td>150.00 USD</td>
</tr>
<tr>
<td>Tenofovir/Lamivudine (TDF/3TC) 300mg/300mg</td>
<td>57</td>
<td>3.75</td>
<td>213.75 USD</td>
</tr>
<tr>
<td>Zidovudine (AZT) 300mg</td>
<td>58</td>
<td>2.75</td>
<td>217.50 USD</td>
</tr>
<tr>
<td>Zidovudine/Lamivudine (AZT/3TC) 300mg/150mg</td>
<td>40</td>
<td>3.75</td>
<td>150.00 USD</td>
</tr>
<tr>
<td>Zidovudine/Lamivudine/Nevirapine (AZT3TC/NNV) 300mg/150mg/200mg</td>
<td>35</td>
<td>3.75</td>
<td>137.75 USD</td>
</tr>
<tr>
<td>Zidovudine/Lamivudine/Nevirapine (AZT3TC/NNV/60mg/30mg/50mg</td>
<td>45</td>
<td>3.75</td>
<td>168.75 USD</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>8,497.80 USD</strong></td>
</tr>
</tbody>
</table>
### Order Summary Report for Example Facility 1

Select month (includes previous):

- 2017 - February

<table>
<thead>
<tr>
<th>Drug Description</th>
<th>Adjusted AMC</th>
<th>ART &amp; PMTCT Consumption</th>
<th>Closing Balance</th>
<th>Days out of stock</th>
<th>Leases / Adjustments</th>
<th>Months of stock on-hand</th>
<th>Opening balance</th>
<th>Quantity received</th>
<th>Quantity Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adefovir (ABC) 60mg</td>
<td>7</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Adefovir, Lamivudine (ABC/3TC) 600mg/300mg</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Adefovir, Lamivudine (ABC/3TC) 600mg/300mg</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Adefovir/Ritonavir (ATV/r) 300mg/100mg</td>
<td>2</td>
<td>5</td>
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<td>4</td>
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<td>5</td>
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<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Complivaxol 220mg</td>
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<td>6</td>
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<td>5</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Complivaxol 480mg</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
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<td>4</td>
<td>1</td>
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<td>Complivaxol 960mg</td>
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<td>4</td>
<td>3</td>
<td>1</td>
<td>7</td>
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<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Disopen 100mg</td>
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<td>6</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Darunavir (CRV) 150mg</td>
<td>5</td>
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<td>5</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
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<td>Darunavir (CRV) 600mg</td>
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<td>5</td>
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<td>6</td>
<td>7</td>
<td>4</td>
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<td>Efavirenz (EFV) 600mg</td>
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<td>6</td>
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<td>5</td>
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<td>5</td>
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<td>Emtravirine (ETV) 100mg</td>
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<td>6</td>
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<td>1</td>
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<td>Fucorivaxol 200mg</td>
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<td>5</td>
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<td>3</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>
Order Summary Report for Region X

Select month (includes previous):

![March 2017](image)

Change aggregation type:

![Average](image)

<table>
<thead>
<tr>
<th></th>
<th>Adjusted AMC</th>
<th>ART &amp; PMTCT Consumption</th>
<th>Closing Balance</th>
<th>Days out of stock</th>
<th>Losses / Adjustments</th>
<th>Months of stock on hand</th>
<th>Opening Balance</th>
<th>Quantity received</th>
<th>Quantity Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abacavir (ABC) 60mg</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Abacavir, Lamivudine (ABC/3TC) 600mg/300mg</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
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<tr>
<td>Abacavir, Lamivudine (ABC/3TC) 60mg/300mg</td>
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<td>4</td>
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<td>2</td>
<td>5</td>
<td>3</td>
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<td>Abacavir, Lamivudine (ABC/3TC) 300mg/100mg</td>
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<td>3</td>
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<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
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<tr>
<td>ConnaMozole 120mg</td>
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<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>ConnaMozole 480mg</td>
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<td>3</td>
<td>4</td>
<td>3</td>
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<td>3</td>
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</tr>
<tr>
<td>ConnaMozole 660mg</td>
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<td>5</td>
<td>5</td>
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<td>5</td>
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<td>4</td>
</tr>
<tr>
<td>Daruvir (DMPV) 150mg</td>
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<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Daruvir (DMPV) 600mg</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Elektrix (BPV) 200mg</td>
<td>4</td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Appendix G - Academy certificate

CERTIFICATE OF SUCCESSFUL COMPLETION

This is to certify that
Mr. Nicolai August Hagen
has successfully completed the
DHIS2 ACADEMY EAST-AFRICA 2016, Tracker-level 1.

22nd - 26th August, 2016, Nobleza Hotel, Kigali, Rwanda.

Ministry of Health.

HISP Rwanda