Routine Child Vaccination in Uganda: Designing a vaccination service delivery model

Simon Karlsson

Department of Mechanical Engineering
Blekinge Institute of Technology
Karlskrona
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Abstract

This paper provides a new system model for delivering routine vaccination service in Uganda in low resource settings by incorporating the entire supporting infrastructure from vaccination suppliers to vaccination receivers. The model introduces ways of improving access, service quality as well as caretakers’ motivation to complete their children’s vaccination schedule. A system model design is provided together with graphical user interfaces for all agents in the new system.

Vaccination service is not easily available and too often not reliable due to rural health facilities being far away and in poor condition with few health workers, and because of an unreliable vaccine supply system [1], [2]. Outreaches are irregular and of ad-hoc character.

System wise, a geographically more centralized outreach program in direct connection to district vaccine stores could circumvent unreliable vaccine distribution channels and strengthen vaccine availability and quality. Families experience low motivation and knowledge about vaccination dates for their children to complete immunization programs [3]. Community Health Workers, coordinated with help of ICT, can be used to encourage families to complete vaccination and inform them on upcoming vaccination outreach sessions.

Qualitative research methodology, with methods including structured, semi-structured and unstructured interviews, observations and literature studies, was chosen to analyze and evaluate the current Ugandan vaccination system. An agile-like product development process was used as a framework for finding and evaluating concepts underlying the artifacts design which represents the system (e.g., GUI).

Outcomes of internal evaluations together with representatives of the client organization indicate that the new system can increase access and service quality. We conclude that the new system can cure several present issues in vaccination service delivery. However, further studies are needed to appreciate practical feasibility of the new system, for example by considering cost and ICT infrastructure.

Keywords:
Vaccination service delivery model, immunization, ICT, CHW, Community Health Workers, ICT4MPOWER.
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Thanks go to the Center of Infection and Immunity and Child Welfare Center in Karlskrona who not only answered questions in a detailed and clear manner but also allowed the project team to observe treatments of patients. We all felt very welcome. Thanks also go to all other companies and organizations which took my calls and answered my emails.

During the trip to Uganda, I was fortunate to meet with people who made the trip into both a professional and personal success. Thank you, Hugh Cameron, for all your help with setting up contacts. Thank you, Mary Ann Gleason, for taking us, a group of strangers, around health centres in Uganda for several days. The hospitality and generosity we were shown at the Saint Clare Orungo Health Centre, who despite limited resources provided us with both food and accommodation, is deeply cherished and will never be forgotten. Thanks also go to all people at these health centers who provided input to the thesis through interviews and displayed work. Also, thoughts especially go to all children around the Orungo health centre and surrounding villages.

I would like to extend my gratitude to all staff connected to the ICT4MPOWER-project which I had the opportunity of working together with. This thesis was a team work. Finally, I would like to thank my instructor at Karolinska, Rustam Nabiev, for all giving me the opportunity of doing this thesis and for all support and trust shown throughout the project.

Simon Karlsson
# Contents

Abstract .......................................................................................................................... 2  
Acknowledgements ........................................................................................................ 3  
Notation .......................................................................................................................... 6  
1 Introduction .................................................................................................................. 7  
1.1 Author’s contributions ............................................................................................. 7  
1.2 ICT4MPOWER: Relation to thesis work ............................................................... 8  
1.2.1 Background and members ............................................................................... 9  
1.3 Thesis pre-requisite: Objectives, scope, deliverables and guidelines .................. 9  
1.4 Thesis paper: Intended readers and deliverables delimitations ............................. 12  
1.5 Integrated Clinical Guidelines and Clinical Decision Support Systems ................. 13  
1.6 The topics .............................................................................................................. 13  
1.6.1 Vaccination ....................................................................................................... 13  
1.6.2 eHealth and mHealth ....................................................................................... 14  
1.7 Field study trip to Uganda ..................................................................................... 14  
2 Background .................................................................................................................. 15  
2.1 Motivation for thesis objective .............................................................................. 15  
2.2 Uganda from a health perspective ......................................................................... 16  
2.3 The Ugandan health system ................................................................................... 16  
2.3.1 Issues within the current health system ........................................................... 18  
2.4 The nature of vaccination and vaccination systems ............................................. 20  
2.4.1 Vaccine cold-chain management .................................................................... 20  
2.4.2 Ways to deliver vaccination ............................................................................ 20  
2.4.3 Routine child vaccination program in Uganda ................................................. 21  
2.5 The Ugandan vaccination system ......................................................................... 21  
2.5.1 Current model ................................................................................................ 21  
2.5.2 Management structure ................................................................................... 23  
2.5.3 Cornerstones of the Ugandan immunization program: Access, Service Quality and Demand ............................................................... 24  
2.5.4 Understanding the problems ......................................................................... 27  
3 Problem formulation ................................................................................................... 31  
4 Project purpose ........................................................................................................... 31  
4.1 Delimitations ......................................................................................................... 31  
5 Project goal .................................................................................................................. 32
# Notation

## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BPMN</td>
<td>Business Process Model Notation</td>
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<tr>
<td>CDC</td>
<td>Centers for Disease Control and Prevention</td>
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<td>CDSS</td>
<td>Clinical Decision Support System</td>
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<td>CHAT</td>
<td>Community Health Africa Trust</td>
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<td>CHC</td>
<td>Child Health Cards</td>
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<td>CV</td>
<td>Community Vaccinators</td>
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<td>CVS</td>
<td>Central Vaccine Store</td>
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<td>DHO</td>
<td>District Health Office</td>
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<td>DVS</td>
<td>District Vaccine Store</td>
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<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
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<tr>
<td>ICT4MPOWER</td>
<td>ICT for Medical Community Empowerment</td>
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<td>ICG</td>
<td>Integrated Clinical Guidelines</td>
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<tr>
<td>LC</td>
<td>Local Council</td>
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<td>MoH</td>
<td>Ministry of Health</td>
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<td>NID</td>
<td>National Immunization Days</td>
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<td>NMS</td>
<td>National Medical Store</td>
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<tr>
<td>UCC</td>
<td>Uganda Communications Commission</td>
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<tr>
<td>UNGASS</td>
<td>United Nations General Assembly Special Session</td>
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<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
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<tr>
<td>VHT</td>
<td>Village Health Team</td>
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<tr>
<td>VTC</td>
<td>Vaccination Traffic Coordinator</td>
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<td>VVM</td>
<td>Vaccine Vial Monitor</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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1  Introduction

My first constraint in finding a thesis topic was that it should potentially create true value for someone other than readers. That’s a big scope, and what is “value”? My guidelines for what was true value, was that it would be closer to human needs than “wants”.

When I took a university course which involved developing a Smartphone application from my part, it sparked an interest in me to find out how these rather new artifacts with their advanced yet readily available technology could be applied to serve and help satisfy human needs. The project thesis which I later came to work with contained this but also a lot more.

I applied for this thesis, which was put out in public for master students to apply for at xjobb.nu¹ by Karolinska University Hospital/Karolinska Institute. I was contacted by research engineer Rustam Nabiev, project coordinator for this and other similar theses initiated by the organization. After some discussion about the thesis objectives and my background and ability in relation to accomplishing these, I eventually was fortunate to be accepted.

1.1  Author’s contributions

This thesis paper is written solely by the main author, Simon Karlsson. However, the underlying work upon which the paper rests is equally contributed by the main author and my thesis partner, Rui Xui. Rui studies a master program in Design Interaction and Game Technologies at BTH, and his specialty in this work is related to creating graphical user interfaces. Therefore he has a report of his own: Human Computer Interaction Design for Mobile Vaccination Delivery System Analysis. Some work of his is, however, included in the section Graphical User Interfaces.

¹ Xjobb.nu is a Swedish website which houses theses in all fields put out by Swedish universities and companies
1.2 ICT4MPOWER: Relation to thesis work

This report is full, independent and *not* a part of another master project or other same-level thesis. However, the project was created to fit “the bigger picture” of a higher level project called ICT4MPOWER (*ICT for Medical Community Empowerment*). ICT4MPOWER is a project run as a joint collaboration between several Swedish organizations in an effort to assist the government of Uganda with expertise and technical support within the field of ICT (Information and Communications Technology) within the health system [4]. It initiates similar projects as this in other health areas with the intention to combine the results into one or several coherent systems. Other health areas in the project are maternal care, HIV and an electronic out-patient health record system (see Figure 1-1).

![Figure 1-1: Other applications within the ICT4MPOWER-project and the hierarchy between them](image)

The overall goal of the project is to improve the information flow from the community (lower levels) to the district (higher levels). It is believed that this can be achieved with applied ICT, therefore ICT4MPOWER has an ICT approach to all health areas within the project. Different software applications within the areas mentioned have been and are being developed as part of the project.

As with other applications in the project, if found successful, the results of this thesis might be further developed into a software application and eventually tested in a pilot study in Isingiro District, Uganda.
The instructor of the thesis for which the authors of this document are responsible for is Rustam Nabiev at Karolinska University Hospital, who is also the project coordinator for ICT4MPOWER.

1.2.1 Background and members

ICT4MPOWER is run as a joint collaboration between several Swedish organizations in an effort to assist Uganda with expertise and technical support within the field of ICT within the health system [4]. Uganda stands for half of the financing of the project (8 million SEK); SPIDER\(^2\) (the Swedish Program for ICT in Developing Regions), a Swedish non-profit organization, the other half. The activities in the project are not done by SPIDER, but by other Swedish organizations. Karolinska University Hospital is the main and connecting actor amongst these organizations.

The project was initiated by the government of Uganda (more specifically Uganda Communications Commission (UCC), the Ministry of Health (MoH) and the Ministry of ICT) as a response to Poverty Assessment reports which identified ill-health as the leading cause and consequence of poverty in Uganda. The idea is that the health service delivery in the rural communities of Uganda can be improved with the help of ICT, generally by improving current workflow processes in community health units and help bringing needed healthcare services to point-of-need [4]. Other Swedish institutions involved in ICT4MPOWER are Karolinska Institute, the Royal Institute of Technology (KTH) and Ericsson AB.

1.3 Thesis pre-requisite: Objectives, scope, deliverables and guidelines

Before the start of this project, a document was provided which was to be used as a starting point for the thesis work. It containes background, information, objectives and scope of the thesis, artifacts to create and guidelines to follow [5]. It is, however, important to note that not all deliverables are fully included in this paper but only provided to Karolinska and ICT4MPOWER (see section Thesis paper: Intended readers and

\(^2\) SPIDER is primarily financed by the Swedish International Development Cooperation (SIDA)
The thesis work objective is to create comprehensive and innovative vaccination service delivery model in low resource settings of Uganda by connecting the vital stakeholders which form a Healthcare Triad that consists of families, community health workers and healthcare delivery points. Hence, the project will apply mobile applications and clinical decision support system (CDSS) to enable better coordination and management of vaccination uptake by Healthcare Triad in rural Uganda.

Conceptually, the project can be divided into two parts: (1) a macro-level displaying an organizational structure with roles and responsibilities of stakeholders, and; (2) a micro-level which demonstrates the relationship and communication between stakeholders which enables them to execute their tasks as intended, as well as the details of the tasks they are responsible of.

Scope
The document states that in order to have sustainable results in the vaccination uptake programs, the entire supporting infrastructure with all the important stakeholders need to be considered. This includes:

- vaccination suppliers,
- logistics of vaccination and needed supplies,
- planning units,
- providers of the vaccination,
- information providers, and
- vaccination receivers

Deliverables: Artifacts
To represent the two parts of the model noted in Objectives above, ICT4MPOWER and the instructor requested five artifacts to be delivered. These are:
1) A Stakeholder system model, identifying the necessary stakeholders for delivering comprehensive vaccination services in low resource settings
2) *Process models and organizational structure model*, which provide a framework for innovative comprehensive vaccination service delivery in low resource settings

3) *Stakeholder informational needs*, necessary for successful collaboration between stakeholders

4) *Information flow model*, for automating information generation, supporting decision intensive processes and communication of right information to the right stakeholders at the right time

5) *Graphical User Interfaces*, for mobile applications (or non-mobile applications) for involved stakeholders

**Guidelines**

Guidelines provided by the instructor have been to be “innovative” and to find novel concepts. Specifically, we have been instructed not to be too concerned with what already exists today within health care to deliver vaccination service, since doing so might reduce our ability to think “outside the box”.

Finally, the importance of integrating “checks and balances” in all parts of the system has been explained. Specifically this refers to introducing ways which does not allow for a stakeholder to act alone without any form supervision or any way of confirming that a task was executed as intended.

**Roles and tasks**

Some specifics about potential roles and tasks of the pre-defined stakeholders – Community Health Workers (CHWs)/Village Health Teams\(^3\) (VHTs), families and HDPs – have also been provided. However, the final roles and tasks, and even stakeholders, must be derived from the overall purpose of the vaccination service delivery model. To define these purposes and to create a model which brings value, the details of the current vaccination system and issues in it need to be well understood. (This is mainly done in the section *The Ugandan vaccination system.*) Therefore, the provided roles and tasks of the stakeholders will be viewed more as guidelines.

CHWs exist in 75% of communities, are elected by the community and experience high confidence among the community’s inhabitants [1]. The definition of what constitutes a community is stated in a report to be arbitrary, but the report also suggests that it at least includes several villages and often whole parishes [6]. CHWs will act as a connection point between the families and health centers. Their role is to increase the awareness and motivation of

\(^3\) The terms “Village Health Team” and “Community Health Workers” are often used interchangeably by NGOs
the families to complete the vaccination program. They can make use of mobile applications with which they can perform the following tasks:

- registration of children;
- monitoring and follow up of the vaccination schedule;
- view where and when vaccinations services are offered;
- remind about upcoming vaccination for specific child;
- book appointment to health centers.

Integrated Clinical Guidelines (ICG) for CHW on child/infant vaccination will enable CHW to give appropriate recommendations and education regarding the benefits/risks of vaccination to the families.

Healthcare delivery points (HDPs) will perform the vaccination and will be the supporting point for CHWs. The mobile applications should connect the HDPs with CHWs to allow the information flow and joint collaboration regarding the vaccination uptake. With mobile applications HDPs can:

- register a child;
- create a vaccination plan for a child;
- register performed vaccinations and adverse events, and;
- order necessary vaccinations and other supplies based on the need from vaccination planning units.

Integrated clinical guidelines will facilitate health professionals in decision making and will provide the most current information and best practices in vaccination of infants/children

**1.4 Thesis paper: Intended readers and deliverables delimitations**

The purpose of this thesis work is to accomplish the objectives as defined in former section. The deliverables help display results and allows readers to evaluate the results. However, the purpose of the deliverables Stakeholder informational needs and Graphical User Interfaces are mainly for the use of (potential) future developers who uses them as a support for developing a real world application. This paper will not be read and used by developers; instead specific documents are produced for ICT4MPOWER which serves this purpose. These deliverables are also extensive and do not contribute to the
understanding of the thesis work. Therefore is Stakeholder informational needs excluded, and Graphical User Interfaces is only partly displayed to support understanding of some of the other work displayed in the paper.

1.5 Integrated Clinical Guidelines and Clinical Decision Support Systems

The objectives earlier states that integrated clinical guidelines as well as clinical decision support systems are to be integrated into the model. ICG is to provide evidence-based health related information CHWs and HDPs to help them make correct decisions regarding health care treatment. A CDSS can be thought of as background computer algorithm which based on different existing data can make conclusions in order to facilitate easier decision making for users. CDSS will be used for the Healthcare Triad to provide them with timely and accurate information on vaccination services.

It must be noted that ICG refers to external software or information which is integrated into an application and CDSS is a software application characteristic, thus it is not a thesis objective but a model objective (when developed) and will not be dealt with in the thesis.

1.6 The topics

1.6.1 Vaccination

Vaccination means providing a (here) a human with an antigenic\(^4\) material (i.e., a vaccine) which causes the person’s immune system to react and develop immunity to a disease.

When it comes to reducing the burden of infectious diseases, only clean water performs better than vaccination – including antibiotics \([7]\). The most obvious reason for having a well functioning immunization system with high vaccination coverage – the amount of people in percentage that receives one or a combination of vaccines – is to save the lives of people who are otherwise unprotected against the contagious diseases. But there are also other reasons: Many vaccine-preventable diseases are transmittable and affect the

\(^4\) An antigen is any substance that causes the immune system to produce antibodies against it
whole community. Another reason for attention is that related diseases are so easy preventable and reduces costs in the long term [8].

1.6.2 eHealth and mHealth

The precise meaning of the term “eHealth” is some what arbitrary, but often it refers to the use of computerized information systems and electronic communication incorporated into healthcare practices [9]. In other words, applications in ICT4MPOWER and also this thesis adhere to this area. Because of the arbitrary and broad definition of eHealth it is difficult to elaborate on its role in today’s healthcare, as well as its potential advantage and disadvantages.

mHealth is a sub-segment of eHealth and may deserve more attention since it is a more narrow field and also an integrated part to solve the thesis objective. mHealth stands for “Mobile Health” and includes the use of mobile communications such as PDAs and mobile phones within health services to improve health outcome [10]. An area mHealth is mobile applications, so called “apps”, which are software programs which utilizes the mobiles hardware to execute some form of task (e.g., taking photo, writing an SMS, playing games etc). In the health sector, these applications can for example be used by individuals to record health related information about a patient and then send the information to another system which stores it – perhaps to a bigger central eHealth system.

Many projects and pilots exist today within the field of mHealth [11], especially in developing countries which suffer from inadequate infrastructure but are progressing fast in mobile technology. Few have, however, yet utilized the potential of newer technologies, for example Smartphones, so the field is still rather unexplored.

1.7 Field study trip to Uganda

As part of the thesis work, the project team visited Uganda for two weeks in February. The aim of the trip was to find indications whether the hypothesis we had developed during the work process was valid, and in general also to develop a higher understanding of the current Uganda vaccination system. The trip lasted two weeks and provided us with valuable input for the thesis work as well as personal experiences and memories.
2 Background

2.1 Motivation for thesis objective

The area which this thesis will evolve around concerns immunization of children in rural areas of Uganda. Why does this area deserve a focus of attention?

The importance of a well functioning vaccination program has already been pointed out in the introduction: it saves lives and money [7], [8]. The Ugandan government is very well aware of this. In fact, the Ugandan Ministry of Health (MoH) has recognized that 75% of the disease burden in Uganda could be prevented through improved vaccination, hygiene and sanitation, good nutrition and other preventive measures [1].

The “goal” of the Ugandan National Expanded Program on Immunization (UNEPI), a government organ who initiates and develops policies and standards for immunization in Uganda, is that “every child” is fully vaccinated against the target diseases. The word “fully” here refers to completing a vaccination schedule – that is, several vaccines at different pre-defined points in time – each country has as a part of routine vaccination. (Information and details about the Ugandan vaccination schedule can be found in section The nature of vaccination and vaccination systems and Appendix A) Unfortunately, this is too vague, since a 100 percent coverage is not realistic. The United Nations General Assembly Special Session (UNGASS) has a more distinct and realistic goal for all nations: “full immunization of children under one year of age at 90%” [12]. One study conducted in 2010 showed that the amount of patients who completed the vaccination schedule – equivalent to coverage rate – was 75% [13]. Thus, well below both the goals of UNEPI and UNGASS. As a comparison, Sweden reaches +96% for all its planned vaccinations [14]. In addition, the WHO reports that the vaccination coverage of individual diseases are 73-86% depending on disease (here measles and tuberculosis, respectively) [15]. This is too low to stop spreading and eradication of the diseases which requires at least 75-94% (depending on disease), so disease outbreaks will continue [16]. (It should be noted that different numbers on coverage is reported from different sources; WHO was chosen since it is unbiased and officially acclaimed.)

Clearly there is a gap between the current vaccination performance and where it needs to be. One aim of this thesis is to find what might be the causes and deliver ways of closing the gap.
Before deep diving into the specific nature and reasons behind the causes for this issue a general understanding of Uganda from a health perspective is in place.

2.2 Uganda from a health perspective

Uganda is a financially poor country in east sub-Saharan Africa and ranks 161 on the global Human Development Index which considers factors such as health, education and living standards [17], [18]. The country population is approximately 35 million [19]. Progress is being made, and as an example the number of people living below the poverty line was reduced from 52% in 1992 to 31% in 2005 [1]. Likewise, the general health status has been reported to having increased [1].

Although Uganda is still a country with a lot of health related issues, things seem to be moving in the right direction.

The government has taken measures to improve the health situation of the people. Since 2001, all Ugandans are entitled to the Ugandan National Minimum Health Care Package (UNMHCP) free of charge at public facilities [1]. About 50% of health sector is public; the other 50% are private and often require patients to pay fees [20]. The private sector is sub-divided into Private For Profit and Private Not For Profit (i.e., religious institutions and international NGOs).

2.3 The Ugandan health system

Administratively, Uganda is divided into 80 districts which are further sub-divided into lower administrative units namely counties, sub-counties, parishes and villages. The last few years there has been an increase into even more districts by dividing existing ones and there are now over 100. In our work we will consider the existing districts and health facilities as they were before last increase of districts, that is, 80 districts.

The Ugandan health care system is characterized by a decentralized management system and different health care levels [21]. There are six plus one levels (top down) [1]:

16
• National Referral Hospitals,
• Regional Referral Hospitals,
• General Hospitals,
• Health Centre IV (HCIV),
• Health Centre III (HCIII),
• Health Centre II (HCII), and
• (plus one) Health Centre I – these are actually Community Health Workers/Village Health Teams.

(See Figure 2-1 of organizational structure below).

In general, the lower the level the more rural the location of the facility is and the less services are being offered.

HCIIIs and higher are suppose to deliver preventive care such as vaccination [1], but according to Dr. Eva Kabwongera\(^5\) who works for Unicef in Uganda and has insight to both the country’s and Unicef’s vaccination program, some HCII also offer this service (2012, interview, 17\(^{th}\) of February).

One notable characteristic with this system is that the only distinction between health units (i.e., hospitals and health centers) is the levels of health care service they are suppose to provide, and not type. An HC IV delivers the same care as HC III, and some more [1]. At least at lower levels, there are no specialized clinics, for example one place for only maternal care or antenatal care which is the case in Sweden. The system is indeed decentralized.

Managerially, the Districts Local Government is responsible for delivery of health services and monitoring of overall health sector performance of General hospitals and HC IVs, and sub-districts local government is responsible for the HC IIIs and lower levels [1] (see Figure 2-1).

\(^5\) Eva Kabwongera works as an upper-level health specialist at Unicef
2.3.1 Issues within the current health system

When examining the current health sector situation in Uganda, there are a few things which are striking: lack of professional staff (amount); allocation of available professional staff; bad work conditions of staff and facility disrepair.

Nearly half of the established positions within the health sector are vacant [1]. A reason for this is the “brain drain” to other countries, that is, nurses and
other professionals leaving Uganda to go to other countries, often Western ones, to work [22].

Another corresponding issue is the current allocation of professionals, in such that most professionals are working in the upper level parts of the health care system (e.g., national hospital) in the cities, and less are working in the lower level parts (e.g., health care centers) in the rural areas. This has lead to big vacancies in health facilities in rural areas (see Figure 2.2) in a country of which 85% of the population are rural inhabitants [23].

Figure 2-2: Vacant (in percent) positions in the health care system [1]

With a too low amount of people serving the needs of the population, rural especially, the staff is reported to be overworked and less motivated [24]. To make matters worse, the state of the health facilities are described as follows in latest (2010) annual performance report by the MoH:

“[Health facilities] (…) in a state of disrepair, do not have the required facilities for them to function effectively (e.g. staff housing, water and energy, theatres, equipment, stores etc) and required ICT and related infrastructure. These tend to compromise the efficiency, quality and access of these services.” [24].

Many facilities still lack reliable and sufficient electricity supply [1].
An additional issue for people in the rural areas is that only 72% live within “walking distance” (5km) to nearest health facility [1]. (The definition of 5 km as walking distance is made by the Ministry of Health.)

To summarize, only a limited amount of people live within good enough proximity to a health facility, and those who do and visit them are at risk to receive bad quality care if any care at all upon visit.

2.4 The nature of vaccination and vaccination systems

In order to fully understand the relevance of some work in this report which would otherwise be unclear, a few things concerning vaccinations and vaccination systems need to be explained and elaborated upon.

2.4.1 Vaccine cold-chain management

A characteristic of vaccines setting it apart from many other medicines in health care is that they need to be stored in certain temperatures to remain functional [25]. This presents a challenge both in terms of distribution as well as stationary storage since the chain of a properly regulated storage temperatures for vaccines must not be broken.

Most vaccines requires to be stored between +2°C and +8°C. They might still function, although for a much shorter period of time and possibly sub-optimally, at temperatures of up to around room temperature; if frozen they also lose potency and risk stop working completely [26].

2.4.2 Ways to deliver vaccination

In Sweden, most children receive their vaccinations at school as part of a national vaccination program which states when and what vaccines children are to receive. This is a routine vaccination type and done at a static facility. However, vaccinations can also be delivered through so called outreach programs where the person to administer the vaccine, often a nurse, goes to location of the person who is to receive the vaccine. This is sometimes the case when vaccines are not given as part of a routine vaccination program, for
instance at disease outbreaks and large masses of people require to be vaccinated quickly – so called mass vaccinations.

2.4.3 Routine child vaccination program in Uganda

There is an official routine child vaccination program in place in Uganda. Participation to this is, as in Sweden, not compulsory. However, occasionally there are so called National Immunization Days (NID) arranged in the country, where all people targeted for vaccinations may be forced to participate. The method of fetching people with brute force does not give vaccination procedures a good reputation and is another reason for making sure the routine programs works satisfactory for all parts.

All children follow the same vaccination schedule in Uganda. The MoH issues a so called Child Health Card (CHC) for health workers, which (among other things) specifies what types of vaccines a child requires and the intervals of when to provide it. See Appendix A for details on the CHC.

2.5 The Ugandan vaccination system

2.5.1 Current model

The current model for vaccination service delivery is depicted in Figure 2-3 below. A few things should be noted:

- Vaccines coming into the country are first stored in Entebbe, at the National Medical Store (NMS) [2]. The vaccine storage function of the NMS is sometimes referred to as the Central Vaccine Store (CVS) and will also be in this report.
- Vaccines and related material (e.g., syringes, needles etc) are transported from the Central Vaccine Store to the District Vaccine Store (DVS) to cover the needs for the whole district [27].
- Vaccines arrive to health facilities in two ways: (1) health facilities pick up vaccines at DVS, or (2) DVS deliver vaccines to the health facilities [2].
- Health facilities deliver vaccination service in one or two ways: (1) facility based, that is, at the health facility, or (2) through outreach
programs, that is, by vaccinating children where they live (e.g., village) [27].

Figure 2-3: The current vaccination service delivery model in Uganda. The arrows depict in what direction the actor travels to receive or provide service.

From the figure, one can depict that patients are supposed to be able to receive vaccinations at all levels. In other words, the vaccination service delivery in Uganda is operationally decentralized, as are the other parts of the health system [27].
2.5.2 Management structure

From a management perspective, the Ugandan vaccination system can be divided into two parts: (1) the national level run by UNEPI, and (2) the district and lower levels managed by the districts and health sub-districts local government [27] (see Figure 2-4).

**vaccine store**

![Figure 2-4: Current management structure](image)

UNEPI has several roles, including policy making, vaccine procurement and storage and distribution. They act on a national level, but are also suppose to “…ensure adequate and correct utilization of distributed guidelines at the District level.” [27]. In terms of storage and distribution, their responsibility ends after delivery to the districts.

The districts and health sub-districts are together (but of separate activities) in charge of [27]:

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23
• Forecasting vaccine demand from all immunization units (i.e., all health centers)
• Storage (at DVS) and distribution of vaccines and other material (e.g., gas cylinders for power) to all immunization units
• Technical support supervision of all immunization units
• Cold chain maintenance and repair
• (And more)

The individual health facilities are in charge of:

• Storage
• Static (facility based) and outreach operations
• Documenting outreaches, material usage, cold chain supervision, immunization data (e.g., wastage, coverage, drop-outs) and be able to report this to upper level
• Monthly analyze documentation and plan according to results
• Follow UNEPI operational guidelines for storage and immunization activities
• Educate families on vaccination
• Undertaking community mobilization to increase vaccination demand
• (And more)

2.5.3 Cornerstones of the Ugandan immunization program: Access, Service Quality and Demand

Information and specific documentation about the UNEPI, displaying detailed information about targets, goals and objectives seem scarce and fairly old. The latest documents we have found issued by the Ministry of Health and only contributed to the UNEPI dates back to 2003. Although the objectives seem unclear, a UNEPI financial plan states that the “aim” of the program is to [28]:

• increase access to immunization services,
• provide effective and potent vaccines, and
• increase demand for services
These aims are basically cornerstones for any immunization program: It has to be possible to receive vaccination, given vaccines need to work, and people must want to be vaccinated.

We wish to find out the performance status of current access, safe and potent vaccines and demand. By understanding potential issues within these areas, we can try to solve, improve or circumvent them when creating a new model. Unfortunately, no adequate extensive investigation and results about this have been found. This is not surprising since the vaccination operations are so spread out that an overall status report into these matters is difficult to make. Therefore, in order to assess the current vaccination service performance, one needs to look at other facts and figures.

To investigate these areas the factors that make up for them need to be found. However, first it needs to be defined what constitutes for example access. WHO has provided a service toolkit for the health care system for low income countries as guidelines for service delivery. They state [29]:

- Access include availability, which refer to “physical access or reachability of services that meet a minimum standard”
- Access include affordability, which refers to the “ability of the client to pay for the services”

(Access also holds acceptability, but this is instead accounted for in the separate Demand section.) Our interpretation of physical access is what the MoH defines as “walking distance”, that is, 5 kilometers to point-of-care. Further, we interpret “minimum standard” to mean that the client at least receives the tangibles of health care as expected, that is, an injection of the right vaccine. WHO points out that affordability from the client’s perspective is difficult to measure. However, cost has been cited as a barrier for people in Uganda in many areas and to highlight its importance in health service delivery it will be included.

We find UNEPI’s statement to provide “effective and potent vaccines” to be inadequate. Except for potency, we wish to include the right administration (e.g., technique) and providing the vaccination at the right time (i.e., in accordance with vaccination schedule). From the book Epidemiology & Prevention of Vaccine-Preventable Diseases, frequently cited by the American Centers for Disease Control and Prevention (CDC) the same conclusion can be derived [30]. These factors can all be categorized as “Service quality”. WHO’s service toolkit also provides guidelines and factors which decisively affect the outcome, so called determinants, of service quality. It suggests that it includes Effectiveness (e.g., ability to do the “right
thing” as the client perceives it), Safety, Patient centeredness (e.g., explaining things clearly and showing respect) and Timeliness (e.g., providing service care at the intended time). The WHO guidelines are specific for health care, but we consider suggested determinants of service quality to be fairly narrow and wish to complement them. Established literature related to the traditional service sector industry other than health care suggests similar but also additional determinants for service quality. Parasuraman suggests ten different determinants of service quality, six of which are not already included by WHO, these are [31]: Reliability (e.g., consistency of performance and dependability), Responsiveness (e.g., willingness or readiness of employees to provide service), Competence (e.g., possession of required skills and knowledge to perform service), Communication (e.g., keeping customers informed), Credibility (e.g., trustworthiness, believability, honesty) and Understanding/Knowing (e.g., understand the customer's needs by knowing their requirements). We believe that not all of these are relevant to the context of vaccination service delivery in low resource settings. Also, no attempt will be made to improve all areas of service quality; it would be too extensive and of low accuracy. Instead, which determinants to use for categorization and continue to work with is dependant on findings below. The approach of categorizing into determinants creates a terminology of economic nature and will hopefully help increase the understanding of the work for readers with economic background (which is likely for readers of this report).

The other side of the same coin of demand when discussing vaccination is “motivation” – the motivation of caretakers to have their children vaccinated. Different to access and service quality, the factors which make up for demand is not something you can readily “improve” (except for access and service quality which in them selves also affect demand), but something you need to adapt to. We aim to find what factors contribute to increasing or decreasing the demand for vaccination service.

Based on the new definitions above, we will re-define the UNEPI aims. They will also made more distinct in order to easier investigate their performance (this is, however, difficult to do with service quality and demand which is less tangible). The new definition is:

- A client has access to vaccination service delivery when service exists within 5 kilometers (physical access), can provide the right vaccine (minimum standard) on first visit and cost is low enough for a client to seek it.
• Service quality is only accomplished when at least provided vaccines are effective and potent, administered correctly and given at the right time.
• (For the sake of the investigation, demand does not need to be re-defined.)

In the next section the aim is to evaluate the performance of at least these factors but also more if found.

2.5.4 Understanding the problems

It is crucial to understand the issues with and within the current vaccination system in order to find a model which solves these problems or circumvents them.

The following information indicates the current access in the Ugandan vaccination system:
• Only 72% of the population lives within walking distance (5 km) of nearest health facility [1]
• Facilities are often in too great of disrepair to serve patients’ needs, and many of these are supposed to offer vaccination [1].
• Irregular outreaches are reported [1]
• Facilities sometimes experience vaccine stockout [2], which prevents patients from receiving vaccination as intended
• Public facilities offer vaccination service free of charge; private facilities often charge fees [20]. All service given at health centers might induce cost expenditure for transport for clients.

These facts and figures indicate that the access to vaccination service delivery needs to be improved. Further, we find these factors to be described by WHO and Parasuraman as Availability, Affordability and Reliability. Reliability is affected by vaccine stockout and facilities unable to provide care.

Vaccines are heat sensitive – cold and warm – and dependent on type they need to be kept between +2°C and +8°C or frozen (-15°C to -25°C) [26]. Some are also light sensitive. For a vaccine to work as intended, the vaccine needs to be alive and optimal, but also administered correctly, that is, with the right technique. We will first focus on the part regarding the vaccine itself.
To keep the vaccine alive and optimal it requires the proper handling mentioned above. Direct information about whether vaccines are “safe” when given is scarce. However, indirect information provides indicators. We do know that health facilities experience power shortages, much due to an insufficient supply of gas and gas cylinders [1]. We also observed this issue during a visit to one of the health centers in Uganda, where lack of gas forced the health unit to temporarily store the vaccines in carriers\textsuperscript{6}. During an outreach which we joined in another village, we also observed high temperature readings of a thermometer, due to a vaccine carrier which was missing the top isolation. In order to prevent the use of vaccines being overexposed to heat, all vaccine vials carries a \textit{Vaccine Vial Monitor} (VVM), which indicates by color if a vaccine has been subject to excessive heat [32]. However, even the use of VVMs is no guarantee for a safe vaccine since it requires staff to be trained to understand and use it as intended [33].

\textbf{Figure 2-5:} Picture of vaccines with Vaccine Vial Monitors [32]

\textsuperscript{6} Vaccine carriers are mainly used by staff or community health workers when performing vaccination outreach
To deliver vaccination service as intended, staff in charge needs to be properly trained and educated. In Uganda, nurses and midwives receive this training. Because of the insufficient amount and overworked staff (see *Issues within the current health system*) there is a risk of lack of competence when it comes to delivering the vaccination service [1], [24]. This has lead to the use of *community vaccinators* in some areas in Uganda. Little information and documentation about the extensive use and role of community vaccinators exist. (We met some of these vaccinators on our trip to Uganda, but we did not find out their precise role and background.) One report suggest that they are local people with or without prior education within the formal health system, who receive specialized training only for the purpose of delivering vaccination [34]. This approach can ease the strain of health workers. However, the extensiveness and quality of the education will decide the skill and competence of the vaccinators and ultimately the quality of care given. To our knowledge, there is no standardized education offered, and the same report informs that “…there is still a need for further training of the vaccinators to carry out proper growth monitoring of the children…” [34]. We are not in position to label this as unsafe, but evidence is needed to proof is as safe. Since we have not found this, we consider it a risk. We define this issue as a *competence* determinant [31].

Another factor related to vaccination service performance is *timeliness* – whether a vaccine is given within recommended time intervals from the dates in the vaccination schedule. Vaccine efficiency increases with timely
vaccination and helps to prevent disease outbreaks [35]. In comparison with coverage, this area is less studied and rather few reports exist. However, two studies on timeliness in vaccination delivery have been conducted in Uganda and South Africa. The main author of both studies was the same, which makes a strong case for comparing them. In Uganda ~35% of patients received vaccination within the recommended time period (all vaccines except measles), compared to ~64% in South Africa (again, all vaccines except measles) [13], [36]. This indicates that timeliness can and needs to be significantly improved in Uganda. We label this as timeliness in accordance with WHO [29].

Demand from caretakers (e.g., usually mother or father) to have their children vaccinated is equivalent to caretakers being motivated to bring their children for vaccination. We consider vaccination to be fully successful when the child completes the whole schedule in a timely manner.

We have found several barriers that often need to be overcome in order for a caretaker to allow for a child to complete the vaccination schedule which spans at least 9 months (see the CHC in Appendix A for more details). We have listed some of them below (note that not all barriers and determinants are listed; we have selected those which seem the most relevant for the thesis work and which are frequently cited):

- **perceived total cost**, including transport, fees (if private health facility) and under the table costs (private and public) [37];
- **traditions and cultural beliefs**, often meaning that the husband or other parts of the community other than the caretaker make decision whether to attend medical appointment [1], [37];
- **vaccine suspicion**, that is, caretakers being suspicious that vaccines will harm rather than protect the children [38], [39];
- lack of (vaccination related) **medical knowledge**, meaning for instance knowing when to receive next vaccination and possible side-effects of vaccines [3], and;
- **low motivation** (caretakers reported that they “not bothered”) [3].

(General formal education was also found to be a frequently cited barrier to seeking vaccination, but we consider it to be out of scope.)
3 Problem formulation

From the basis of the findings above, we concluded that the access and service quality in the current immunization program is in need of improvement. Likewise, we identified several barriers to demand which contributes to caretakers not attending vaccination or completing vaccination schedules. We believe that these are issues which all need to be dealt with or considered in order to create a well functioning immunization program.

We wish to increase access, service quality and demand. Then, more specifically, the questions we are interested in are:

- How availability, affordability and reliability can be increased, by considering physical access, frequency of access and service being available when patient seeks it (e.g., staff and material);
- How safety, competence and timeliness in service quality can be improved by considering current power shortage issues and shortage of qualified personal;
- How demand can be increased by considering barriers such as cost (affordability), traditions and cultural beliefs, vaccine suspicion, (lack of) medical knowledge and general low motivation.

4 Project purpose

The purpose of this project is to increase access, service quality and demand in the Ugandan routine vaccination program by creating a new conceptual vaccination service delivery model which incorporates the entire supporting infrastructure from vaccination suppliers to vaccination receivers.

4.1 Delimitations

A few delimitations in relation to the vaccination service delivery model should be noted, these are:

- Only children under five years of age are considered in the model
The model only deals with *routine* vaccinations; National Immunization Days are not considered. Eligible for routine vaccinations in Uganda are except for children also women between 15-45 and those pregnant [40]. These will, however, not be included into the model. This does not mean that the model cannot still handle these cases or that these people will not receive vaccinations in the real system. It is simply a delimitation to make the development process more focused by concentrating on the principles of the model.

5 Project goal

The goal is that the new vaccination service delivery model will make it practically possible for *all* children of Uganda to complete their vaccination schedules and doing so in a timely manner.

6 Methodology and Development process

The work of this thesis is characterized by combining the fields of both research and what closest can be described as new product development (e.g., a new vaccination model). Thus, research and product development process need to be integrated. More specifically, the research methods needs to be integrated into (parts of) the new product development process.

Both research methodology and product development process should be chosen to fit the purpose and objective of the thesis, and methods used within the research and development process should reflect instructor guidelines and other constraints.

6.1 Methodology and methods

The objective has been to create something *new*, specifically a vaccination service delivery model. When creating something new, rather than exploring (e.g., testing, evaluating etc) something already existing, *qualitative* research methodology is generally preferred to quantitative [41]. Methods within
qualitative research methodology usually include Observation, Field Notes, Reflexive Journals, Structured, Semi-structured and Unstructured Interviews, and Analysis of documents and materials [42].

The qualitative research is most prevalent in the early stages of this development process when the weight is put on data mining. Later in the process, specifically before, during and after concept generation, the thesis has a distinct element of analytical methodology. Also, as often the case when finding technical solutions to problems, the thesis uses applied research in the sense that already existing knowledge within study fields of the students’ (e.g., Business and ICT) is used as when generating and supporting new concepts.

All the methods earlier noted to belong to qualitative research will be used to some degree in this thesis. These methods will be applied at different stages of the development process (see Development Process for more details).

Analysis of documents will provide the greatest input to the work of this thesis, as oppose to mainly applying general theories within disciplines (e.g., Business and ICT) or basing findings on field experts’ opinions. There three main reasons for this: (1) For the new generated concepts to be truly novel, we should not too much consider already existing models and field opinions; (2) if the main effort is put on designing concepts built on general theories of disciplines from the perspective of the “western world”, there is a risk that finding will be incompatible with the real issues and solutions, and; (3) access to expertise within some areas is scarce mainly due to the constraints that follows from working with a project where people are geographically situated elsewhere (i.e., Uganda) and communication is technically unreliable. Also, the authors were advised to not seek input from certain sources which might provide unfavorable biased opinions. Analysis of documents provides the advantage of that it allows us to probe where we believe it is needed. To be confident that we do not “miss the target” which is a risk when working without detailed explicit rules, internal focus groups are used where findings are discussed (to be iterated) and new direction is given.

Interviews provide input to the work at early stages and late stages of development process. Through interviews we can learn about things on work on a micro level which are otherwise hard to find, such as the detailed process of providing vaccination or shipping goods from a warehouse terminal. More information about interview techniques used is found in the next section.

Observations and taking field notes are done at early and late stages of the development process. Observations can provide us with insight and understanding (as oppose to knowledge) which cannot be gained simply
through reading. The main observation input comes from the visits to health centers in Uganda.

### 6.1.1 Interviews methods

Types of interviews used are structured, semi-structured and unstructured.

Structured interviews are ready-made questions in a specific order, and no modification or addition of questions are done throughout the interview (this type was mostly done through email correspondence). Semi-structured interviews are ready-made questions initially at a specific order, but modification of sequence and content and additions of questions can be changed during the interview as a response the situation. Unstructured usually means that questions have not been prepared before an interview, most likely because it was unknown before that the interview would take place.

The authors have made use of telephone interviews; in person interviews; in person, observing work and work flow; presenting material and receiving feedback.

Literature used for supporting us in setting up interviews in a correct way are InterViews: Learning the Craft of Qualitative Research Interviewing [43] and a presentation on interviews named Interview as a method for qualitative research [44].

For regular semi-structured interviews, a template, constructed based on the recommendations from the literature, is used to make sure information about person profile is collected (including whether they agree to us using information for thesis work and later reference). Interviews are not recorded – instead the written material is summarized and sent back to interviewee who can confirm/change results.

### 6.1.2 Data mining

The documents used for analysis have mainly been found through the internet. To be more confident of the validity of sources, some specific sites have been of preferred usage. When finding “basic” information, such as a fact or figure, for instance, the vaccination percent coverage in Uganda, the principle has been to find that information where it is most likely to be valid and unbiased (i.e., the Unicef website). When other types of more complex information are sought, such as general discipline knowledge (e.g., business and ICT) or situation studies, Google Scholar, Google Books and libraries have been used.
Also used is the Ugandan MoH’s website for published resources which is to foster evidence-based decision making. The search strategy in Google Scholar has been to use those findings which seem relevant and has the highest “cited” number. Article/journal/study A is cited when Article/journal/study B refers to A in its work. Many citations for an article imply that it is well recognized by other authors.

Websites frequently used and cited:

- [who.int](http://who.int) – The World Health Organization’s website. The WHO conducts studies and recommends practices for health care often used in low resource countries, including Uganda. The WHO works on a strategic level.
- [unicef.org](http://unicef.org) – Unicef do work in areas related to health, education and equality with a focus on children. For this thesis, Unicef’s major input is within child immunization which it can be considered to be the biggest actor in within the developing world, especially in terms of operational actions.

Search engines used:

- [scholar.google.se/](http://scholar.google.se/)
- [books.google.com/](http://books.google.com/)

### 6.1.3 Support literature

The documents analyses provide both situational frameworks and detailed information which the work of the thesis builds upon. However, in some areas and situations there is a need for the support of general literature within discipline studied. Except for the interview literature already mentioned, the ones primarily used are:

- *Principles of Marketing* [45] – This is a comprehensive book on introduction to marketing on a higher level, widely recognized in the field. The role of marketing in this work is mainly prevalent in the area of promotion (e.g., promoting the new model to caretakers)
• *Logistik: Läran om effektiva materialflöden* [46] – Logistics is an integrated part of constructing a comprehensive vaccination service delivery model. The book can provide logistics principles which can be applied to confidently generate concepts related to logistics (e.g., storage and distribution).

• *New Products Management* [47] and *Product design and development* [48] – These books provide input to the use of a product development process as well as methods used within that process. See next section *Development process* for more details.

### 6.2 Development process

The team employs a process for conducting thesis work. The process provides a strategic direction for the team and helps structure work flow. It is extra important in this thesis to have a distinct process since it involves the creation of artifacts, similar to product creation.

The process chosen must fit the purpose the work and be familiar enough with the authors to enable good use. Because of the similarity between designing a conceptual model and creating a product we have looked at processes originally for this purpose. The process used was derived from the book *New Products Management*, which offers a general process from idea to development and launch, and also *Product design and development* which has a clearer focus on the product development (e.g., excluding marketing etc) [47], [48]. Since we do not develop neither a full product nor launches or market it, we only make use of parts of these two models. Both models before modification are shown below (Figure 6-1 and 6-2).
Figure 6-1: The development process model from New Products Management [47]
The purpose of this thesis is to create an “innovative” vaccination service delivery model, and we have been explicitly instructed to be creative and not look too much at already existing models. Finding novel results implies a specific development process and methods. One needs to use methods which entices creativity but also allows results to be quickly evaluated and potentially changed or discarded. Because of this we have chosen to work in an “agile” manner and thus adjusting the process accordingly. In practice, this means that we aim to develop concepts quickly and then evaluate them and iterate if needed.

6.2.1 Methods

For the concept generation we applied two methods: (1) brainstorming and (2) a “use case-GUI comparison”.

The brainstorming was done in steps – first individually then together and eventually reaching consensus. The choice of first doing it individually is that it tends to create less conformity and more radical concepts [47].

The use case-GUI comparison means that use cases (in text) are sketched, than a GUI is produced alongside to support it. When the actions are seen as they are eventually supposed to look for a stakeholder, it is easier to find what might be missing and haven’t been looked at, and it indicates whether the final solution will be feasible.

For evaluation, the main method used is “Internal focus groups”. This means that when the team requires feedback on new concepts (or other matters), a small group is gathered the results evaluated. Except for the authors, the group
consists of the thesis instructor as well as a few other members of the ICT4MPOWER project team. The instructor has valuable experience in the development of health service in Uganda and the team also employs GUI developers – together it makes up for good feedback.

Finally, to strengthen and evaluate agreed upon concepts, “Role play” is used. This is implemented by using use cases and GUI together as during concept generation, but by focusing on the details, for instance the information sent between stakeholders. This assures that nothing is left “hanging”; that the system is cohesive.

### 6.2.2 Process model

Based on the needs elaborated upon above – purpose, agility, methods – the process model is outlined below. The top row shows the stages of the process; the bottom line shows the methods used in that stage.

![Figure 6-3: The top level shows the process stages; the lower level the methods used in that stage](image)

1. **Research**: This part involves developing an understanding of the health care situation in Uganda from a macro level perspective
   a. Situation analysis through literature studies (present situation; problems, etc)
2. **Identifying needs and issues**: This part takes a micro level perspective, trying to find the details (needs and issues) of tasks executed by stakeholders, for instance the work of nurses and the process of vaccinating children.
3. **Concept generation**
   a. Concepts found through brainstorming then analyzed through use case-GUI comparison
4. **Evaluation**
   a. Step 3 and 4 iterates several times through internal focus groups until a concept is chosen.

5. **Trip: The trip to Uganda**
   a. Observations and interviews provide unique insights and understanding to the real work done around health centers and specifically within immunization

6. **Evaluate/Update**
   a. A final evaluation after the trip. If needed and time allows for it, changes will be made to earlier chosen concept.

### 6.3 Field study in Uganda

The aim of the trip to Uganda was to find indications whether the hypothesis we had developed during the process could work, and also to gain insight and develop a higher general understanding of the current Uganda vaccination system.

The objectives set out to achieve this was to

- Receive feedback on model
- Receive feedback business processes
- Visit DVSs
- Visit health centers
- Travel to villages
- Visit villages, and
- Receive feedback on GUI

All but receiving feedback on business processes and GUI was accomplished to some agree. The instructor was satisfied with what we accomplished and we consider the trip a success.

Data was collected through semi-structured and unstructured interviews and observations.

The record of observations and interviews conducted in the trip is as follows:

- Meeting with Eva Kabwongera at Unicef (head of Health/Nutrition team)
• Interviewed Mary Ann, volunteer nurse at HC3 in Ococia
• Interviewed nurses and CHWs at Ococia
• Visited a RRH in Mbale
• Visited vaccination unit at HC3 in Mbale
• Short visit to Health District Office (i.e., DVS) in Mbale
• 2-day visit at HC3 in Ococia (Amuria District) (NGO run)
• Visited a village around Ococia
• Joined an outreach around Ococia

The trip only lasted two weeks which is obviously a too short of time to draw big and final conclusions. However, most of the information we got out from the trip seemed to support our prior findings and only small details in the model, mostly concerning the GUI, required changing. A few examples depicts this: We were worried that a CHW would have trouble finding the homes of families and before the trip a lot of time was spent arguing what and how address information should be displayed to the CHW. We found, however, that CHWs seemed to know their surroundings very well, and all houses in villages had paths between them which made them easy to find. We also found the DVS to be fairly small with not much daily action in terms of deliveries. We were worried before how our work processes at the DVS could practically be integrated into daily work, but our findings pointed to that it would not be a major issue.

6.4 Interviews conducted

Interviews were used at several stages of the development process. Below follows an account for what departments, companies or areas in which interviews were conducted. Also stated is during what part of the development process they took place and the interview methods used. For a full display of people interviewed and their contact information, see Interview references section.

<table>
<thead>
<tr>
<th>Department, company or area</th>
<th>Development stage</th>
<th>Interview method</th>
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<tr>
<td>Center of Infection and Immunity and Child Welfare Center</td>
<td>Needs identification (2)</td>
<td>Semi-structured</td>
</tr>
<tr>
<td>Logistics companies</td>
<td>Needs identification (2) and Concept generation</td>
<td>Structured; Semi-structured</td>
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Center of Infection and Immunity and Child Welfare Center
In order to develop processes and tasks involved in performing vaccinations one needs to have a proper understanding of the practical work performed by nurses. Deeper understanding of otherwise unknown areas is often gained through observation and interview with the people involved; this was the reason for visiting infections centers in Karlskrona. Several nurses and a doctor were interviewed, and treatment of clients was observed.

A lot was learned from the visits. Perhaps the most valuable information received was that serious adverse events due to allergic reactions were extremely rare and either way could not easily be found out in low resource settings since blood samples were needed. There were also mixed opinions whether people with no previous medical training could perform vaccinations in a correct way.

Logistics companies
The purpose of contacting companies within the logistics sector was mainly to learn about cold-chain management and work details in the storage warehouse. In addition, Logistimo, an Indian company offering a service product which enables low-price supply chain management in developing countries through the use of low-end mobile phones, was asked to review some concepts to confirm whether they were technically feasible.

Details about warehouse storage tasks were learned which served as input to the model later developed. Through the interviews with Logistimo we also learned that concepts were technically feasible; similar features and functions were used in their product today.

CHAT (Outreach program)
When the idea of using outreach programs as a part in the model was brought up, there was a need to find out more about the nature of this concept. An organization, called Community Health Africa Trust (CHAT), involved with bring health care to rural parts of Kenya was found. The program director of CHAT, Shanni Wreford-Smith, was very helpful in answering questions regarding outreach programs through email.
The most valuable things learned from the correspondence with Shanni, was that it was normal for them to stay out for many days at a time (which might be needed for an outreach program), and that outreaches was normally reliable enough to show up on a designated location at a pre-defined time.

Field study Uganda
During the two weeks in Uganda, people were interviewed at health centers, villages, a hospital and a District Vaccine Store. This included nurses, midwives, CHWs and Local Councils. In addition, a meeting was conducted with Unicef.

The interviews with people around health centers especially provided input regarding details of tasks and documents they used for inventory tracking (which provided input to the GUI). Interestingly, during the meeting with Unicef we found out that in their process of re-thinking ways of delivering vaccinations they were considering similar concepts to what was developed by the thesis team. Unicef asked to be shown some of the GUIs developed.

All together the interviews increased our understanding of common ways of reasoning and tackling tasks among stakeholders.

7 Analysis
This thesis conceptually consists of two parts – macro perspective and micro perspective. The macro solutions – the big picture with stakeholders and tasks – set the framework for the micro solutions – the details of how stakeholders work and what they deliver. In our work process of analyzing identified issues and delivering a “solutions-package” in the form of a designed service delivery model, we have iterated between the macro and micro world. The two main reasons for this are insufficient information at the time of the analysis and incompatibility between perspectives – a solution fit from a macro perspective is not fit to implement from a micro perspective, and vice versa.

Displaying the detailed process of iteration between macro-micro perspectives will be overwhelming and confusing for the reader and at the end the motivation for the final solution risk being unclear. For this reason, we have decided to part the analysis and conclusion into two parts: One analysis from a macro perspective; one from a micro perspective. This analysis section and the next conclusion section will mainly evolve around macro matters and thus macro solutions. In the deliverables section following the conclusion, we
will deliver full results – macro and micro – and motivate the details (i.e., analysis and conclusion).

Note that this analysis section only displays the analysis which forms the basis of final conclusion and solution. In the discussion following the Analysis conclusion section, other alternatives which were considered during the development process are laid out.

Discussion

We have earlier identified access, service quality and demand to be the cornerstones of the Ugandan vaccination system, and similarly derived factors making up for these, for example availability and safety. We will continue on this path and analyze these factors below.

7.1 Access

Because access involves multiple factors – availability (e.g., physical access), reliability (services being available when sought for) and affordability – it’s intuitive that improvement requires a multi-factor solution approach. Below we will analyze these factors to see whether our intuition holds and if we can find directions on how to improve access.

Vaccination service availability can be provided in two ways: (1) Static facility based, and (2) outreach based.

Currently, only 72% of people live in Uganda within 5 kilometers from a health facility. It should also be noted that HC IIs don’t offer static vaccination service because they have no electricity supply (E Kabwongera 2012, interview, 17th of February). (Some, however, do outreach programs by first collecting vaccines from nearby higher-level health centers.) Even if all currently existing health centers could be used, there would still be 28% of the population without full availability to vaccination.

If all health facilities could offer outreach programs, which is not the case today [24] due to insufficient funds, all children could in theory experience full availability to vaccination services since a mobile unit can cover a bigger area than 5 kilometers. There are, however, three major issues involved in doing so: Funds, staff and material supply (i.e., reliability). It will take a lot of money and time – years – before all health facilities in Uganda can (not certain if they ever will) be equipped with the staff and transport means needed. Further, supply of material from higher levels is a problem. The Ministry of Health quotes two studies regarding the matter: One showed that
“…only 45.7% of the public health facilities had key essential medicines; the situation was a bit better in mission facilities at 57.5% and private facilities at 56.3%” [1]. Another study showed that “…even though 72% of the households were close to a public health care facility, only 33% of the households believe that medicines are available in public health care facilities”. In other words, material-supply is not only scarce, but people also know about it which might cause them to cancel a planned and needed visit.

The connection between the different factors is evident and the conclusion clear: Fixing one issue will not provide full access.

Apart from the strategic and financial shortcomings of implementing vaccination outreach at all health facilities, outreach programs do offer several advantages: They can cover a wider area than can a static health facility due to mobility; they seem to be preferred by village inhabitants, and; they can be deployed now, without necessarily constructing a new health facility.

In one study concerning vaccination in Uganda, which main purpose was to find caretaker constraints to immunization, showed that among those who received vaccinations through outreach service, more completed the schedule than did they who received through static facilities [3]. The potential underlying reasons for this were not revealed. However, during our visit to health centers and villages in Uganda the information was confirmed from local people. A Local Council (LC 1), a person who can be described as the “head of the village” and who possess insight to families’ general attitudes, told us that people accept outreaches more than they do facility based which requires them to seek care far from home (Michael 2012, interview, 23rd of February). As noted earlier, however, it is not enough to secure outreach to all people mainly because of issues with material supply – what good does an outreach do if you cannot bring vaccines. We will now look at logistics to find the reasons behind this.

### 7.1.1 Logistics

A logistics assessment report conducted by the United States Agency for International Development (USAID) concluded the following:

[A Local Council is a form of local elected government within the districts of Uganda. The lowest level is the Local Council I, and is responsible for a village.]
• Structures for effective management of logistics information is in place with clear guidelines for staff responsible for logistics management, but information is never reported or captured adequately at the facility level [2]. Health facility staff is busy with other roles and don’t give adequate attention to logistics activities [2].

• There were no established and documented systems or schedules for distribution of supplies from the districts to the lower-level units, and where a schedule did exist, they were not being followed [2]. They further concluded that “distribution of supplies is done on ad hoc basis” [2], and that this in part explained why some facilities had stockouts [2].

The dysfunctional logistics operations leading to stockouts were due to inadequate task implementation both at district and health unit level, partly due to staff too overwhelmed with other tasks. Not only does this show that the logistics system is unreliable, but the underlying factors also indicates that extensive measures are required to mitigate issues. If possible, it might be preferred to instead avoid the involvement of current stakeholders with their current roles and tasks.

One thing which was encouraging with the USAID report was that the use of expired vaccines was concluded to not be of great issues [2]. This was also confirmed by Dr. Eva Kabwongera in our interview (2012, interview, 17th of February).

7.2 Service Quality

In this section we analyze the different factors we have identified and defined to make up for service quality in the Ugandan vaccination system: safety, competence and timeliness. Each factor is analyzed separately below.

To make sure a vaccine is safe to administer, it needs to be properly stored and handled. This requires both physical means, such as correct cooling, and human resources for maintenance (of vaccines).

Proper cooling requires well functioning cooling equipment, that is, fridge and freezer, and an adequate supply of electric power. An issue with the use of this equipment in rural areas is maintenance and repair. In fact, according to an annual MoH report (2008/2009), among all health facilities only 40% of available equipments were in good condition and about 17% were reported to
be in need of replacement [1]. The responsibility of maintaining cooling equipment is on district level [27]. There seem to be a gap of information and resources between health units and districts to provide the service needed, as seen before concerning logistics. This gap also plays its role – although not alone – when it comes to delivering sufficient and reliable power to health units. The Ministry of Health has already concluded that gas distribution is irregular [1], and the report from USAID suggested that this was due to district staff not following distribution guidelines and health facilities not reporting accurately and quick enough to higher levels [2].

To maintain the stored vaccines as intended, human resources are needed. This maintenance is quite extensive: The UNEPI, through the MoH, has provided 13 points related to daily maintenance of vaccines at the facility (and seven for outreaches), including, for instance, using the earliest expiry dated vaccines, checking fridge temperatures and maintaining vaccine ledgers (e.g., vaccine and supplies control book) [27]. When considering the insufficient amount of staff prevalent in most health facilities, this can be a daunting task. We believe that this creates condition for an environment where vaccines are prone to mishandling.

We have identified a competence related risk in administering vaccination with the current situation considering an insufficient amount of skilled health workers and uncertain education and use of community vaccinators.

The issue of not enough formally educated staff within immunization (e.g., nurses and midwives) will be around for a long time. WHO has actually projected the situation to get worse, with even less health workers (physicians, nurses and midwives) per inhabitant in the coming years due to too few new workers being trained [49]. The concept of using community vaccinators, then, becomes interesting.

CVs can help ease the strain of health workers, and, in fact, the method of using non-formally educated people to do work traditionally done by nurses is used to some extent today within the area of HIV/AIDS. The concept is referred to as “task shifting”, and often practically means (here) that lower-level workers take over tasks which are traditionally done by higher-level workers [50]. For instance: A nurse taking over tasks from a physician, or a CHW doing the work of a nurse. However, there are things we believe need to be considered before scaling such approach in a vaccination system. First, the education provided to CVs must be adequate and standardized to ensure that workers posses the needed skills. Such a system will, at least initially, require regular control and evaluation from higher level to asses whether vaccination services are up to the intended standards. This might prove difficult in
practice, considering the already current gap between districts and health units. Another question one must ask is also if this is something a country should strive for to make permanent – after all, we must assume that the current roles of nurses and midwives are there for good reasons. To summarize, the approach of scaled-up and system integrated task shifting holds many uncertainties – can a vaccination system relying on it be considered solid?

We reported earlier of studies indicating poor vaccination service timeliness in the Ugandan vaccination system today (see Understanding the Problems). The only found determinant to timely vaccination was that higher formal education was connected to high timeliness [13]. Other suggestions (but not proven in study) to correlations of timeliness were sufficient vaccine stock (positive), inadequate staffing (negative) and phone or text message reminders (positive).

Today, mothers are given official Child Health Cards upon their child’s first given vaccination. On the CHC, the health workers write the date of when next vaccination is to be received. This is one way used to improve the chance of a vaccine being given timely. According to both the study above and the experience from our trip, most mothers (though not all) manage to keep and bring these cards to their vaccination visits.

There are, however, some issues with this approach. One problem is, as often, supply – clinics sometimes run out of CHC because of insufficient distribution (Nurse\textsuperscript{8} 2012, interview, 22\textsuperscript{nd} of February). (In these cases a notebook is, if available, provided to mothers in which information is manually written.) Another issue which we were told during interviews conducted was that mothers sometimes miss the dates and show up a few days later. The reason, we were told, was that many could not read and were reliant on others who could tell them (M-A Gleason\textsuperscript{9} 2012, interview, 22\textsuperscript{nd} of February). It is not surprising that dates are missed considering that the time between vaccinations sessions are around six weeks.

Where we spent most of our field work time in Uganda, a health center in Amuria District, some other methods for gathering families to vaccination session were used. Two community health workers, who were referred to as “mobilizers”, told us about this work. One week before, on a church day (i.e., Sunday), a planned outreach was to take place in a nearby village they would tell everyone in the church about the upcoming vaccination session (Charles

\textsuperscript{8} Nurse (no name taken) working with immunization at Mbale hospital, Mbale District

\textsuperscript{9} Mary Ann Gleason is an American volunteer nurse who has been working in health centers in Uganda the last 4½ years
This acts as a reminder and should provide positive results, although no data on effectiveness exists. It is, however, not a bullet proof method: All people might not go to church; some caretakers might be sick on church day; caretakers might still not check their schedule, or, if they can’t read, forget to ask someone to read it to them, or; caretakers might not feel obligated enough to adhere to recommendations when an announcement is broadcasted rather then told to face-to-face.

If enough information is known about the client, promotion can be made more customized and interactive than currently today to make promotion more persuasive and thus effective [45]. We believe the element of persuasiveness is much needed in promotion. The approach of reminding individuals in a timely fashion is theoretically possible already today since facilities keep record of given vaccinations and know when the next one is due, it is just not pursued.

### 7.3 Demand

There can be any number of reasons for why a caretaker does not follow through on the child’s vaccination schedule – it can be a choice or, as noted earlier, due to lack of accurate and timely information. Many barriers to demand was found, but we finally settled on five which were frequently cited or we considered solvable in this thesis work. The five were: perceived total cost; traditions and cultural beliefs; vaccine suspicion; (lack of) medical knowledge, and; low motivation. Some of these may also be linked together.

Lack of medical knowledge within immunization for one’s child, means that a caretaker does not know about standards of procedures, such as scheduled times of vaccination, or understands the medical basis of vaccines, for instance how it works and of possible side-effects. This can cause a caretaker not to undertake vaccination. This existing issue indicates that caretakers don’t receive enough adequate education about the role and importance of vaccination, and that the system of informing about upcoming sessions needs to be improved.

The meaning of general “low motivation” is vague, and the study reporting this issue did not go deeper than to say that caretakers “not bothered” or were “reluctant”. We cannot claim to know all thoughts and feelings of local people surrounding this issue, that is for sure. However, during the outreach we

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10 Community Health Workers at Saint Clare Orungo Health Centre III, working as "mobilizers"
joined, we asked the health workers about how one can increase the amount of people showing up for vaccination. They all agreed that if people were offered some food or entertainment, much more people would show up (Nurse and students\textsuperscript{11} 2012, interview, 25\textsuperscript{th} of February). Providing incentives other than medical for families was brought up early in this work by our instructor and is something that should be considered.

\textit{Traditions and cultural beliefs, vaccine suspicion and perceived total cost} are each barriers in themselves, but there is also a connection between them. Vaccine suspicion – local people fearing that vaccines will harm their children rather then helping them – is something which exists in places in Uganda, particularly in the Eastern parts of the country. We were encouraged to hear from a CHW that education often helps to reduce suspicion among families (Charles 2012, interview, 23\textsuperscript{rd} of February). We believe, however, that if deep rooted and sustainable progress of immunization is to be made, one needs to be cautious about considering education of caretakers, most often mothers, about vaccines as a final “fix”. You don’t need a certain culture to find something suspicious or too expensive, but in Uganda, traditions and culture will play a role in the decision making process which finally decides the action towards these matters. Unicef stresses the importance of “community partnerships”, especially in low income countries. It implies that matters are not solved through independent and separate actions to a community or individual groups in it, but by involving the community and also to work between programs – in other words to emphasize a holistic approach \textsuperscript{[51]}. This thesis can not offer a full scale solution for this (we rather “treat the symptoms”), but it needs to be in the mind of future implementers.

8 Analysis conclusion

Based on our analysis, we have reached some conclusions and derived a set of macro solutions which can potentially improve the areas of access, service quality and demand. In short these are:

- Availability, reliability, safety, competence and potentially affordability can be improved through a more centralized outreach program, which uses District Vaccine Stores as base points and serves areas of 5 km in radius throughout the district

\textsuperscript{11} Nurse (Naomi) and students at Saint Clare Orungo Health Centre III
• Individual and timely reminders for caretakers should be used to increase vaccination timeliness
• Education of caretakers regarding principles of vaccination and the importance of completing vaccination schedules should be an integrated part of the vaccination system
• Opportunities for offering families incentives other than medical to attend vaccination should be considered

The approach of a centralized outreach program can grant full physical access to services by never being longer than 5 km from clients. Opposite to facility-based care who will require many years before being physically available to all people, mobile units can be developed and implemented now. As noted in the analysis, outreach services also seem to be the preferred service method by village inhabitants.

Reliability would be strengthened by cutting off the weak distribution line between districts and health units. Instead, reliability would only be dependent of Central Store-DVS delivery. The current, and believed to be future, logistic issues – poor distribution of vaccine material and power supply equipment (gas and gas cylinders) from district level, and inadequate information record keeping and reporting from health units due to overworked staff – are too big and deeply entrenched to overlook nor improve in their principal current state.

The two factors we defined contributing to vaccine safety in the analysis – physical means and human resources – can both improved by centralizing the vaccination. Today, maintenance and repair is difficult to manage partly because information and material resource gaps between districts-health units, partly because there are so many health units per district. One big facility might require more extensive management, but being only one and geographically closer to service repair outweighs this. In the perspective of human resources involved in vaccine maintenance, this could be made more safe and efficient with centralization. With only one vaccination service unit per district it would serve many children, making maintenance a full time job and thus enabling specialization and distinct work tasks.

Competence wise we believe that vaccination performance should be done by a formally educated nurse. Similar to vaccine maintenance, the many children served per vaccination service unit theoretically increases nurse utilization efficiency. It is generally supported within health care that the principle of shared resources is used when there is considerable pressure to achieve economies of scale [52]. At the same time, tasks related to vaccination are removed from nurses in health units and allow them to focus on other
areas. This decreases elements of role conflict and multitasking which has been found as a determinant for job burnout [53].

Finally, an outreach program can potentially also lower transport costs of clients by situating service closer. In addition, the issue of under the table costs seen in the health care system might be possible to solve or make less prevalent considering how a centralized approach can make checks and balance easier, for instance by tracking individual service satisfaction.

In order to remind individuals in a timely fashion about upcoming vaccination, there needs to be a system in place which allows for tracking of individual children’s vaccination schedule and a way of communicating events to caretakers. A centralized system implies that information about children also needs to exist centrally. This is a challenge but also an opportunity since information about individuals from rural areas in low resource countries are typically hard to capture and disseminate to higher-level but can provide great value. We believe that the use of ICT can make tracking more manageable since it often enables users to filter large amount of information and then act upon it. Information can be communicated in several ways, both digitally through mobile phone reminders but also through direct contact, suggestively by community health workers. In either way, ICT will likely play a crucial role in delivering information from low-high levels and vice versa.

Based on our findings concerning barriers to demand we conclude that education on vaccination needs to be an integrated part of the immunization program in Uganda. Exactly what form of education and the content of the same are unclear at this point and the thesis might not be able to deliver a full answer. However, it is reasonable that one and the same person deliver information to caretakers, and that this is a person in which local people have confidence. Therefore, we aim to make use of CHWs to be deliverers of information in all areas where considered possible.

What and how non-medical incentives for families are to be delivered will be decided in our deliverables where we will take the micro perspective needed to get a clear understanding and requires a clear micro perspective
8.1 Discussion: Alternative models

Several other alternative models than the one chosen were discussed throughout the project. In retrospect, one might question why these models were suggested or at least considered in the first place. Often the case was that all necessary information needed to make a sound judgment was not known at the time, or there was a general lack of understanding (i.e., appreciating the magnitude of implications) of the full picture, which is not uncommon when dealing with previously unfamiliar areas. Also, things which might work on a macro level might not work on a micro level.

The concept of the current model used was suggested first after two formal internal focus group meetings. The models before conceptually be divided into two stages:

1. CHW or nurse performing vaccinations at either a health center (HCIV-HCII) or at a village
2. Nurse performing vaccinations at Arena, using an HCIV as outreach base point

Below these models are explained and reasons are given for why they ultimately were not chosen.

To the first evaluative internal focus group we brought four different concept models. In accordance with the agile development principle, we first focused on the “must work” (rather than the whole system), that is, delivering vaccinations to children – where, how and by who.

The models were named (1) Nurses carry out vaccination at HC; (2) Stationary CHWs carry out vaccination at HC; (3) Mobile CHWs carry out vaccination at HC, and; (4) CHWs carry out vaccination in villages. All these shared some common functions, including the use of VTC to coordinate efforts between stakeholders, trying to adapt to the logistics conditions on district level, and making use of all HC. Similarly as today, CHWs would be used to disseminate information, but in some models also to deliver vaccination shots. There was no one vaccination session day which gathered all children eligible for vaccinations; vaccines were given on a day-to-day basis as today.

The first option was very similar to how it works today in that vaccinations were to be performed at the local health centers. The job of the CHW would be gather people from the village and bring them to health center. We believed that having the CHW do this would increase the chance of families attending
vaccinations. At the health center, a stationary nurse would perform vaccinations.

The second option is the same as the previous one, with the difference in who gives the shot – the community health worker. As before a (another) CHW would be used to gather and bring children for vaccination. We believed that using CHWs to perform vaccinations would lessen the work burden on nurses in clinics. The nurse would still be around to give medical advice and checks and balance would still exist. The issue with this approach, except for the fact that many health centers still cannot enable anyone to give vaccinations due to lack of resources, was that it did not seem feasible or right that an outside person would have access to drugs and other equipment and take the role of a formal health worker. Another issue with this model is that resource allocation risk being inefficient since vaccination would not be a full time job in most HCs.

Instead of having a stationary CHW at the health center, the CHW could perform vaccinations after having followed them to the health center. With this approach, CHWs would only work when needed. There are several setbacks, however, following this process: As with the former approach it is not feasible for a CHW to run in and out of health center. Secondly, there would be no checks and balance if a CHW would do work alone, so the work would go unattended.

All the first three option share the disadvantage of requiring people to travel to the health center. The fourth and last option is the only in which vaccination is to be given in the villages. The CHW would carry vaccines in a vaccine carrier from a nearby health centers and alone carry out vaccinations. Although this solves the issue of transport for families, it presents some other problems. Similar as before, there is no checks and balance. Other things which are added to the process are that extra resources are needed in the form education of CHWs and a reliable system for using and maintaining carriers (which might need sharing between CHWs). No nurse would be around to provide medical assistance if needed.

An important part, if not critical, was that vaccines should be available when clients seek the service. Families would only be called/brought when vaccines were in stock. The idea in models above was to adapt to the ad-hoc nature of the logistics at district level. This would be done through having a system in which staff at district level would deliver when they could, and first after the delivery, families were called. However, this would mean that vaccines would have to lie for a while in health centers whose power supply we were unsure of. And still, getting the delivery down to each health centers is not straight forward undertaking.
We now appreciate the implications of unreliable power supply and unreliable material supply to the *reliability* of the service. We also understand that all HCs can, and *should*, not offer vaccination services because of poor resource utilization, which is even more important considering the high percentage of vacant positions.

The decision made in the evaluative meeting was to continue working on model 4 – CHWs carrying out vaccination in villages. Some changes were made: A nurse would follow CHWs during vaccination sessions to create checks and balance, and; storage of vaccines would only be done at HC IVs due to insufficient power supply at lower levels and the fact that it would be too expensive to provide all CHWs with the equipment needed (e.g., vaccine carriers). At this point, the team still collaborated with the thesis group creating the Cool Bag. The next step after this meeting was to develop the details of concept.

The concept of having nurses at HC IVs going to Arenas to meet up with CHWs was developed. This approach is similar to the one finally chosen (see Figure 8-1).
A few things in this model differ from the model chosen: Nurse’s outreach base point is at an existing HCIV; and; material delivery is required from district level. The advantage of this model is that it requires less initial investment: When the ICT is in place the nurse can travel to an Arena on motorbike (with driver) and perform vaccinations; not much on how work is currently conducted on district level need to change, and no car with customized equipment is needed. At the point in the process where we were to develop the details of the concept, we had almost settled with the sub-optimal
logistics capacity from higher level, and the perceived issues with storage maintenance. However, even this aside, we found issues on the micro level. We presumed that the nurse would still have her “old job” since it was doubtful that serving the catchment area of the HC IV would be a full time job. Then, coordinating nurse and CHW to show up at the same place at the same time proved impractical, especially considering that extra constraints of material being delivered on an ad-hoc basis.

During an internal focus groups meeting we discussed the details of the concept and the issues we had found. We had earlier thought of the alternative of going directly from the District Vaccine Stores to Arenas, but felt there was not enough time to explore the idea since a lot of uncertainties existed around it. We still chose to present the option – the result is clear. Going with the new concept created a lot of work since we need to find out the feasibility of the idea. Our main concern was the distance between the DVS and Arena was too far to be practical. However, these concerns dampened after being in contact with the program director of CHAT who showed that this was in fact not unfeasible.

9 Deliverables

The results of the Analysis conclusion are materialized below through designed artifacts which will help increase understanding of the macro and micro levels of the new model.

A discussion follows the section Stakeholder system model and aims to clarify the roles of some stakeholders where believed needed and also give reasons some tasks allocated to them.

Note that information flow is included in the business processes through input and output references.

As noted in the introduction of the thesis paper, the information details required by stakeholders is left out, and graphical user interfaces are only partly displayed.

9.1 Stakeholder system model

In short, the new model works in the following way (see Figure 9.1):

- All children living within a specified area meet up with nurses at pre-
defined dates at a pre-defined location to receive vaccinations – these days are referred to as “vaccination sessions”;

- The vaccination location – village center, village market, church or health center – is referred to as Arena and has a catchment area of 5 kilometers;
- Each Arena is normally visited once every month to provide timely vaccinations in accordance with the vaccination schedule;
- CHWs registers and mobilizes families within an area to join vaccination sessions;
- Nurses perform outreach vaccination service;
- Nurse’s base point is located by the district’s District Vaccine Store where vaccine and related material is fetched;
- Staff at the DVS collects and delivers vaccine and related material to nurse, and;
- a Vaccination Traffic Coordinator (VTC) is in charge to enable and coordinate tasks for and between stakeholders

Figure 9-1: Vaccination service delivery model chosen
CHWs form the core of the system by visiting families and registering their details for the immunization program. They do this with the help of a mobile device, a Smartphone. The registration information is sent to the VTC.

Based on the information from the CHW, the VTC sets up times of when each individual child is to receive its next vaccination. This is theoretically a fairly straightforward process since all children’s vaccination schedules are the same (i.e., same vaccines at same intervals) and the time of the vaccination sessions are fixed – once every month for every Arena. Some days before each session, the CHW is informed by the VTC of which children are planned for vaccination. The CHW contacts the children’s caretakers and remind them of upcoming vaccination.

At the day of the vaccination session, nurses collect vaccination related material needed at an existing DVS. (Long-stay outreaches can also be done where nurses are out several days in a row and visiting many Arenas, in that case a larger material batch is collected before departure.)

CHW, nurse and family meet at the Arena for the vaccination session. The nurse administers vaccines while the CHW assists.

A more detailed picture displaying delimitations, all physical interaction and some information flow in the model is shown below.

![Diagram](image_url)

Figure 9-2: The picture displays delimitations in the model as well as stakeholder interaction
The VTC is a hub for information flow and uses the information to perform or order actions. With information at hand the VTC can, for example: Setup children’s vaccination schedule; Schedule children for Arena and provide CHW with this information in a timely manner; Order vaccine and related material for DVS to collect for the nurse; Order the amount of vaccines and related material from Central Vaccine Store to DVS to cover one month of supply for the whole district.

The double sided arrows between DVS-Nurse and Nurse-Arena depicts that vaccines and related material are brought back from sessions and replaced in the DVS who also updates its local inventory.

9.1.1 Delimitations

There is some delimitation in regards to the model which should be noted. These affect and evolve around:

- Central Vaccine Store
- District Vaccine Store
- Nurse
- CHW
- Waste
- Non-medical incentives

The Central Vaccine Store is used but not managed, meaning that we only specify when and what we require out from it but not how.

_How to conduct internal_ operations at the DVS is not defined in the system. For instance, we do not specify how staff resources should be allocated to best receive, deliver and maintain vaccines and equipment.

In our system, the nurse will only perform the act and management of vaccination, that is, the administering and registration of the vaccine. Normally, other actions are also performed during vaccination, such as weighing, measuring, recording of family circumstances (e.g., death in family), and more. (For full disclosure about actions taken see the Child Health Card in Appendix A.) More information on reasons for this decision can be found in the discussion section following this section.

When visiting families for registration and mobilization, the CHW will inform families on the importance of vaccination. We will, however, not
specify what families will be informed about and in what way, hence the GUI will not provide any information regarding this. Vaccinations create a lot of waste – vaccine vials, syringes, needles etc – which needs to be disposed of. The act of correctly disposing waste is a field in its own, referred to as Health Care Waste Management (HCWM). We will not consider the handling of waste other than to specify that it needs to be brought back to the DVS by nurse. In one of the health centers we visited they disposed of waste simply by burning it outside of the facility. However, whether or not this was according with guidelines is unclear since we have found no official Ugandan policies on the matter. WHO stresses the importance of proper waste management and states that injections with already contaminated syringes causes millions of people each year to be infected with diseases like hepatitis B and HIV [54]. WHO provides comprehensive guidelines for HCWM which should be addressed and eventually implemented in the final system.

We do not define anything regarding the incentives other than medical for bringing families to vaccination sessions. We have noted that it is something which might hold great potential, but it needs to be further explored to find what and how this would be implemented in reality. Due to time constraints we will not explore this further in this thesis.

9.1.2 Stakeholders: Roles and responsibilities

There are six stakeholders in the system:

1. Vaccination Traffic Coordinator
2. Central Vaccine Store
3. District Vaccine Store
4. Nurse
5. Community Health Worker
6. Caretakers

The role and responsibility of each stakeholder is presented below.
Title | Role | Interfaces
--- | --- | ---
Vaccination Traffic Coordinator (VTC) | The VTC’s role is to manage and monitor parts of the vaccination process so that other agents in the system will receive the right information at the right time to do their tasks. | Physical: ---
 |  | Information: Central store; DVS; Nurse; CHW
Other: The VTC will use a computer | |

**Responsibility**

- Setup and maintain individual children’s schedules for vaccination session
- Enable the correct material flow in the system, by
  - Sending order information to Central store for delivery to DVS based on stock at hand (DVS inventory)
  - Sending order information to DVS for delivery to nurse based on vaccination sessions
  - Providing nurse with session information before sessions (e.g., material and clients)
  - Providing CHW with information on what people who are to attend next vaccination session
  - Maintaining stakeholder accountability by doing checkups on service quality: Occasionally calling families to evaluate last vaccination session performance

**Comments**
The VTC can physically be located anywhere in the country. One VTC can in theory handle multiple districts.
<table>
<thead>
<tr>
<th>Title</th>
<th>Role</th>
<th>Interfaces</th>
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<tbody>
<tr>
<td>Central Vaccine Store</td>
<td>The role of the Central store is to supply DVS with vaccines and other equipment on a monthly basis.</td>
<td>Physical: DVS (delivery)</td>
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<td></td>
<td>Information: VTC</td>
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**Responsibility**

- Supply DVS with vaccines and other equipment on a monthly basis
- (Conduct delivery checking balance (together with DVS personal) at delivery)

**Comments**

See *Delimitations*
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<th>Title</th>
<th>Role</th>
<th>Interfaces</th>
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| District Vaccine Store | The DVS maintains and delivers vaccines and other equipment used by nurses during outreach. This means that DVS personal is responsible for making sure that vaccination session material is available at time of need. The DVS also manages the local inventory which VTC bases monthly CVS-DVS orders on. | Physical: 
  Nurse; 
  Central Vaccine Store (delivery)  
  Information: VTC |

**Responsibility**

- Receive monthly orders of vaccines and other related equipment
- Maintain vaccines and other related equipment
- Pick together vaccines and other related equipment for sessions
- Deliver vaccines and other equipment to nurse
- Conduct material inventory (non-used and waste) *after* sessions at DVS (together with nurse)
- Take care of waste (burn or ship elsewhere for disposal) (*see Delimitations*, previous section)
- Update inventory

**Comments**

The DVS is in reality often equivalent to a District Health Office (DHO). For more information on internal operations at DVS, *see Delimitations*

**Other:**
The DVS will use a computer; 
Local inventory (digital)
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<th>Title</th>
<th>Role</th>
<th>Interfaces</th>
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<tbody>
<tr>
<td>Nurse</td>
<td>The nurse’s role is to perform vaccinations of children in an outreach program manner. She is responsible for bringing the right vaccine and equipment to vaccination sessions. At the Arena she will be responsible for the education of caretakers about vaccination and the procedure to come.</td>
<td>Physical: DVS; CHW; Families; Information: VTC;</td>
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**Responsibility**

- Retrieve vaccines and equipment before vaccination sessions
- Bringing the right vaccine and equipment to vaccination sessions (by conducting delivery checking balance together with DVS personal)
- Travel to areas to perform vaccinations
- Educate families about immunization and the importance of it
- Providing the right vaccine for the right child in the right way
- Reporting session outcome (to VTC)
- Bringing back vaccines and related equipment to DVS

**Comments**

The education of families at the Arena can be done in several ways. During the outreach we observed during the trip, health workers stated that they broadcast education verbally to groups of mothers (Nurse and students 2012, interview, 25th of February). Another approach to use is to display a movie which would do a similar job with some additional functions.

**Other:**
The nurse will use a mobile device, Smartphone.
<table>
<thead>
<tr>
<th>Title</th>
<th>Role</th>
<th>Interfaces</th>
</tr>
</thead>
</table>
| CHW   | The CHW’s role is to act as a connection link between families and the health care service. She encourages families to attend vaccinations, registers them into the system, and mobilizes them when it’s time for next session. Before sessions she will be responsible for preparing the Arena for the nurse (e.g., gathering families; preparing work stations, etc). At the session she assists the nurse by putting in the information the nurses orders her into the nurse’s digital device. | Physical: *Families; Nurse;*  
Information: *VTC;* |

### Responsibility
- Inform on vaccinations and answer questions regarding it
- Register families
- Mobilize families for sessions
- Prepare Arena on day of session
- Assist nurse at session

### Comments

**Other:**
The CHW will use a mobile device, Smartphone; The CHW will need training before starting the job, including vaccination knowledge and use of application
## Title

<table>
<thead>
<tr>
<th>Title</th>
<th>Role</th>
<th>Interfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caretakers</td>
<td>The role of parents is to bring their children to the Arenas. Some caretakers might also provide feedback to VTC about previous sessions to ensure the quality of the service.</td>
<td>Physical: CHW; Nurse Information: (VTC)</td>
</tr>
</tbody>
</table>

### Responsibility

- Bring children to Arena for vaccination
- Provide feedback to VTC (in some cases)
- (In exceptional cases, visit CHW for vaccination information)

### Comment

In areas with scarce population with people spread over a larger area than the CHW can possibly cover, families might need to visit CHWs to receive vaccination information, for example the time of their child’s next session.

### 9.1.3 Discussion

Below we aim to elaborate on the stakeholders used in the model, and sort out what we believe might be unclear at this point.

Starting the with the Vaccination Traffic Coordinator, the first question might be “why is he needed?”. First, lets look at some tasks which need to be done in the system: Scheduling of individual children’s vaccinations; scheduling/coordinating nurse’s work (e.g., vaccination sessions); provide CHW with correct information for mobilization; make orders from CVS-DVS. The scheduling of children’s vaccination, scheduling of nurse work and even CVS-DVS ordering could theoretically be done by the district nurse; she can (not with the current system) get all information needed. However, it is a general principle of management that work is divided in a way which allow people to specialize and thus become better at their tasks [55]. In short principle, the nurse should do what she is educated in and best at; providing health care service to patients.

One notable thing regarding the work of the Central Vaccine Store, is the changes of material orders in this system compared to the old. In the old (current) system, the Central Vaccine Stores forecast and order the vaccine needs at district level based on the district’s stock on hand, previous hand-out
to health units and estimated wastage [2]. Stock on hand, consumption, and losses/adjustments (e.g., waste, theft etc) are the recommended three essential logistics data to use when ordering [2]. USAID conclude in the report that ordering to district level should be based on actual consumption and losses/adjustments rather than estimated [2]. The issue with the old system is that data on actual consumption and loss is hard to come by since it relies on health facilities tracking and reporting it to higher level [2]. In the new system, this data is available. However, the only data used for ordering – done by VTC – is stock on hand. The reason for this was uncertainty on precisely how to do the ordering (i.e., the metrics relation between order factors), especially since we were unsure if data demographics (e.g., birth rate) and other logistics factors (e.g., minimal/maximum warehouse storage principles etc) were to be applied. Because of time constraint issues we chose not to investigate it further. However, in the final release of the system, making this option available can increase order accuracy and hence save money.

The nurse’s task of vaccination performance in this model is not full, meaning that in the real world she will be required to do more tasks. The full process of administering vaccinations is quite extensive, and in order to implement all functions into the GUI the vaccination process first needs to be properly investigated together with user analysis (e.g., nurses). The main objective of this thesis is to identify the vital stakeholders needed and provide ways of connecting them – details of actions are important but secondary. Fully understanding the process of vaccination performance and creating corresponding GUI requires literature study and user analysis which will take too much time in comparison to value retrieved. However, if the system is to be developed into a real application, these matters will need to be investigated before the release of the final version.

We have declared that one role of the community health worker is that of an informer regarding vaccinations, such as safety and the importance of following through on vaccination schedules, but have not declared what and how that teaching will be done. Partly our stand on this matter is a result of practical matters such as what and how to put information into the GUI (if needed), but partly it is also a matter of how to assure that this information is delivered as intended. The latter part concerns finding the right incentives for a CHW to actually perform an act which for her is not necessarily connected to getting the family to attend the vaccination session. One question one must ask is, “why CHWs do anything of what we require from them?”. Although no formal decision has been made on incentives, the general idea has been that CHWs will be compensated based on the number of people showing up for vaccinations. The use of ICT makes it a fairly straight forward approach to
keep record of this since all children registered in the system also “belong” to the CHW who registered them. But what incentive does the CHW have to educate families? One can say that doing this will increase the chance of families following through on the vaccination schedule – but it is not certain that a CHW reasons in the same way. Skipping to inform a family on the importance of vaccination might cause the family not to show up, but it can also allow a CHW to quit her job earlier that day – it’s a matter of perspective. Our findings suggest that it is important to educate families on these matters, and it is important that teachings come from a trusted part, such as a CHW. Therefore the details of education delivery need to be investigated further.

9.2 Process model and organizational structure

This section aims to explain operational processes developed by the authors, sought to bring vaccination service delivery to children in rural areas in Uganda. This will be done through visual models depicting stakeholders’ tasks from beginning to end, followed by supportive text.

We are using two methods for depicting processes: (1) Activity Diagrams and (2) Use Case Diagrams. The activity diagrams involve stakeholders interacting with other stakeholders. The use case diagrams involve stakeholders interacting with a system. In the perspective of the reader, the difference between the two can be said to be that activity diagrams depict general processes to explain the functioning of the system, while use case diagrams are more specifically for the use of programmers when developing applications.

Activities and use cases are separate yet still interdependent. Some activities may rely on stakeholders interacting with the system to complete a process (and vice versa), and the results of some activities may have implications in later use case diagram processes (and vice versa) – for example when information is sent from one stakeholder for later use by another stakeholder.

During “normal” circumstances, the activity diagrams and use case diagrams follow a certain order in relation to each other, for example, an activity diagram is process wise sometimes followed by a use case diagram which in turn is followed by an activity diagram. An example of this is when the CHW first registers a family – activity diagram – and then the VTC acts upon that information to create the child’s vaccination sessions – use case diagram. Since there are only two use case diagrams which cover matters
which the activity diagrams do not, we have decided to put them in the same section.

Information sent and received between processes is given a reference id which readers will need to refer to better understand processes and the information dependency between them.

9.2.1 Visual modeling method: BPMN and symbols explanation

The activity modeling method chosen is the official Business Process Model Notation (BPMN) language, implemented in accordance with the industry standards maintained by the Object Management Group [56]. BPMN was chosen since it is the de facto standard used by business today and provides a comprehensive enough tool for our purposes.

The version used is BPMN 2.0 [57] which is the latest official release. Below is an index explaining symbols used in the BPMN diagrams:

Activity

![Activity symbol](image)

**Figure 9-3: Symbol: Activity**

An Activity is something that the stakeholder “does”, it can be a task or taking a decision.

Events

![Event symbols](image)

**Figure 9-4: Symbols: Start, Intermittent, End, Message (start) (in that order)**

Events are something that “happens”, for example a house being *found* or a sub-process being *finished*. Different symbols are used to depict whether an event is starting, intermittent (between activities) or ending. In addition, symbols might have “marks” inside them, specifying “type”, like message.
Gateways

Figure 9-5: Symbol: Gateway

Gateways shows that a decision is being made and that depending on the decision, a different sequence flow will follow.

Data Objects and messages

Figure 9-6: Symbols: Data objects and Message (in that order)

Data Objects show information which has been produced, for instance an email, fax or note. Messages display communication between stakeholders which does not produce an artifact, like a conversation.

Pool/Lane

Figure 9-7: Symbol: Pool/Lane

The Lane refers to individual stakeholders within a process – every stakeholder has one lane. The Pool refers to a process which may or may not involve several stakeholders and thus lanes. Every activity shown in a lane, means that the stakeholder who “owns” that lane is executing the task. Lanes are used when a process involves more than one stakeholder and actions “flows” between them.

When processes are dependent on each other, for example when information produced in one process is later used in another, multiple pools are displayed. This is also the case when a process is too long to be fit in one pool; another pool is put below where the process continues.

Connections

Figure 9-8: Sequence Flow and Message Flow (in that order)
Connections are put between activities, events, gateways and data objects to display flow. Connections within and between lanes and within the same pool are displayed with Sequence Flow (full line). Between pools, only messages can flow and therefore depicts information (exception: Data Store) – the Message Flow (dotted line) symbol is used to display this.

**Color and numbering**

All activities, events, gateways and data objects between sequence flows are indexed with numbers. The default or “normal” sequence flow, that is, what is usually required to deliver the vaccination service as intended, is number with integer numbers (i.e., 1, 2, 3 etc). Sequence flows which deviate (alternative) from the normal are numbered with decimal numbers (i.e., 1.1, 2.1, 3.1 etc). Normal and alternative flows are also semantically separated with colors: Normal flows are green; alternative flows are red.

**Diagram titles, IDs and reference: role and nomenclature**

The purpose of the titles of diagrams is to give the reader a clue of the purpose with the process, for instance, “Family Registration”.

All processes will have unique IDs to identify them. For activity diagrams the ID will start with 1AD, then 2AD, 3AD and so on; use case diagrams will similarly start with 1UC, then 2UC, 3UC and so on.

Id references are used to reference data objects used between processes (or pools). For instance, if a data object created in 1AD is later to be used in 2UC, there needs to a way of knowing from who and when the data came from when analyzing 2UC. References make this possible. The nomenclature for references are based on the IDs used to uniquely identify a process. For instance, the first data object in process 1AD which will be used in another process will be named 1Adi, the second (if there is one) will be named 1Adii, then 1Adiii, 1Adiv and so on.

**9.2.2 Use case diagrams: Framework and notation**

In this thesis the work presented won’t be used directly be programmers to develop the system.

It is not crucial to understand the details of the use case diagrams. Most important is to understand that there is a process between activities in which stakeholders don’t directly physically act or interact but still produce
something which is needed in other activities. Still, a quick explanation of the notation and what the use case diagrams depict is good to have.

Use case diagrams depict the following [58]:

- **Actors**: An actor is a person, organization, or external system that plays a role in the interactions with a system
- **Associations**: Interactions between actors are shown through “association” and are indicated in use case diagrams by *solid* lines. An association exists whenever an actor is involved with an interaction described by a use case.
- **System boundary boxes**: A rectangle with solid lines is drawn around the use cases to indicate the *scope* of the system. These are called system boundary boxes.

### 9.2.3 Business processes

In order to increase the understanding of the system as a whole, processes are put in beginning-end order sequence: From the registration of a family to the session performance (and monthly supply order from the Central Vaccine Store to the DVS). Note that the use case diagrams will not be displayed, only explained briefly in text format.

<table>
<thead>
<tr>
<th>#</th>
<th>Type</th>
<th>Name</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Activity diagram</td>
<td>Family registration</td>
<td>1AD</td>
</tr>
<tr>
<td>2</td>
<td>Use case diagram</td>
<td>Setting up session</td>
<td>2UC</td>
</tr>
<tr>
<td>3</td>
<td>Activity diagram</td>
<td>Mobilization visit</td>
<td>2AD</td>
</tr>
<tr>
<td>4</td>
<td>Activity diagram</td>
<td>DVS prepare session material</td>
<td>3AD</td>
</tr>
<tr>
<td>5</td>
<td>Activity diagram</td>
<td>Nurse retrieve session material</td>
<td>4AD</td>
</tr>
<tr>
<td>6</td>
<td>Activity diagram</td>
<td>Vaccination session performance</td>
<td>5AD</td>
</tr>
<tr>
<td>7</td>
<td>Activity diagram</td>
<td>Material return and inventory update</td>
<td>6AD</td>
</tr>
<tr>
<td>8</td>
<td>Use case diagram</td>
<td>VTC order monthly supply</td>
<td>9UC</td>
</tr>
<tr>
<td>9</td>
<td>Activity diagram</td>
<td>DVS receive supply</td>
<td>7AD</td>
</tr>
</tbody>
</table>
1. Family registration

ID: 1AD

Figure 9-9: Family registration process
Process description
The CHW starts by visiting a village’s Local Council (LC1) to ask for permission of going to the home of families to register them. Under normal circumstances this is not a problem. The LC provides the CHW with new information about a baby being born or a woman being pregnant. He also provides the CHW with direction of finding the families’ house. CHWs know their communities very well, and should have no problem finding houses. Upon reaching a family, the CHW explains the program and her role in it. She answers any questions the family might have. She finishes by asking if the family wishes to join. If they answer “No”, that information is noted into the CHWs mobile device and sent to VTC so that (temporarily) no more efforts are done to reach that family. If the family responds “Yes”, the CHW starts a registration process (for detailed info, see “Family registration” under the Graphical User Interfaces section). When finished, the information is sent to the VTC who can use the profile information to create a child’s sessions. The VTC hands over a note to the caretaker which displays the unique serial number she has been allocated (since the date of the next session is unknown at this point, that information is not included).

Information reference input:
---

Information reference output:
1ADi or 1ADii
2. Vaccination session setup

**Title:** Setting up session  ID: 2UC

**Description**
The VTC puts all newly registered children into sessions – the whole schedule for each individual child is planned. All children are also allocated with the vaccines they require for each particular session. A list of the material needed for all children for a session is sent to the DVS. The same list plus the profile list of children for that session is sent to the nurse. The CHW is sent a list of the children to be mobilized to the upcoming session in a particular Arena. (see “Setting up session” in the *Graphical User Interfaces* section).

**Information reference input:**
1ADi or 1ADii

**Information reference output:**
2UCi; 2UCii; 2UCiii

---

**Figure 9-10: Vaccination session setup**
Description
The CHW starts by reading the information sent from VTC containing the names and address of people to mobilize. As usual, the LC1 is first contacted and notified of the CHWs attempt to inform families about an upcoming session.

When a family is found, they are informed about the upcoming session. The CHW provide time and place of next visit. The family can confirm their visit if possible; this information is good for a CHW to have at the session day so that she and the nurse do not have to wait in vain for a caretaker not planned to show up.

The CHW then continues to the next house for a similar procedure.

Information reference input:
2UCi

Information reference output:
---
4. DVS prepares session material

Figure 9-12: DVS prepares session’s material process
Description
The DVS starts by reading the information sent from VTC containing a list of material which is to be prepared for the nurse till the day of session. All material is picked together – vaccines and support material such as dilutes and alcohol. When all material has been collected, a written note is put on the boxes/bags with the unique session code sent with the material list. This is done since a DVS might prepare material for multiple sessions. When the nurse comes to pick up the bags/boxes, she and the DVS will compare their session codes to confirm the right session has been prepared.

Information reference input:
2UCiii
Information reference output:
---
5. Nurse retrieves session material

Figure 9-13: Nurse retrieves session material
Description
On the day of the session, the nurse starts by reading the information sent from VTC containing a list of material (as well as a child profile list) which the DVS should have prepared for her. At the DVS, her session code is compared with that of the DVS personal’s. They should match, leading the DVS to hand over the boxes with that code on them. If there is no match, something has gone wrong. In this case the VTC should be contacted. The VTC should be able to sort out the situation and provide the correct material list. After this, the process continues (step 5). The nurse and DVS both double check the delivered material to agree on type and quantity, but the nurse will be the person responsible for bringing the correct content.

When agreed, the DVS saves the information about material delivered for later until the nurse returns. The inventory is updated first after the return of the nurse to account for material used and wasted.

The nurse and driver heads to the Arena.

Note that several sessions may be prepared at once and that a nurse might visit multiple arenas in one outreach.

Information reference input:
2UCii

Information reference output:
---
Figure 9-14: Vaccination session performance process
Description
(Only the nurse uses a device in this process, but the CHW can assist her by inputting information into the device as instructed by nurse or follow instructions from nurse based on information from the device.) When the nurse arrives at the Arena, she and the CHW starts preparing the work stations to use. When the families arrive, the nurse starts checking attendance of families as indicated by device. The families are educated in group. (Note that we do not specify how this is done, for instance if done verbally or through video display.)

The process of performing vaccinations starts by the CHW calling out the name of the child (and caretaker) who are to receive vaccination. The family is identified through name and photo shown on the device. If photo is unclear and name misspelled, the serial number can be used if brought by the family. When the family is identified, the process of performing and registering vaccination starts (see “Vaccination Session Performance” in the Graphical User Interfaces section). The performance and registration of children continues until the last child has been served. The session is over.

The nurse and CHW both sign the process into the mobile device to prove that both attended the performance and stand behind the information registered. The information is sent to VTC.

All equipment used, including empty vaccine vials and waste (e.g., syringes and needles), is collected to be brought back to the DVS. CHW and nurse help out dismantling the stations. The nurse and driver then heads back to DVS (or next Arena).

Note that the preparing of work stations and execution of vaccination should be done in accordance with WHO recommendations [59].

Information reference input:
---

Information reference output:
5ADi
Figure 9-15: Material return and inventory update process
Description
The nurse and driver returns to the DVS. She displays her session code, and based on this the DVS retrieves information saved earlier. Some vaccine vials will still have doses left, but depending on their temperature they might not be in condition to use again. Nurse and DVS help out to decide whether or not they are (e.g., through vial monitor and temperature readings of boxes). The DVS decides which are to be used again and hence put back into storage. When the vials are put back, the inventory is updated.

Information reference input:
4ADi;

Information reference output:
6ADi;
8. VTC orders monthly supply

Description
The VTC has access to the same database as the DVS uses. Based on the individual DVS’s stock on hand, the VTC places an order of supply to cover the needs for a month. The list is sent to both DVS and the Central Vaccine Store for balance checking at delivery. (see “VTC orders monthly supply” in Graphical User Interfaces section for more details.)

Information reference input:
---
Information reference output:
9UCi
9. DVS receives supply

Figure 9-17: DVS receives supply
**Description**
(This process does not follow the rule of order sequence as the other processes do since process 1-8 might be iterated many times before this process is executed (or this process is executed first).) When the truck from the Central Vaccine Store arrives, they (DVS staff and driver) check and compare order numbers provided by the VTC. Upon agreement, material is provided to the DVS. DVS staff and driver checks the type and quantity of the material provided. The DVS is responsible for making the decision of accepting or declining the shipment. The results are put into digital device and the database is updated.

**Information reference input:**
9UCi

**Information reference output:**
7ADi
9.3 Graphical User Interfaces

The Graphical User Interfaces provides a clear view over the tasks that stakeholders are responsible of. Alongside each Activity Diagram there is a GUI to enable the stakeholder to execute its task as intended. In other words, a full display of the GUI created would provide a view over all process and thus the whole system. However, we have chosen to only display a few GUIs in this thesis. There are a total of almost 40 interfaces – one process/task often requires multiple “pages” to become finished. We believe that a full display does not serve the purpose of this thesis which is to argue for, provide and explain the principles of a new conceptual vaccination service delivery model. Also, the GUIs provide most readers with too much information, especially if they are all to be properly explained. Finally, it would simply be unjust to only display the results of a work and research process lasting several months. For a full disclosure of the GUIs, please refer to the master thesis *Human Computer Interaction Design for Mobile Vaccination Delivery System Analysis*, done by Rui Xui.

The GUIs chosen for display are parts of those which are involved in sub-processes in the activity diagrams and those which are only tied to the use case diagrams. This will help clarify information in these otherwise unclear areas.

Each GUI is followed by a short description.
Family registration

Figure 9-18: Family registration, CHW’s GUI
**Description**

The mobile device allows the CHW to take a photo of members of the family which are registered to the profile. The device also automatically and asynchronously produces a serial number, based on the CHW's registration info which makes it unique.
Setting up session

Figure 9-19: Setting up sessions, VTC’s GUI
Figure 9-20: Aggregated session material list to send, VTC’s GUI

**Description**

First the VTC chooses which district and Arena which the sessions are to be planned for. Then, the VTC can easily put the children into new sessions simply by dragging them into the calendar (the date of sessions are pre-defined).

The aggregated list of material and children are later sent away to DVS and nurse.
Vaccination session performance

![Image of Nurse's GUI for vaccination session performance](image)

**Figure 9-21:** Vaccination session performance, Nurse’s GUI
Description
The first picture displays a list of all the children which are to be vaccinated in the session. Also displayed are the vaccines which they are to receive, these are checked by the nurse after being given.

The nurse can enter the profile of a child by clicking its picture or name. Here is information which the nurse can use to identify child-caretaker.
VTC orders monthly supply

**Figure 9-23: VTC orders supply**

**Description**
The VTC chooses the district of which to order a monthly supply. The DVS database displays its inventory. Based on the stock on hand, the VTC order enough to cover the estimated needed supply. The information is sent to both DVS and Central Vaccine Store.

### 10 Project conclusion

In this section the work accomplished in the thesis is compared with the objectives, purpose and goal earlier set out. Similarly, the aim is to identify a
potential gap between deliverables created and what we consider to be a real and full version of the vaccination service delivery model.

10.1 Objectives, purpose and goal in relation to results

The main objectives of this thesis were to create a (comprehensive and innovative) vaccination service delivery model (in Uganda) by connecting the vital stakeholders needed to bring vaccination to the children of caretakers’. This was accomplished: There is now a new conceptual system which involves all stakeholders needed for vaccination delivery service, and they are all connected and enabled to communicate to execute tasks as intended.

The purpose of the project was to increase access, service quality and demand in the Ugandan routine vaccination program, and the goal was that it would be practically possible for all children of Uganda to complete their vaccination schedules in a timely manner. Of course, only theoretic speculation can be made regarding the results of these matters.

In terms of the reaching the goal, the new model provides a theoretic possibility of full physical availability for all children since it is simply a matter of what geographic coverage is chosen at vaccination outreaches. What then might hinder children from receiving the service is the amount and coverage of CHWs who puts people “in contact” with the service. Currently CHWs are reported to exist in 75% of communities. Because the arbitrary interpretation of what constitutes a community, it is difficult to assess their theoretic coverage. However, based on reports read on the work done today by CHWs/VHTs together with our own judgment and experience from the trip to Uganda, we believe that a full scale implementation of the model today would not cover all children in terms of being reached by a CHW. We believe that for all children to receive the vaccination service, more CHWs will need to be recruited and trained.

An evaluation whether access, service quality and demand is likely to increase with the new model is desirable. This can partly be done before an implementation through additional expert opinions within the area. Due to time constraints this has not been possible in the thesis.
10.2 Deliverables in relation to conclusion

In the *Analysis conclusion* section, it was stated what solutions were needed to correct the issues identified and to increase access, service quality and demand. The aim was to implement these solutions in model later designed. However, this was not fully accomplished. Below the gap between conclusion and deliverables are accounted for.

The education of families regarding vaccines and vaccination was to be an integrated part of the service delivery. While it is included in the model that both CHW and nurse are to educate families, we did not define how this would practically be integrated into the system for both system and education delivery to work. It seems evident that education plays a key role of creating demand and therefore more research is needed to find proper ways of integrating into the system.

Another potentially strong factor in creating demand was found to be non-medical incentives. However, this area was not investigated enough to confidently bring about a solution. As with the practical integration and implementation of education into the system, what role and how non-medical incentives can be used to create demand for vaccination services needs to be further investigated.

10.3 Deliverables in relation to a full and real up-running system

Some parts of the model were not fully implemented. More specifically, not all tasks which can be expected that stakeholders will do were defined. This section aims to provide what the authors believe future developers and implementers will need to consider.

In the model, the nurse is in charge of several tasks. The most critical is of course to perform vaccinations at the vaccination sessions. The GUI only supports the nurse in providing children with vaccines. Normally, the nurse would be expected to measure and weigh the child as well as interacting with the caretaker to inform and record regarding parent caretaking (e.g., breastfeeding etc). Future implementers will need to first evaluate whether the care should be delivered as today or change, then find ways of developing and implementing it fully.
The CVS-DVS ordering is currently only based on stock on hand. Because of the opportunities of basing orders on real consumption and loss as is recommended, this function should be sought.

Similarly to CVS-DVS ordering, the material delivery from CVS-DVS in the GUI requires to be addressed for future implementation to make it more user friendly.

Waste management is not dealt with in the current model, it is only defined that the nurse is responsible for bringing it back from sessions and likewise the DVS is responsible for taking care of it. Waste management is nothing new or unique and there are recommendations for how it should be handled, it is just a matter of implementing it.

11 Future work

The thesis work have been focused on delivering a novel concept model with the purpose of increasing access, service quality and demand in the vaccination service program. Except for using “common sense” to prevent results and conclusions from becoming too extreme, no work has been done to evaluate the practical feasibility of the model. Perhaps the two most important steps to take before a possible pilot launch, is to (1) appreciate the costs involved with developing and running the system compared with the benefits received (for instance through a Cost-benefit analysis and/or Social return on investment analysis) and (2) to evaluate the current performance status in ICT infrastructure.

It is always very difficult, if not impossible, to say when costs outweighs benefits when it is related to human health. However, in reality, even health care has a price, especially under very limited resources. In order to run a program successfully over time, costs cannot be (relatively) too high. An analysis indicating the costs linked with a certain system helps decision making. Also, with the support of such an evaluation one can modify a model, or parts related to it, as needed to bring down costs.

Finally, it needs to be investigated whether the ICT infrastructure can support tasks in the model as needed. Since the model might not be fully scaled and implemented in years, time should be taken as a factor in such an investigation; what is not possible now, might be in a few years.
References


# Interview references

**Center of Infection and Immunity and Child Welfare Center**  
(Swedish: Infektionsmottagning respektive Barnavårdscentralen)

<table>
<thead>
<tr>
<th>Name</th>
<th>Title and experience</th>
<th>Company/ org.</th>
<th>Contact info.</th>
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<tbody>
<tr>
<td>Charlotte Augustzén</td>
<td>Nurse, Dep. Chief; 30 years</td>
<td>Center of Infection and Immunity, Karlskrona</td>
<td>Charlotte.Augustzé<a href="mailto:n@ltblekinge.se">n@ltblekinge.se</a></td>
</tr>
<tr>
<td>Karin Holmkvist</td>
<td>Nurse; 15 years</td>
<td>Center of Infection and Immunity, Karlskrona</td>
<td><a href="mailto:Karin.holmkvist@ltblekinge.se">Karin.holmkvist@ltblekinge.se</a></td>
</tr>
<tr>
<td>Carina Thårlin</td>
<td>Nurse; 11 years</td>
<td>Center of Infection and Immunity, Karlskrona</td>
<td><a href="mailto:Carina.Thalin@ltblekinge.se">Carina.Thalin@ltblekinge.se</a></td>
</tr>
<tr>
<td>Rickard Eitrem</td>
<td>Associate professor, Physician within the field of infectious diseases; 38 years</td>
<td>Center of Infection and Immunity, Karlskrona</td>
<td><a href="mailto:rickard.eitrem@ltblekinge.se">rickard.eitrem@ltblekinge.se</a></td>
</tr>
<tr>
<td>Marianne Manneklint</td>
<td>District nurse; 6 year</td>
<td>Child Welfare Center, Karlskrona</td>
<td><a href="mailto:Marianne.manneklint@ltblekinge.se">Marianne.manneklint@ltblekinge.se</a></td>
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<tr>
<td>Helene Eklund</td>
<td>District nurse</td>
<td>Child Welfare Center, Karlskrona</td>
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**Logistics companies**

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<tr>
<th>Name</th>
<th>Title and experience</th>
<th>Company/org.</th>
<th>Contact info.</th>
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<tr>
<td>Thomas Svensson</td>
<td>Customer service manager; 3 years</td>
<td>GlaxoSmithKline</td>
<td><a href="mailto:Thomas.svensson@gsk.com">Thomas.svensson@gsk.com</a></td>
</tr>
<tr>
<td>Claes Ohlsson</td>
<td>Chief of Logistics; 5 years</td>
<td>Oriola</td>
<td><a href="mailto:claes.olsson@oriola.com">claes.olsson@oriola.com</a></td>
</tr>
<tr>
<td>Susan Claesgard</td>
<td>Order administrator, Customer service; 4.5 years</td>
<td>Oriola</td>
<td><a href="mailto:susan.claesgard@oriola.com">susan.claesgard@oriola.com</a></td>
</tr>
<tr>
<td>Anup Akkihal</td>
<td>CEO; N/a</td>
<td>Logistimo</td>
<td><a href="mailto:anup@logistimo.com">anup@logistimo.com</a></td>
</tr>
<tr>
<td>Ryan McWhorter</td>
<td>CFO; N/a</td>
<td>Logistimo</td>
<td><a href="mailto:ryan@logistimo.com">ryan@logistimo.com</a></td>
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**CHAT (Outreach program)**

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<tr>
<td>Shanni Wreford-Smith</td>
<td>Program Coordinator</td>
<td>Community Health Africa Trust, CHAT</td>
<td><a href="mailto:mobileclinicsafrica@gmail.com">mobileclinicsafrica@gmail.com</a></td>
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**Field study Uganda**

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<tbody>
<tr>
<td>Eva Kabwongera</td>
<td>Upper-level health specialist; N/a</td>
<td>Unicef</td>
<td><a href="mailto:ekabwongera@unicef.org">ekabwongera@unicef.org</a></td>
</tr>
<tr>
<td>Mary Ann Gleeson</td>
<td>Clinical officer; 29 years</td>
<td>Saint Clair Arungo, Health Center III Hospital, Mbale, Uganda</td>
<td>N/a</td>
</tr>
<tr>
<td>N/a</td>
<td>Nurses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/a</td>
<td>Community vaccinator</td>
<td>HCIII, Mbale, Uganda</td>
<td>N/a</td>
</tr>
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</tr>
<tr>
<td>* N/a</td>
<td>District Health Office (DVS), Mbale, Uganda</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>* Nurse</td>
<td>HCIII, Ococia, Amuria District, Uganda</td>
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<tr>
<td>* Midwife</td>
<td>HCIII, Ococia, Amuria District, Uganda</td>
<td>N/a</td>
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<tr>
<td>* CHW</td>
<td>HCIII, Ococia, Amuria District, Uganda</td>
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<td>* CHW</td>
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<tr>
<td>* LC1</td>
<td>HCIII, Ococia, Amuria District, Uganda</td>
<td>N/a</td>
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</tr>
<tr>
<td>N/a</td>
<td>LC1</td>
<td>Village in Ococia, Amuria District, Uganda</td>
<td>N/a</td>
</tr>
</tbody>
</table>

* Request information by contacting author
**Appendix A: Child Health Card**

*Figure 1-14: Child Health Card used by health workers today*
GROWTH PROMOTION CHART

IMPORTANT: Give your baby only breast milk for the first 6 months. Add foods and other liquids only at 6 months.

Weight-for-Age: GIRLS (Birth to 2 years)

Weight-for-Age: BOYS (Birth to 2 years)

INFANT & YOUNG CHILD FEEDING

<table>
<thead>
<tr>
<th>Time</th>
<th>Birth</th>
<th>1m</th>
<th>2m</th>
<th>3m</th>
<th>4m</th>
<th>5m</th>
<th>6m</th>
<th>7m</th>
<th>8m</th>
<th>9m</th>
<th>10m</th>
<th>11m</th>
<th>12m</th>
<th>13m</th>
<th>14m</th>
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<tbody>
<tr>
<td>YCF Code</td>
<td>01</td>
<td>02</td>
<td>03</td>
<td>04</td>
<td>05</td>
<td>06</td>
<td>07</td>
<td>08</td>
<td>09</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
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Infant and Young Child Feeding (YCF) Codes:

- Exclusive Breast Feeding: 01
- Exclusive Replacement Feeding: 02
- Mixed Feeding: 03
- Appropriate Complementary Feeding: 04
- Other, Specify: 05

Mother's PNC/TCT Code:

- Results of the child: Reactive: ( ) Non- Reactive: ( )
- Child initiated on treatment: Yes: ( ) No: ( )
- Date child initiated on treatment: ____________

Watch this line showing the child's growth. This growth curve should continue to go up every time you have your child weighed.

- A child is severely underweight for his or her age when the growth line crosses the lowermost curve ("d") or the weight lies below the lowermost curve ("d").
- A child is severely underweight when the growth curve crosses the lowermost curve ("d") or the weight lies below the lowermost curve ("d").

Weigh the child during each visit. Properly record on the card and interpret to the mother or caretaker.

- Know the child's age and gender.
- Measure the child's weight.
- Ensure the child is dressed in the same way.
- Take the measurement in a quiet, comfortable environment.
- Use a standardized scale.
- The child should be undressed and weighed in the same manner as the previous measurement.

Spending time with your child: Playing with him or her, talking to him or her, and encouraging him or her to learn will help him or her to develop.

DISCUSSION:

1. Breast feeding
2. Maternal nutrition
3. HIV and AIDS
4. Immunization and Vitamin A supplementation
5. Feeding the baby during illness and after illness
6. Other foods from 6 months of age
7. Frequency of feeding
8. Clean food and water
9. Child spacing
10. Sanitation and hygiene