Lessons from implementing a league table application in the health sector

A case from Malawi

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Abstract

Malawi’s Health Management Information System (HMIS) is currently going through a strengthening process. Though good progress has been made, the data in the system receives limited usage and is of poor quality. As HMISs are dependent on available quality data to support decision-making, further strengthening efforts are needed to increase the availability of quality data.

This thesis and its research builds upon prior research suggesting that league tables can be used to improve data quality and usage in Malawi’s routine health management. Earlier research also found that creating league tables using the existing functionality of Malawi’s HMIS can be challenging, suggesting that an dedicated application could be a solution. Hence, this thesis looks at the process of designing, developing and implementing an app, called the League Tables Application (LTA) in Malawi’s HMIS. Furthermore, it looks at challenges and opportunities related to these processes.

This study has involved potential users from all levels of the health system in the process in order to identify common thoughts and ideas for the application.

Through demonstrations and users testing the application, feedback suggests that the LTA was a user-friendly tool to analyse data for decision-making. It also proved to give motivation as well as stimulating competition. Though the application showed promise, it also showed a lack of quality data and usage which in turn reduced the analytical value of its results.

In order to properly utilize data and tools to support decision-making, efforts need to be put into increasing data quality and usage.
Acknowledgements

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Abbreviations

ALMA  African Leaders Malaria Alliance. 14
API  Application Programming Interface. 56
AR  Action Research. 32
ASD  Agile Software Development. 40

CHAM  Christian Health Association of Malawi. 24
CMED  Central Monitoring and Evaluation Division. 25

DHIS2  District Health Information Systems 2. 1
DHMT  District Health Management Teams. 25
DMO  District Medical Officer. 13

GDP  Gross Domestic Product. 20

HIS  Health Information System. 1, 19
HISP  Health Information Systems Program. 1
HMIS  Health Information Management System. 2, 19
HSA  Health Statistician Assistant. 92
HTML  HyperText Markup Language. 64

ICT  Information and Communications Technology. 22
IIs  Information Infrastructures. 7
IMF  International Monetary Fund. 20
IT  Information Technology. 8

JSON  JavaScript Object Notation. 64
LTA  League Tables Application. 1

MDG  Millennium Development Goal. 10

MGDS  The Malawi Growth and Development Strategy. 21

MMR  Maternal Mortality Ratio. 23

MOH  Ministry of Health. 1

MVC  Model-View-Controller. 64

MVP  Minimum Viable Product. 37

NGO  Non-Governmental Organization. 3

NICE  National Initiative for Civic Education. 92

NSO  National Statistical Office of Malawi. 92

QA  Quality Assurance. 1

SWAp  Sector-Wide Approach. 27

UiO  University of Oslo. 27

WHO  World Health Organization. 24

WIP  Work-in-Progress. 43
Chapter 1

Introduction

Rankings are often used to compare institutions in various sectors such as sports, education, banking, finance and health\[67\] based on performance. Using league tables is one technique to present such rankings. In the health sector league tables can be used as tools for measuring and comparing the performance of similar service providers.

This thesis looks at the various uses of an application customized for league tables, called the League Tables Application (LTA) developed for District Health Information Systems 2 (DHIS2). It also tries to understand how it can act as a tool to support decision making across all levels of a Health Information System (HIS). In the application service providers can be the facilities within a district, the districts within a country etc. These are ranked by a score calculated based on a set of indicators. In this setting this means a set of health-related variables which represents a provision of health services to a specific population\[34\]. Potential league table usages include acting as feedback mechanisms, support in decision-making, a data Quality Assurance (QA) tool and promote transparency and accountability.

1.1 Background

This project and thesis is part of a larger project in Malawi supported by the Health Information Systems Program (HISP) which focuses on strengthening of the country’s HIS.

The research team consisted of five people. Two of the members being us as the authors of the thesis and developers of the LTA. The next three were members of the HISP including a Postdoctoral Fellow which helped supervising the research and development, the head of Health Information Systems in the Malawi Ministry of Health (MOH), and a Professor with
much knowledge and experience with Health Information Management System (HMIS) in Malawi.

The development of the LTA happened throughout the entirety of the project and is divided into four prototypes, which are described in section 5.6. The main bulk of the data collection was done over a one month period in Malawi, where the application was presented and tested with various organizational bodies in four districts.

1.2 Motivation

"We want to go beyond collection data, we want to use it"
(MOH staff member)

Performance measurement and providing feedback in health management systems can be a challenging task, especially in a developing country like Malawi with limited resources. In the health sector, it can be demanding to monitor how well districts and hospitals are performing compared to each other and if they are improving at all. To be able to highlight which parts of the system that are performing as expected and which parts should be taken action upon and improved would be advantageous.

League tables have had some promising results in earlier studies and implementations. One example is a study on league tables in Malawi where it was concluded that league tables promote transparency and accountability through openly presenting data as well as increasing the quality of data. It was also suggested that there is a wish for more comparative feedback in Malawi[34].

An example of a successful implementation is one who took place in Sierra Leone. It showed that league tables can contribute to significant improvements of data reporting and data quality. It also created a competitive environment which caused lower ranking chiefdoms(sub-districts) to improve their performance and placing them in the top ranks of the league table in later periods[53].

While the concept of league tables have shown promise, there is currently no simple solutions to create league tables in Malawi’s HMIS and DHIS2 in general. Developing an application customized for league table creation could reduce the perceived complexity of DHIS2 and further explore the use of league tables to support decision-making in HISs.
1.3 Scope

This thesis looks at the entire process of designing, developing and implementing the LTA into the Malawi HMIS. It looks at the many uses such an application may have, where the main purposes include performance monitoring, improving data usage and quality, increasing transparency and supporting decision-making in the Malawi HIS.

1.4 Research questions and objectives

The purpose of this thesis is to explore the different factors, including challenges, opportunities and approaches that influence the design, development and implementation of the LTA in Malawi. Firstly, design refers to choices made regarding functionality and visual representations. Secondly, development is the process of realising the design concepts. Lastly, implementation refers to the deployment of the application in Malawi’s HMIS. This thesis is limited to the national, zonal and district levels of Malawi in addition to various Non-Governmental Organization (NGO)s involved in routine health management in Malawi.

The research question that will be addressed in this thesis is presented below:

- Which factors influence the design, development and implementation of a league table application in Malawi?

In practice, the process of design, development and implementation is closely linked without clear boundaries. However, in this thesis the processes have been divided into three. This is merely an analytical approach in order to more conveniently identify the various factors influencing them.

1.5 Chapter Overview

Chapter 2 - Relevant literature presents relevant literature for the theoretical background of this thesis. This chapter is split into four sections. The first section aims to provide an understanding of information systems as both socio-technical system and infrastructures, and the installed base and its functions. The second section presents HISs and common challenges. The third section describes the concepts of league tables and score cards. Lastly, concepts of usability are presented.

Chapter 3 - Research Context gives an introduction to the status of
Malawi’s various conditions, including the economic, infrastructural and health status. This chapter also describes the HIS, HMIS and HISP in Malawi as well as Malawi’s history of league tables.

**Chapter 4 - Methods** presents the Research perspective and methodology of this thesis. It also presents the various methods used in the development and deployment of the application.

**Chapter 5 - App Development** presents the current and final product of the LTA and its technical environment and solutions. Further it describes the applications functionality as well as the formula for score calculation. Lastly, a section dedicated to describing the different iterations or prototypes of the application.

**Chapter 6 - App Deployment** present the empirical findings made during the deployment of the application in Malawi. The main topics being the Installed base and the LTA, as well as the reception of the LTA.

**Chapter 7 - Discussion** compares the literature presented in Chapter 2 to the findings in Chapter 6 and discusses the research questions of this thesis. It also reflects upon the methodologies used in the research and development the LTA.

**Chapter 8 - Conclusion and further work** provides a summary of the discussion in Chapter 7 and presenting some thoughts and suggestions for future work.
Chapter 2

Relevant literature

This chapter will present relevant background literature for the thesis. Firstly the different aspects of information systems will be introduced. Secondly the concept of league tables as well as scorecards will be presented followed by a section covering themes within user-friendliness significant to the development of the LTA.

2.1 Understanding Information Systems

Understanding certain concepts of information systems will be important to this thesis as it helps explain why context matters when developing and implementing information systems. It also helps explain how information systems evolve on its own without external controlling mechanisms. These concepts played important roles when it came to decision making on how to approach the task of developing an application for DHIS2.

Information systems are networks of people, organizations and software made to collect, organize, analyse, store and communicate information. These systems are then used to facilitate planning, control, coordination and decision making in an organization[47][30].

2.1.1 Information Systems as Social Systems

The approach one should take when developing and implementing information systems may not always be the same because "... context matters, and approaches to design and development of HIS must be broad-based and flexible enough to adapt"[14, p. xii]. The development and implementation processes are affected by the context because they are not
strictly technical systems, but also consist of social and organizational elements. Baxter and Sommerville further explains that "it is widely acknowledged that adopting a socio-technical approach to system development leads to systems that are more acceptable to end users and deliver better value to stakeholders"[11, p. 4]. Establishing the concepts of a socio-technical information system is therefore useful to understand the various issues related.

Many technological studies considers technology as an independent artefact with consistent outputs. Kling[52, p. 206] explains why this approach of technological determinism is not enough to understand the issue by referring to what is called the productivity paradox. "Many people have assumed that computerization should directly and dramatically improve productivity"[52, p. 207], why is this not always the case? Kling then gives several explanations to what might cause this paradox[52, p. 207]:

- many organizations develop systems in ways that lead to a large fraction of implementation failures
- few organizations design systems that effectively facilitate people’s work
- we significantly underestimate how much skilled work is required to extract value from computerized systems

Kling further argues that the productivity paradox shows that "... technology alone, even good technology alone, is not sufficient to create social or economic value"[52, p. 207]. Together these observations show how many organizations lose potential value from the ways that they computerize. Technological artefacts and social systems should thus not be seen as two separate components, but rather as complex, interdependent socio-technical networks. This means that information systems should be seen as socio-technical systems[52][21, Chapter 4][41]. "Put simply, the socio-technical system perspective contends that organizations are made up of people that produce products or services using some technology, and that affects the operation and appropriateness of the technology as well as the actions of the people who operate it"[73, p. 1182]. This means that socio-technical systems consist of many different components like people, hardware, software, techniques, support and resources, all of which are interrelated within a matrix of social and technical dependencies[52, p. 213]. Kling suggests that all of these components should be taken into consideration when designing systems in order to gain a sufficient understanding of which features and tradeoffs future users will find the most appealing[52, p.213].
Another concept used to understand the nature of information systems is Information Infrastructures (IIs). IIs can be defined as "...a shared, open (and unbounded), heterogeneous and evolving socio-technical system (which we call installed base) consisting of a set of IT capabilities and their user, operations and design communities"[41, p. 4].

Infrastructures have no life cycle – they are "always already present"[41]. An example drawn from nature are the paths and roads that have been there since the first path was created by an animal, always evolving with new routes while the barely used routes slowly disappear. The evolution of the IIs are dependent on the adaptability of the existing components. Thus in IIs some components more than others work as an installed base for new features[40]. One can see this as the II building upon its existing features to evolve.

IIs can in a sense behave like a living organism. It grows and evolves over time based on existing infrastructure, without ever having a clear target group or purpose. Because of this, researchers have applied biological metaphors in describing how II develops such as evolution, cultivation, growth, and nurturing [80, p. 225].

To expand on the characteristics given by Hanseth to define IIs: An II is shared by a larger community in the sense that it is the same single object used by all members of said community, although it may appear different to some. IIs can be seen as irreducible meaning that they cannot be split into separate independent parts. IIs are open in the sense that they exhibit unbounded openness: new components can be added and integrated with them in unexpected ways and contexts. In addition, there are no clear boundaries for whom can use and build upon the IIs. This results in an ever increasing social and technical diversity and heterogeneity over the lifetime of an II[21, Chapter 4]. Hanseth explains that IIs can be heterogeneous in two different ways. First, they can be seen a something more than pure technology, namely socio-technical networks. IIs consisting of more than one type of component is what makes them heterogeneous in a socio-technical way. Secondly, IIs consists of several ecologies of sub-infrastructures that again can consist of more sub-infrastructures. This happens when infrastructures are built on top of others making a sort of layered structure. This links logical related networks and components making them interdependent[21, Chapter 4][41]. The different structures and networks within each ecology of sub-infrastructure is what makes IIs heterogeneous in a structural and organizational way.
2.1.3 The Installed Base

An installed base is the existing components of an infrastructure which work as foundations for new components. As IIIs are seen as heterogeneous, this means that anything from data and hardware to more abstract elements like information, organizations and knowledge. The installed base is the components the evolution of IIIs build upon, but that doesn’t make them static and constant. They are, along with the rest of the II, always changing based on its environment. Thus, IIIs require a continuous adoption of the new socio-technical elements[Chapter 4 21, p. 60].

"Overall, the evolution of infrastructures is both enabled and constrained by the installed base, that is the existing configuration of II components”[41, p. 4].

The creation of large infrastructures are done over long periods of time. It does not happen instantly, as all elements are connected meaning that the new also has to be connected to the old. New elements has to be designed in a way that links the old and the new together making them interoperable. This is how the old, the installed base, influence the design and implementation of the new. Infrastructures develops or evolve through extending and improving the installed base [42, Chapter 9].

IIIs evolve by always building upon, and adding to, the installed base creating a self-reinforcing cycle as seen in figure 2.1. This happens when the installed base attracts complementary Information Technology (IT) capabilities which makes the original capability increasingly attractive causing some users to adopt it, increasing the value of its standards. This again makes it more likely that another user will adopt it as a larger installed base also increases the credibility associated with the capability and reduces user risks of foregone investments, which causes further increasement of its value meaning more users to adopt it, and so on[41].

Figure 2.1: Self-reinforcing cycle[42, Chapter 9]

Having an understanding of the installed base is crucial for the project
This thesis describes. It includes all the existing components of the Malawi HIS including infrastructural, social, technical and organizational aspects. This limits what is possible to accomplish, as any addition to the installed base will have to ensure compatibility with the existing components. It also gives great opportunity, as the installed base can be leveraged for improvement, which in our case where we developed a relatively small app, could use existing data and structures such as district review meetings.

2.2 Understanding Health Information Systems

A Health Information System (HIS) can be defined as a collection of components that work together to improve health services management through optimal information support. Information in this context is a meaningful collection of facts or data[57]. A description made by Hurtubise(1984) explains that they are systems that provide relevant information to support the decision-making process at each level of an organization. The main goal of the HIS is therefore to improve action rather than gathering information. By applying this description in conjunction with the earlier definition to the health sector, one can define HIS as "a set of components and procedures organized with the objective of generating information which will improve health care management decisions at all levels of the health system"[57, p. 2-3].

There are many different types of information systems supporting health services. This thesis concerns specifically HMISs. There are other prevalent types of information systems, such as logistics information systems, patient records, lab information systems, etc, that can also be defined as subsystems of a unified HIS[57]. Although these are not the focus of this thesis. HMISs aim to aggregate, report and process data to improve efficiency and effectiveness of health services[14][34]. They are specially designed to assist in the management and planning of health programmes at all levels, as opposed to delivery of care[93].

Understanding the meaning of these terms is important to gain an understanding of the research and development context for this thesis. It helps to understand the complexities of IIs as well as the functions of HIS and relevant subsystems like the HMIS.
2.2.1 Common Challenges with HIS in developing countries

"It is not because countries are poor that they cannot afford good health information; it is because they are poor that they cannot afford to be without it"[5, p. 582].

Like we established earlier, HISs should be a network of components communicating and working together to improve and support decision-making. So how well are HISs performing currently? The sobering response is not very well as there is a serious lack of sound information to be used for effective decision-making[5] which is the main purpose of a HIS. This section will describe typical challenges with the HIS in developing countries as the research in this thesis is based on the Malawi HMIS which is a developing country.

In reality, HISs have many issues when it comes to functioning as an organized and coordinated system. They can often be seen as products of historical, social and economic forces, making them too complex, fragmented and unresponsive to needs. Generating good data in such heterogeneous systems can be a challenge as public and private provision and financing usually coexist. Responsibility is also an issue as it becomes diluted as an unintended consequence of donor actions. Donors often support and implement their own data collection platforms to meet demands of accountability. They want to maximize comparability, prioritizing urgent needs for health program related data rather than long-term investment that could help countries build capacity.

Anxiety about the availability and quality of data reported by individual countries cause the establishment of independent bodies primarily concerned with global monitoring[5]. The result is duplicated mechanisms that responds to donor requests rather than to the needs of the country’s decision-makers. The problem is particularly acute when modelling is used to fill in missing data elements, which countries see as an externally driven process[5].

Having insufficiently developed systems, filled with on-demand indicators prevents them from being able to perform regular monitoring like cause-specific mortalities. All of this becomes very clear when one looks at many countries inability to generate the data needed to monitor progress towards the Millennium Development Goal (MDG)[5].

Thus most country HISs lack cohesion, as they are developed in a piecemeal way, fashioned by administrative, economic, legal or donor pressures[5]. This is reflected through countries selection of indicators often are unused, duplicated and inaccurate. This can be seen as a sign of sustainability failure for HISs, meaning that they succeed initially but are
then abandoned after a relatively short period of time[44].

Establishing sustained and comprehensive systems of vital registration is an expensive, long-term proposition that lacks appeal for governments with short-time horizons. But there is still evidence that significant financial resources are being directed towards the generation of health information in developing countries. It is estimated that approximately US$ 1.25–2 billion are spent each year on different aspects of health information, of which around US$ 0.75–1 billion is spent by low-income and lower-middle-income countries and some US$ 0.5–1 billion by global organizations[5].

Another important challenge many countries face is that health information is made up of poor quality data and the information receives little use. Poor quality data is not used, and because it is not used, it remains of poor quality[14, Chapter 9], leading to a vicious cycle that is hard to break.

The demand, supply and quality of information is connected. If information needs are not specified and quality information not requested by various user groups, the information will not be provided and thus use of information will not improve[14, Chapter 9]. Countries often struggle the most with the first step which is generating quality data rather than the following steps of exploring how to actually use it. Improving the quality of data requires there to be more use of data closer to its source as well as more use of data in general. It also requires users and producers to gain a sense of ownership of the information system they use as well as participation in related decisions. Without this, quality data and its sound use will be hard to achieve[14, Chapter 9].

### Summarizing common challenges

To summarize, HISs struggle with fragmentation and lack of cohesion due to different parties pulling in different directions and poor data quality due to lack of use. They have a tendency to focus on achieving short-term goals rather than long-term sustainability. This causes a build-up of independent or duplicate components within the system defeating its intended purpose. There many challenges related to lack of data usage, especially at lower levels and those closer to data sources, causing data quality to deteriorate.
2.3 League Tables & Scorecards

Of the identified challenges with HISs, this thesis concerns the lack of information use and ranking systems is one measure that could improve these shortcomings. "There are various ranking systems have been developed to measure the performance of institutions in various sectors such as sports, education, banking and finance, and health to achieve accountability and comparative evaluation"[67, p. 1]. The selection of ranking systems does have an impact as "the analysis and presentation of performance data does matter since it contributes to whether the information is used in decision making or not"[84, p. 218].

One way of measuring performance is to use league tables. "The popularity of such league tables suggests that they are easily interpreted and valued by subscribers, which may, in part, explain the rapidity with which they were introduced in a modified form to rank the performance of public sector and similar organisations"[6, p. 95]. League tables can be defined as a technique for displaying comparative rankings of performance indicator scores of several similar providers[6]. In other words, league tables are principally used when no standard against which to judge performance has been set[6]. A prerequisite in league tables is that the entities that you are comparing are comparable[84].

In health systems, it can be difficult to get an adequate overview of the current health profile and justify when and where to invest resources. "The public health system is there to serve community health, so strengthening their capacities to analyze the health situation and make appropriate action plans is in itself a way to use information technologies to improve community health"[54]. Implementing league tables could be one contribution to information usage in health systems.

This thesis will be researching the implementation of ranked league tables in the Malawi HMIS. These league tables share many similarities with the scorecards which will be described later and the league tables implemented in Sierra Leone(see figure 2.2). The league tables are aimed at ranking comparable units that are providing similar services within the health sector like districts and health centers. The tables are ranked based on a set of selected indicators resulting in a total score. In figure 2.2 chiefdom performance is presented by a composite average score based on the indicators included in the table resulting in a rank. With the appropriate set of selected indicators, league tables can assist in decision making at different levels through the health sector as it could help the managers allocate resources and set focus areas. Ideally, league tables should be used within the existing management practices as for example quarterly reviews.
There are many potential advantages league tables can give. It can for example function as a tool for monitoring and ensuring accountability for providers[6]. It can highlight the facilities strong performances as well as those who are struggling. This can initiate investigations to determine the reasons for said results. One can then use this knowledge to learn from those who perform well and help those who struggle. The league tables can also raise awareness about information that is available and encourage managers to introduce improvement strategies when performing poorly. Previous research have also shown cases where league tables have raised much discussion especially in relation to a few indicators that had much variation among the districts[54].

League tables have contributed to stimulating competition between similar service providers[6]. An example can be seen in a case from Sierra Leone; after the district Western Area ranked at the bottom of a league table, change was desired. Being concerned by the poor performance in their own district, the District Medical Officer (DMO) in Western Area decided on two strategies to improve the health services which resulted in placing first the next two quarters[54]. "By comparing themselves and knowing more about health indicators, local community leaders decided to better organize health service delivery in their community and put more pressure on upper level for more resources and more support"[54]. Additionally, "preparing data from neighbouring districts or chiefdoms, available from an integrated data warehouse, in league tables that are then shared widely with these stakeholders has been a powerful result from several districts in Sierra Leone"[54].
One more advantage with league tables is its ability to make the most of out available data with the help of the comparative aspect. "In a context where information about your own situation is sparse, and knowledge about what it should be is even sparser, the availability of comparative data from other districts and chiefdoms can at least give a relative performance indicator"[54].

However, usage of league tables provokes several challenges. One of the most noticeable is the data quality problems and the value of league tables depends on the quality of data used in the calculation of tables. In a case in Sierra Leone, data completeness was an issue, only indicators for which there would be adequate data available were included[54]. Studies have shown that most performance indicators have been selected on the basis of what is available and practical rather than what is meaningful[6]. The lack of data in health systems stigmatize an environment where the indicators missing data simply are avoided in addition to ignoring indicators outside of the ones used for ranking.

Another issue with league tables is the comparison of entities that are not really comparable making it unfair; the deceptively simple and at times misleading summary indices given complexity and varying contexts in health systems; the ‘naming and shaming’[84]. Managers of poor performing units feel blamed although confounding factors such socioeconomic status, levels of education, water and sanitation situation, social policy implementation, nutritional situation and political stability parameters are not taken care of in the ranking[48]. In some situations the ranking in league tables is not a fair method of comparing performance given the different contexts in the districts and that the rank of the district is not capturing the complex realities of districts[84].

"Creative reporting" once providers know they are publishing data is another potential disadvantage in ranking systems such as league tables. There is a problem that units deliberately report wrongly to appear better on the ranking. "It is suspected that the desire to be seen to perform well may have contributed to data manipulation by some district managers"[84, p. 9]. The fear of being ranked can be solved by displaying charts without ranking, but rather displaying the special causes.

A popular alternative to league tables are balanced scorecards. They can be described as a list of key performance indicators and performance benchmarks in several domains[31]. Although the scorecards were originally developed for industry, they are now becoming a popular strategic management tool in the health sector[31]. African Leaders Malaria Alliance (ALMA), which is an coalition of 49 African heads of state have implemented another version of scorecards called ALMA Scorecards. The ALMA Scorecard is produced quarterly and "...is a tracking and action tool provided to heads of state and government and their ministries..."
to ensure transparency, accountability and action on malaria control across Africa”[8]. These scorecards present much information at once giving an overview of the status of health with the help of colors to indicate levels of performance. An example of the can be seen in figure 2.3. This thesis will be focusing on league tables even though scorecards have many of the same features and functions as league tables.

Figure 2.3: ALMA Scorecard For Accountability and Action, Quarter 4, 2015[9]
2.4 Designing for usability

In this thesis there will be presented ideas, implementations and observations during the deployment of the LTA regarding usability which is also commonly known as user-friendliness. Usability is one of the key factors of software quality and can be described as the science of making technology work for people[79]. Although most have an idea of what user-friendliness is when it comes to software, it can be hard to pinpoint the aspects that actually makes an application easy to use. This section will present aspects around the theme usability.

Usability is "...generally regarded as ensuring that interactive products are easy to learn, effective to use, and enjoyable from the user’s perspective"[74, p. 20]. Furthermore ISO 9241 defines usability as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"[49]. To help set a frame for the term it can be broken into a set of usability goals[74, p. 20]:

- effective to use (effectiveness)
- efficient to use (efficiency)
- safe to use (safety)
- having good utility (utility)
- easy to learn (learnability)
- easy to remember how to use (memorability)

**Effectiveness** is a very general goal and refers to how good a product is at doing what it is supposed to do[74]. In other words effectiveness considers the completeness and accuracy with which users achieve specified goals[76]. For example when critical transactions are present like in a ticket booking system, displaying the correct information and making the correct transactions would be more important than the actual booking speed. Put somewhat extremely, another example is to reflect the precise status of the airspace at any time in an air traffic control system, organizing the traffic ultimately preventing collisions. However, when it comes to **efficiency**, the time taken to finish tasks is central. For example, in an inefficient application the users could have trouble finding exactly what they are looking for when navigating using many unnecessary steps. Making the right choices for efficient use of the software depends on an understanding of the users and how they prefer to work[76].

**Safety** involves protecting the user from dangerous conditions and undesirable situations[74]. More specifically it is about how easy it is to make errors, and how easy it is to correct them. Although the task
of covering errors in all possible errors within software development is impossible, it is important to have a mindset where the software is designed to prevent errors caused by the users interaction. A practical example of a preventative measure could for example include having descriptive error messages which an average user would understand. Another example is to be cautious on the placement of destructive actions like deleting. Designing the software in a way that its it’s hard to unintentionally do a delete action would increase the safety.

**Utility** boils down to the extent to which the product provides the right kind of functionality so that the users can do what they need or want to[74]. In a design with high utility users find the tools they expect and use them to complete tasks. In design where the utility is low the functionality doesn’t offer enough to enable the users to conduct tasks.

**Learnability** refers to how easy it is to learn to use the product. An interface which is easy to learn allows users to build on their knowledge without deliberate effort[76]. It is limited how much time and effort an user are willing to put down in learning how to use new software, and in general people want to start right away carrying out tasks. Lastly, **memorability** is about how easy it is to come back to use a product once learned.

There is no definitive answer on how an application should interact with users, but developing an application with the usability goals in mind could increase the chances to making an application that will be well received by the end-users. To have a general approach on how to develop an application in such fashion one could adopt the four basic activities in the process of interaction design[74, p. 17]:

1. Identifying needs and establishing requirements for the user experience.
2. Developing alternative designs that meet those requirements
3. Building interactive versions of the designs so that they can be communicated and assessed.
4. Evaluating what is being built throughout the process and the user experience it offers.

The activities can help with reflecting around the goals throughout development and help identifying the target users needs and raise awareness on the usability of the application. Thus, contributing to a better overall design avoiding complex and unintuitive solutions. Simplifying functionality through applications can give power to the users in a heavy system where complex systems may disrupt the tasks the users want to do.
Chapter 3

Research Context

In this chapter a brief overview of the research context will be given. The research of this thesis were mainly conducted in Malawi, so the content will give a view of the challenges Malawi’s health sector is faced with as well as the complexities of its health system. More specifically the chapter is divided into sections giving an overview of Malawi and the status of Malawi’s economy and infrastructure, an introduction to the country’s HIS and HMIS and lastly, a brief overview of previous attempts of implementing league tables will be presented.

3.1 Overview

Malawi is a landlocked country in southeast Africa. It is bordered by Zambia to the northwest, Tanzania to the northeast, and Mozambique on the east, south and west. The country is separated from Tanzania and Mozambique by Lake Malawi.

Administratively, Malawi is divided into three regions namely North, South and Central. These regions are further divided into 28 districts countrywide. The Malawi health system, however, is divided into five zones; north zone, central east zone, central west zone, south east zone and south west zone. Furthermore the health system consists of 29 districts country wide as one of the districts (Mzimba) is divided into Mzimba North and Mzimba South. This thesis presents data collected from national level as well as 4 districts in the central region, namely Dedza, Dowa, Kasungu and Mchinji.
Malawi extends over an area of 118,000 km² with an estimated population of 17,964,697 (July 2015 est.[87]), making it a densely populated (152.5/km²) country. Malawi’s population had a growth rate of 3.2% during the years 2010-2015 (3.32% (2015 est.)[87]) and is the fastest growing country in Sub-Saharan Africa. Approximately half (46.7%) of Malawi’s population is aged 0-14 years old, and the proportion has continued to increase in recent years with only 2.7% of the population being over 65 years.

With only $463.6$ Gross Domestic Product (GDP) per capita as of 2010[88], it was estimated that just over half (50.7%[24]) of the country’s population was below the poverty line. In comparison, Norway had a GDP per capita $129,5$ as of 2010[88].

The country’s economic performance has historically been constrained by policy inconsistency, macroeconomic instability, limited connectivity to the region and the world, and poor health and education outcomes that limit labor productivity. The economy is predominately agricultural with about 80% of the population living in rural areas. Agriculture accounts for about one-third of GDP and 90% of export revenues. The performance of the tobacco sector is key to short-term growth as tobacco accounts for more than half of exports. The economy depends on substantial inflows of economic assistance from the International Monetary Fund (IMF), the World Bank, and individual donor nations[87]. As a result, 40 percent of the budget for the financial year 2012-2013 was expected to be met by donations[62]. Over the past years the country has experienced fallout
with donors, leaving the public service delivery negatively affected, and the country in a deep economic crisis[62].

### 3.2 Infrastructure

According to The Malawi Growth and Development Strategy (MGDS), Malawi’s infrastructural goals are "to create wealth through sustainable economic growth and infrastructure development as a means of achieving poverty reduction"[59, p. 5].

![Graph 7: Infrastructure Index, 2008](image)

Figure 3.2: Graph comparing the infrastructural rankings of Malawi to the rest of Africa [58, p. 10]

Malawi has made considerable progress towards developing its infrastructure. For example, as of 2006, the country had already met the United Nations MDG target for water, ten years before the deadline. Only four other Sub-Saharan African countries had achieved the same[33]. The country has also made significant progress on investment and institutional reforms like introducing a road fund in order to improve its road infrastructure. Foster and Shkaratan report that institutional reforms for the power sector were ahead of the average score for Sub-Saharan Africa countries. Malawi also has one of the highest GSM signal coverages in Africa. With a coverage of 93% they are exceeding the average of 85% across middle-income coun-

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tries in the region[33]. Still many challenges remain[33]. These challenges include Transportation, Energy, Agriculture, Water and Information and Communications Technology (ICT)[58]. Given these challenges, Malawi compares poorly with other countries with a rank of 106 out of 140 as seen in figure 3.2.

The infrastructural challenges affect many areas, including Malawi’s HMIS. Its efficiency is dependent on ICT and power to store and access data, communicating between levels and training of personnel to operate the HMIS. The HMIS is also dependent on road infrastructure as a big part of the process around gathering data are done manually. More specifically physical transportation of monthly summary form (see figure 3.3) are delivered from community to district level.

Figure 3.3: A filled out monthly summary form from a Health Center which needs to be sent/colllected physically from community to district level.

The challenges most relevant to this thesis are related to shortcomings within ICT and Energy/Electricity. "Outages in Malawi have been about three times the average levels observed in the peer group"[33](peer group, 24 Sub-Saharan countries). These outages could happen due to errors at the electricity suppliers, but also because of unpaid bills. Unpaid
bills is a quite common problem as only 60 percent of bill payments due are actually collected.[33]. Although Malawi’s GSM network has a signal coverage of 93%[33] and with reasonable prices, prices for ICT services remain relatively high in Malawi while the coverage and speeds are limited. This is mainly due to Malawi’s landlocked position and the lack of a submarine cable along the East African coast[33]. Malawi’s ICT also has other challenges including stability, which is also affected by the lack of reliable power sources.

3.3 Health

Over the last decade, life expectancy in Malawi has risen from about 45 years (2000) to 60 years (2012)[61]. One of the main contributing factors has been a decline in childhood mortality. Under-five mortality has been reduced from about 225 in 1990[61] to about 46 in 2015[87] which is slightly above the MDG of 45.

Maternal Mortality Ratio (MMR) has also been reduced over the years, from 1100 in 1990 to about 460 in 2010 resulting in a 59% decline over a 20 years period[60]. This is a substantial decline, though still above the MDG of 275.

Other contributing factors are total expenditure on health per capita which has increased from just over 0$ in 1995 to 90$ in 2013. The expenditure on health is still very low and can be seen when compared with Norway which had a total expenditure on health per capita of 6308$ in 2013, which is about 70 times higher than Malawi. This in addition to many other factors, gives the people of Norway a life expectancy of about 82 years. The GDP in Norway is indeed much higher as well, but the percentage of GDP spent on health is still lower in Malawi, being 8.3% in contrast to Norway’s 9.6%[22].

The reduction of deaths caused by HIV/AIDS were reduced drastically from 99,000 in 2004 to 33,000 in 2014[46], effectively reducing it by more 2/3 in a decade, has been a major contribution factor to the increased life expectancy as well. HIV/AIDS in addition to Malaria and Lower respiratory infections, are the three most common causes of death in Malawi.
3.4 Health Systems

3.4.1 Structure

In Malawi nearly all formal healthcare services are provided by two main agencies. The MoH provides about 60% and the Christian Health Association of Malawi (CHAM) provides 37%[43], where the remaining 3% are provided by private practitioners, commercial companies, army, police etc.

The public health system of Malawi delivers services at three different levels of care, namely primary, secondary, and tertiary levels[65, p. 3].

- **At primary level** you have community initiatives, health posts, dispensaries, maternity facilities, health centres, and community/rural hospitals. These services are provided by trained personnel from the community such as health surveillance assistants, distributing agents, village health committees, and other volunteers. In short, primary level services provide a range of mostly promotive and preventable services and some curative services.

- The **secondary level** services are provided by district hospitals. If the primary level cannot provided the required services, then clients will be referred to these hospitals. The secondary level services provide both inpatient and outpatient services for their target population.

- **Tertiary level** services are provided at central hospitals. Again, if the secondary are unable to provided the required services for their clientele, the tertiary level is their target for referral. They provide services for their region and are mandated to offer professional training, conduct research, and provide support to the districts.

3.4.2 Health Management Information System in Malawi

World Health Organization (WHO) states that "the health information system provides the underpinnings for decision-making and has four key functions: data generation, compilation, analysis and synthesis, and communication and use"[70, p. 2]. In other words, the HIS works as the overlying structure for the more specific health related systems such as the HMIS, patient journals and patient management systems. WHO further describes that the health information system "...collects data from the health sector and other relevant sectors, analyses the data and ensures their overall quality, relevance and timeliness, and converts data into
Malawi’s HMIS encompasses data collection, reporting, processing of said data and use of information to improve efficiency and effectiveness of the health services. The HMIS hierarchy (see figure 3.4) has four different levels, starting from the bottom is facility level, then district level, zonal level and at the top is the MoH or national level.

- **Facility level** offers primary level services treating the largest portion of patients.

- **District level** offers secondary level services.

- **Zonal level** provide technical support to District Health Management Teams (DHMT)s and facilitate central hospitals’ supervision of districts[65].

- **National level** provide tertiary level services and "...is responsible for developing, reviewing, and enforcing health and related policies for the health sector"[65, p. 4].

The information flow in the HMIS goes through the levels and begins at facility level where data collection is done, usually with pen and paper. At district level, the data collected is digitalized by entering it into DHIS2. This data is then available for all levels, with access to computers, to analyze. Non-routine information such as head-counts or censuses are also gathered and entered into DHIS2.

At national level, the Ministry of Health’s Central Monitoring and Evaluation Division (CMED) has oversight over the national HMIS and is responsible for producing quarterly and yearly comparative reports, for use by managers and other relevant stakeholders, at different levels of administration[62].
In September 1999, Malawi began a process of strengthening its HMIS after several challenges had been identified. These include a lack of reliable data, coupled with poor appreciation and use of available information in health services planning and management. There was an absence of indicators to guide data analysis as well as fragmentation of information systems along vertical health programme lines. Lastly, there were issues with the access to centralised data for geographically distributed stakeholders. Interventions undertaken in this period were mainly focused on creating a foundation for the national HMIS. These efforts led to many things, including handbooks, training manuals, policies and implementation strategies for health information systems. Most notably, and with support from the Dutch government, they led to the commissioning of a desktop-based HMIS software solution (DHIS 1.3) in 2002 [62].
Within the period of 2002 to 2009, the Malawi government, with support from various donors, was also designing a Sector-Wide Approach (SWAp) to strengthen health service delivery and monitoring in Malawi. The purpose of SWAp was to harmonize donor support by channelling funds through a common basket. SWAp was rolled out in 2004 with resources allocated to strengthen the HMIS of Malawi. However, the allocated resources for HMIS support were deemed insufficient, which resulted in the government approaching the World Bank for additional resources targeted at HMIS strengthening[62].

The HISP is a global network established, managed and coordinated by the Department of Informatics at the University of Oslo (UiO). They design, implement, and sustain HISs following a participatory approach to support local management of healthcare delivery and information flows in selected health facilities, districts, and provinces, and its further spread within and across developing countries[86].

The purpose of HISP in Malawi is to support and improve the implementation of an integrated HIS. HISP is expected to facilitate increased integration and more rational data and information flows in Malawi. The need for information support in planning, monitoring and evaluation of healthcare interventions is an expressed need by health workers and international agencies as one of the factors which can lead to the achievement of the MDGs. Some optimal achievements in terms of structure and availability of information for decision making has been achieved so far, however the health information system is still characterized as inflexible due to its inability to respond to the ever changing needs of the health system[45].

In 2009, The Ministry of Health, through CMED and with funding from HISP Oslo began the process of upgrading the national HMIS software solution. This included replacing DHIS 1.3 with DHIS2, setting up an internet server-based solution and integration of parallel health information systems with DHIS2 as the overarching national health data warehouse. It also included the process of decentralizing access to routine health data across administrative levels, and building IT capacity to enhance end-user support and maintenance of existing solutions[62].

Additional technical support was needed to do the shift from DHIS 1.3 to DHIS2. Consequently, a team of three DHIS2 coordinators were established. This team was based in Blantyre along with the DHIS2 servers, 300km away from CMED in Lilongwe, between 2009 and 2012. This caused financial and logistical difficulties, making the process slow and few of the planned pilot projects were commenced[62].

The following year, CMED prioritized strengthening of local area networks and internet connectivity at the district level, to enhance utilization of the online DHIS2 server solution. Mobile modems were purchased in
order to provide district health offices with reliable internet connectivity. In addition, migration of data from parallel programme centred legacy systems to the national DHIS2 solution was also being done[62].

As a result of this long and tedious migration process, DHIS2 is available today at district, zonal and national level.

Despite these efforts, many challenges and shortcomings related to Malawi’s HMIS remain. HMIS is experiencing some weaknesses, these include a multitude of things. Inability to report data in appropriate formats, lacking completeness, reliability and timeliness of data sets. This causes delays in the production of reports, mainly the 6-monthly ones from districts and central hospitals. There is little coordination between data sources as some vertical programmes collect their own data. In conjunction with little quality assurance of the reported numbers results in frequent duplication and/or faulty data[32]. There is also a lack of qualified and motivated human resources to utilize the HMIS efficiently. This is a problem as qualified and motivated people are crucial to increase productivity and quality of health services[39].

3.5 History of League Tables in the Malawi HMIS

The first use of league tables in Malawi for performance monitoring was done in the Malawi joint annual health sector review in 2006, using selected health sector indicators[64]. The district performance league table was presented at the national SWAp review meeting and received mixed reactions. Some saw potential in it as it could promote behavioural change and encourage teamwork. Others were against it, especially those that were performing worst and were ending up at the bottom of the table. The use of league tables to measure district performance was criticized due to its methodological shortfalls including the selection process of indicators and weights. Criterias for weighting the selecting indicators were questioned as participants didn’t know how it was done. Participants also expressed concerns on the lacking transparency regarding the methodology used for coming up with the rankings, as the weighting of indicators was arbitrary. At the time, data used from the routine health information system was considered of poor quality in terms of completeness and timeliness. In addition, other participants questioned the data used as it was not audited and verified. The concept of league tables was then used for a couple of years before it was discontinued due to numerous shortcomings[67].

A later attempt at bringing back league tables as a feedback mechanism
to support routine health management in Malawi, was done in 2014-15 by a master student at UiO. While testing the concept in Malawi, a set of enabling and constraining factors were found. Of the enabling factors there were HMIS-routines, HMIS-software, existing practices and a wish for more comparative feedback, while constraining factors included things like infrastructure, training, access to DHIS2 and more[34]. There were also a series of shortcomings when using existing functionality in DHIS2 to make league tables, causing customization of tables to become very troublesome. Despite the earlier efforts in 2006 having been met with criticism and concerns, it was found that "... the general impression was that most participants were interested in implementing league tables."[34, p. 88]. For further work on implementing the concept of league tables in Malawi, it was proposed that data quality needed much improvement, increased user-friendliness of DHIS2 and the creation of a specific application within DHIS2 for creating league tables[34].

### 3.6 Summary

Malawi is faced with many challenges when it comes to creating a successful working HMIS. The most notable challenges are poor data quality and little use of said data. There is a lacking infrastructure supporting electricity, ICT and transportation. Both of which hinders the development and efficient use of the HMIS-software, DHIS2. Lastly, a lack of resources, that being funding and trained personnel. Without the two, it is hard to fit things like internet bills and data analysis into budget and schedule.

This thesis builds upon prior work and research on league tables in Malawi. However, current tools to create league tables are limited in terms of functionality as they are not specifically designed for supporting league tables. The goals for this research includes to develop an easy to use application for league tables that can help solve some of the mentioned challenges and continue the research on league tables.
Chapter 4

Methods

The aim of this chapter is to describe the research approach and the methods used in this thesis. The chapter is divided into three sections which describe the research perspective, the methods used in app development and lastly the methods used in the implementation of the app.

4.1 Research Perspective

The thought behind this section is to describe the research perspective in the thesis prior to describing the methods used more in detail. Myers describes that "research methods can be classified in various ways, however one of the most common distinctions is between qualitative and quantitative research methods"[69, p. 1]. Furthermore one definition describes the distinction as follows; "While quantitative research is based on numerical data analyzed statistically, qualitative research uses non-numerical data"[68, p. 3]. The research in this project falls under the category of qualitative research as the data sources are originating from fieldwork through observations, interviews and focus groups where the researcher’s impressions and reactions are captured during the activities. This type of data, or empirical material can not easily be analyzed using mathematically based methods. Another aspect with qualitative research methods is that the "... methods are designed to help researchers understand people and the social and cultural contexts within which they live"[69, p. 2] which is highly relevant to the design of the League Table application as the app is developed for the users of DHIS2. Furthermore, when it comes to interviewing the stance the researcher take does matter in the research. Walsham describes two roles, "namely that of the outside observer and that of the involved researcher, through participant observation or action research"[90, p. 77].
In positivist research "... truth and reality is free and independent of the viewer and observer"[7, p. 81]. It could be reasonably contended that this thesis however does not fit this statement as it was inevitable that the constructions of the empirical material were affected by the researcher when observing the LTA in use. Interpretative research however is probably one of the research approaches with the best fit when data are viewed in an interpretative way which "...are really our own constructions of other people’s constructions of what they and their compatriots are up to"[35, p. 9]. Furthermore, interpretative research "...is conducted from an experience-near perspective in that the researcher does not start with concepts determined a priori but rather seeks to allow these to emerge from encounters in 'the field'"[97].

The research in the thesis is coloured by our interpretation of health workers thoughts and perceptions on the possible addition of league tables in a HMIS. The general interest was to research how league tables can influence the health system, which includes the people using the system and possibly improve information flow and contribute to transparency of health data. However, research in such HMISs can be difficult to conduct as "the IS researcher entering an organization today is also faced with complex and intertwined conceptual structures which it is difficult to grasp and render intelligible"[90, p. 75]. Furthermore "interpretive studies assume that people create and associate their own subjective and intersubjective meanings as they interact with the world around them. Interpretive researchers thus attempt to understand phenomena through accessing the meanings participants assign to them"[91, p. 5]. Thus, one way to understand the system better could be by researching the people that ultimately is the building blocks that make up the system.

4.2 Action Research

"The choice of research method influences the way in which the researcher collects data"[69, p. 7]. An approach to Action Research (AR) was used in this thesis and the project took place in Malawi, much due to practical reasons as the foundation for implementing league tables is set in previous project. The approach is appropriate because application focus of AR involves solving organizational problems through intervention while at the same time contributing to knowledge[26], which the project seeks to do. The research process in AR is cyclical and the cycles in the research roughly consists of the steps diagnosing, action planning, action taking, evaluation and specifying learning as seen in figure 4.1. The cycles produced information to develop the application and contribute to the research regarding the potential of league tables in general.
By participating with the organization, one can get an inside look at procedures and work patterns. One of the challenges the Malawi HMIS is facing is low usage of available information, and the idea behind introducing league tables is to increase the information usage as well as increasing the understanding of said information. As this thesis revolved around researching the viability of using league tables in the HMIS of a developing country, involvement with the local organization was crucial in the development of the application which lets the user create the league tables. One can argue that such involvement lets the researcher experience and observe situations and problems that otherwise would not be discovered lowering the chance of collecting valuable information. In such a research setting when it comes to developing an app involvement from end-users was an important factor to be successful because the design decisions and features were directly aimed to solve the health workers needs.

Figure 4.1: The cyclical process of action research after Susman et.al [83]
4.2.1 Description of the steps in the AR Cycle

1. **Diagnosing**: In the first cycle, there was identified a need for an application to further explore the potential use of league tables in Malawi’s health system. The hypothesis is that the use of league tables through an application may improve information usage and could be an asset for feedback mechanics in the HMIS. In the following cycles the diagnosing step will be dependent on the previous cycle results which should set the direction of both the application and the research itself.

2. **Action Planning**: This step will mostly consist of developing the application. Initially in the first cycle a prototype will be made based on input from earlier findings regarding league tables in Malawi. The application will be implemented through agile development as the project has to be open for changing requirements from the stakeholders. In following cycles we change focus areas in the application according to new findings.

3. **Action taking**: The action taking phase will be the primary source of the data collection. The process of gathering data is conducted both in Oslo and Malawi and consist various activities described in the data collection section.

4. **Evaluation**: The results will be evaluated and changes in the application will be made based on the findings in the intervention step. Input from the users and others stakeholders are highly important for the application to be successful.

5. **Specifying Learning**: At the end of each cycle, the process will be documented and summarize the learning outcome. The successful of the application will be discussed and aims will be set for the next cycle based on findings.
The main cycles can be presented as follows;

**Figure 4.2:** The cycles of this project

The prototypes produced within each cycle will be described more in detail in chapter 5.6 while feedback and content of each cycle will be described more in detail in chapter 6. The learning outcome of the app itself and the concept of league tables goes interchangeably.
4.3 Prototyping

One of the methods of development in this thesis has been *prototyping*. We used the prototypes to test with users as to gather feedback and data.

To support the research of this thesis, we have developed several versions of a League Table application. We did this to be able to tests the concept with potential users in a live environment. We used prototyping as a methodology for developing our application. Software prototyping is the act of making prototypes of software applications. A prototype is defined by Oxford Dictionary as "a first or preliminary version of a device or vehicle from which other forms are developed"[75]. Software prototyping is then the act of making an early, incomplete version containing the essentials of the final product which later versions can build upon. Creating a prototype can be seen as a cycle which begins by identifying the product requirements. This means understanding the very basic software requirements, especially in terms of user interface. The important part is to get it working, so intricate details about performance, security and such can be ignored.

The next step is to develop the prototype, where the basic requirements together with the user interface are showcased. Making the software work as well as giving it the expected look and feel is prioritized. This can be done through workarounds and suboptimal solutions to early get rid of the things that do not work well. The prototype approach share similarities with one of the core lean startup techniques which is called the Minimum Viable Product (MVP) and can be defined as "that version of a new product which allows a team to collect the maximum amount of validated learning about customers with the least effort"[77]. Although the MVP is mainly used in start up companies aiming to explore the viability of commercial products, the concept still is applicable in this thesis as the importance of developing an app that contains the right functionality is just as important.

The prototype can then be presented to stakeholders in the project. Feedback is collected to be used for further enhancements of the product under development. The feedback is then discussed by the team to agree upon which changes are feasible to implement with regards to time constraints, technical feasibility and budget. The accepted changes are then incorporated into the next version of the prototype and the cycle repeats until the deadline is met or the stakeholders are satisfied with the product[81][82].

The cyclic nature of prototyping very much resembles that of the AR and is appropriate in this research setting in the sense that there are cycles that start with some planning and action taking, and end with an evaluation
of results, producing new knowledge of the subject. Although prototyping and AR share similarities, the AR-project seeks to improve information usage in the health sector of Malawi while prototyping the LTA is one of the methods used in the AR.

4.3.1 Prototyping variants

Software prototyping has many variants, but all are in some way based on two major types of prototyping, namely Throwaway and Evolutionary prototyping.

Throwaway prototyping, also called Rapid Prototyping, refers to the creation of a model that will eventually be discarded rather than becoming a part of the final product. The main idea behind this variant is to rapidly create a model for which user can re-examine their expectations and clarify requirements. When this has been done, the model is discarded, and the system is formally developed based on identified requirements[23].

Evolutionary prototyping aims to build a robust, working prototype in a structured manner and constantly refine it. "...evolutionary prototyping acknowledges that we do not understand all the requirements and builds only those that are well understood"[25, p. 73].

This way of prototyping allows the development team to add features and make changes that were not specified in the requirements and design phase.

"For a system to be useful, it must evolve through use in its intended operational environment. A product is never "done;" it is always maturing as the usage environment changes"[27, p. 6].

The advantage Evolutionary prototypes have over throwaway prototypes is that they are functional systems. They may be incomplete, but they can still be used on a temporary basis til the final product is done.

4.3.2 Benefits of prototyping

Prototyping requires user involvement and allows them to see and interact with a prototype allowing them to provide better and more complete feedback and specifications. Through user involvement, one can quickly identify and improve the quality of requirements and specifications, resulting in faster and less expensive software[72].

Prototyping allows users to interact with a prototype, allowing them to give more accurate and complete feedback on the current implementa-
tion as well as requests for new features and specifications[23]. In short, prototyping increases and improves user involvement in the development. Having a working prototype of the product may prevent miscommunication and misunderstandings as users can see and feel how the product currently works. In the end, with the use of prototyping, the product is more likely to satisfy the customers desires.

4.3.3 Potential disadvantages of prototyping

Potential risks include spending too much time on a prototype. This does not go well with how prototyping should actually be done, namely fast. Users and developers can also grow attached to the prototype or certain features. This can cause problems like developers trying to convert a limited prototype into the final product or users becoming attached to features that might be discarded later. All of which cause conflicts that can be quite time consuming, reducing the efficiency of having prototypes.

4.3.4 Our approach to Prototyping

We used prototyping as a way of quickly developing a working version of the league table application in order to be able to get feedback from end-users. There were no clear instructions on how the application should be, other than the basic concepts and some functionality discovered in previous studies[34]. Getting feedback from end-users was therefore very important as our development had to base itself on just that, what the customer, or the end-users liked and did not like.

Using prototyping as a method was then very beneficial as it allowed us to always have a product for the end-users to try out and give feedback on. We could then build upon the existing prototype to implement changes and new specifications that arose after end-users tested the application, which could then again be tested and the cycle begins anew.

We made a total of 4 prototypes, where the fourth version could be said to be the final version, thus no longer a prototype, as that is where we will end our development. The development of these prototypes were mostly evolutionary. One could argue that our early sketches of the application were prototypes of sort, and were thus part of a rapid prototyping process. This meant that they were to be discarded in favor of an actual working prototype when the design was agreed upon. The later prototypes were all made using the Evolutionary Prototyping method, as there was only one prototype that was in working order and continuously built upon.
In a sense, prototyping acted as a pendulum, moving between the methods of application development and deployment, combining the two into one larger cycle. This is because we start each cycle by developing the prototype, implementing changes and features based on earlier work and/or cycles. We then deploy said version of the prototype into the field for testing by various end-users. These then give us feedback, which we evaluate and learn from, and take this new knowledge with us into the next cycle.

4.4 Methods in app development

This section will present the methods used in the development of the LTA, some useful tools as well as our approach to the methodologies. The main methods used has been Agile Software Development (ASD) with the underlying methodology Scrumban.

4.4.1 Agile Software Development

According to Agile Alliance[95], ASD is an umbrella term for a set of methods and practices based on the values and principles expressed in the Agile Manifesto[63]. Solutions evolve through collaboration between self-organizing, cross-functional teams utilizing the appropriate practices for their context. It promotes adaptive planning, evolutionary development, early delivery, continuous improvement, and encourages rapid and flexible response to change[95]. SearchSoftwareQuality also adds that ASD "... anticipates the need for flexibility and applies a level of pragmatism into the delivery of the finished product" and "... the goal of ASD is to build upon small client-approved parts as the project progresses, as opposed to delivering one large application at the end of the project"[78].

Compared to traditional software engineering, ASD mainly targets complex systems and projects with dynamic, non-deterministic and non-linear characteristics, where accurate estimates, stable plans, and predictions are often hard to get in early stages—and big up-front designs and arrangements would probably cause a lot of waste[55]. Waste meaning unused documentation, plans, functionality, or in short, unnecessary work. "Agile methodology is an alternative to traditional project management, typically used in software development. It helps teams respond to unpredictability through incremental, iterative work cadences, known as sprints"[85]. The differences between traditional methods and ASD can be described using the Agile Manifesto[63].
"Individuals and interactions over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan
That is, while there is value in the items on the right, we value the items on the left more."

The Agile Manifesto also suggest 12 principles ASD should follow. All of the are very relevant to our development process, but the most relevant ones to our process were:

- Welcome changing requirements, even late in development. Agile processes harness change for the customer’s competitive advantage: As we got feedback on the league table application, the requirements were changing as well. This principle was therefore very important for us to follow as the requirements of the application were so frequently changing.

- Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale: This was an important principle to allow us to quickly get feedback on new developments. This was because of the short timeframes we had in Malawi, were incorporating new changes, between for example district visits, would allow us to get more feedback.

- Simplicity, the art of maximizing the amount of work not done, is essential: This principle is important due to our short timeframe, especially in Malawi, efficiency was very important as we wanted to test as many iterations of the application as possible, to gain the most feedback.

- At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly: As we were developing, we also learned how to do it better, making us changing the way we did things. Having discussions about how to refactor old code and then doing said refactoring accelerated further development to a high degree, increasing our efficiency.

ASD is still only an umbrella for several development methodologies. "One can not do agile ... one can only really be agile, or not"[56].

Most ASD methods break the tasks into small increments with minimal planning and do not directly involve long-term planning. Iterations are short time frames (timeboxes) that typically last from one to four weeks. Each iteration involves a cross-functional team working in all functions: planning, requirements analysis, design, coding, unit testing, and acceptance testing. At the end of the iteration a working product is demonstrated to stakeholders. This minimizes overall risk and allows
the project to adapt to changes quickly. An iteration might not add enough functionality to warrant a market release, but the goal is to have an available release (with minimal bugs) at the end of each iteration [12].

**ASD Shortcomings**

It can be a hard task to predict estimates when doing agile development, meaning deadlines are hard to set. However, as long as one measures progress in working software and steady efficiency is maintained, this will not be an issue. Tasks are done when they work well enough to be tested in such a way that a user can give valuable feedback on it, or in other words, is considered working software.

This takes us to the "definition of done", or when to stop working on a task. As to not make the process too time consuming for the customers and developers, defining criteria for a task to be done or a feature to be working, is very important.

Embracing changing requirements during development may cause some confusion, resulting in bugs. It is therefore important to test the product regularly and especially after each implementation of a new feature. This is to discover and correct bugs as early as possible and that new implementations satisfy the specified criteria.

Lacking or no documentation of code can lead to difficulties when revisiting old code. This can be solved by simply making structured, clean code. (What clean code is could be a thesis of its own, so this will not be discussed.) This could potentially become an issue as prototyping was used as a development method, which encourages as described in section 4.3, the use of quick and working solutions in favor of clean code. If too many solutions become to "hacky" or messy, reusing or reformating said solutions will become substantially more time consuming which in turn defeats the purpose of prototyping. To remedy this, reformation of old code was done in periods where there were few other tasks that needed to be done. Doing this kept the amount of "hacky" solutions in the code to a minimum, while ensuring steady progress when needed.

**4.4.2 Scrumban in development**

Scrumban is a methodology based on the development methods Scrum and Kanban, thus the name Scrumban. Scrum is an iterative and incremental methodology that focuses on development strategies that allow teams to reach a common goal. Kanban is more of a method for managing knowledge and tasks. It emphasises just-in-time delivery while presenting
team members with a detailed view of every task from creation to delivery. Scrumban then a methodology under the ASD umbrella where teamwork is organized in small iterations with the help of a visual board. It takes the most useful features from both scrum and kanban and combines them into a more flexible, not as strict methodology. Teams that use Scrumban often use post-it notes, whiteboards, digital boards and other thing to illustrate what needs to be done. For this project, Trello boards were used to keep track of tasks and their statuses. Trello is described more in detail in section 4.4.3.

Work iterations in Scrumban are kept short. This ensures that a team can easily adapt and change their course of action to a quickly changing environment. The length of the iteration is measured by the number of user stories in that iteration and team velocity (the number of story points the team can complete in an iteration). The ideal length of an iteration depends on the work process of each team, and it is recommended not to have iterations exceeding two weeks[92].

The basic scrumban board is composed out of three columns: “To Do”, “Doing/Work-in-Progress” and “Done”. After a planning meeting, tasks are added to the “To Do”-column. When a team member starts working on a task, they move it to the “Doing”-column. When the task is completed, the task is moved to the “Done”-column. The scrumban board visually represents the progress of the team, making it easy to see the current status of each task and the project as a whole. The board and columns can be adapted and expanded to suit the team’s needs. Common add-ons include priority columns for the “Doing”-column, and other columns like Design and Testing/Review[36].

Planning meetings are held to determine what user stories to complete in the next iteration. The user stories are then added to the board and the team completes them. The team should keep the amount of user stories, or tasks, being worked on at a time within a practical limit, also known as Work-in-Progress (WIP) limit. To keep iterations short, WIP limits are thus used, and a planning trigger is set in place for the team to know when to plan next, which is when WIP falls below a predetermined level. There are no predefined roles in Scrumban; the team keeps the roles they already have[89].

The planning in Scrumban is based on demand and occurs only when the planning trigger goes off. The planning trigger is associated with the number of tasks left in the 'To Do' section of the board - when it goes down to a certain number, the planning event is held. The number of tasks that should trigger a planning event is not static. It depends on team velocity (how quickly they can finish the remaining tasks) and on the time required to plan the next iteration. The tasks planned for the next iteration are added to the 'To Do' section of the board. It is recommended
to prioritize tasks during the planning event. This means marking the tasks that should be prioritized in some way to signify that these tasks should be completed first. This can be done in many ways, for example by splitting the todo tasks into two columns. One “Need to have” and one “Nice to have” column, where the former contains the prioritized tasks.

4.4.3 Tools for supporting development

Trello

The developers of Trello describes the organizing software as "the easy, free, flexible, and visual way to manage your projects and organize anything"[4]. Trello is a web application that lets you create and share digital boards reminiscing scrum and kanban boards. You can create boards with any number of columns to suit your needs. These boards are usually made to organize tasks for a project within a team. This ensures that everyone can see the current status of every task in a project, helping to prevent duplication of work.

![Figure 4.3: Snapshot of Trello board used in development](image)

Git

In the development of the LTA there was a need to merge the code produced. Git as the version control system for the project was a natural choice as both developers prefer the system and have had positive experiences in earlier projects. The creators of Git describes it as a "a free and open source distributed version control system designed to handle everything from small to very large projects with speed and efficiency"[38]. In other words the tool allows developers in a team to work independently on different branches of a project without worrying too much about how their work will be merged with the work of others. Git
allows you to easily create, merge and delete code in seconds. If any errors occur, it is also very easy to roll back the code to the last working iteration. With git, every iteration of a project will be available (to those with proper credentials) to download from anywhere with an internet connection. In short, it allows you to always keep your project up to date with the work of other in the team, preventing mistakes such as faulty code and duplicate work to ever become a big issue. Furthermore the source code of the LTA have been made open for public view, so it can be inspected by anyone interested (link provided in section 5.2).

4.4.4 Our approach to Agile Software Development

During the development of the several prototypes of the league table application, we have been following ASD principles and using elements from the Scrumban methodology to organize the work. Agile development quickly proved to be the most suitable method as specifications arose and new knowledge was acquired during the development of the league table application, making long-term planning hard to do. Instead, planning was kept to a minimum while organizing all of the specifications in a digital scrum/kanban board called Trello[4]. ASD methods was also chosen as they go well with AR. This is mainly because of agile development’s ability to be agile, or embrace changing requirements. This tends to happen in every cycle of AR, as the researchers are evaluating results, after for example testing the app, and thus, learning new things about their subject. Many ASD methods like Scrumban tries to do the development in increments or iterations, which resembles the cyclical process used in AR. This makes integrating agile development with AR quite effortless as well.

Our planning meetings usually only involved which tasks from the Trello board to focus on first and not much else. These decisions were made based upon how feasible it would be to complete the tasks within the given iteration or also called sprint. This could depend on how quick a certain task could be done with the existing software (leverage) and knowledge of how to do it. In short, less work required to complete tasks, means more tasks included per sprint. In the end, it was all about maintaining efficiency in the sprints, ensuring that the end goal of each prototype would be met.

The development of the application was split into 3 stages or prototypes. The duration of the sprints in each stage varied, but was usually between 1 week and 1 day. This depended on things like how much time we had til development should move on the the next stage, how much work the tasks included in the sprint required and more. For example, during the
development of the first prototype, the sprints were done weekly. This was done to ensure steady progress in the development, according to ASD principles, this means ensuring steady development of working software.

In contrast, the sprints during the development of the second prototype were done daily. This was due to the frequent and large amounts of feedback we were getting in addition to time constraints in regards to our stay in Malawi. Implementing new features and changes daily would allow us to get further feedback, ensuring the quality of the application and satisfaction of the end users.
4.5 Data collection methods in deployment

In a fashion fitting AR, a suitable approach to creating the LTA and conduct research around league tables in general would to be conduct semi-structured interviews and observe users in real situations. Considering the stakeholders, it made the most sense to do a qualitative approach to the data as human opinions would matter the most in this research setting. The research was done as a part of a team in Malawi to get an inside look at how things were being done. In such an approach we can get an overview of user context, tailoring and improving the application based on the user’s needs. Furthermore it could perhaps gauge a general interest for using league tables in the Malawi HMIS if they are found useful. As an outsider, one could argue that not get as much valuable information would be collected. The research in Malawi should shed light on the different use-cases the LTA can be used, like for example in review meetings. Based on feedback from users, the application have been tweaked (participatory design principles). During the project, four districts and two zonal offices were visited, in addition to two departments at the national level and three NGOs operating in Malawi. Methods used to collect data consisted of;

- Demonstrating the application
- User-testing the application
- Observing users
- Interviewing users
- Discussing with users

Figure 4.4: Demonstration of app at district level.
4.5.1 Participants

In total, 68 users participated in either testing or discussing the application. An overview is provided in table 4.1. The users had varied backgrounds, these include district offices and hospitals, NGOs, MoH in Malawi and external interviewees. The participants of the study was selected mainly based on availability and convenience at the time, but it was still wanted to include end users and experts from different areas with varying IT capabilities. This was important as our application had to balance the scales of usability for novice users and functionality for expert users. Novice users were those who struggled with the use of basic functionality, even using a computer. Expert users were those who immediately understood the basic concepts and quickly dove into the more advanced functionality and customizability, even asking for more. We held interviews in four different districts in Malawi which were selected beforehand based on geographical convenience, that is, distance from the city of Lilongwe which was where we were staying. The potential participants were notified of our plans and a time was set according to their schedules, as it had a tendency to be quite busy. The meetings with NGOs and zonal offices were selected based on their interest in the LTA as well as availability. The External section in the table refers to two interviews with where the interviewee are familiar with DHIS2, outside of Malawi.

<table>
<thead>
<tr>
<th>Location</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>District A</td>
<td>6</td>
</tr>
<tr>
<td>District B</td>
<td>15</td>
</tr>
<tr>
<td>District C</td>
<td>12</td>
</tr>
<tr>
<td>District D</td>
<td>7</td>
</tr>
<tr>
<td>Zone A</td>
<td>5</td>
</tr>
<tr>
<td>Zone B</td>
<td>3</td>
</tr>
<tr>
<td>NGO A</td>
<td>1</td>
</tr>
<tr>
<td>NGO B</td>
<td>4</td>
</tr>
<tr>
<td>NGO C</td>
<td>3</td>
</tr>
<tr>
<td>National Meeting</td>
<td>8</td>
</tr>
<tr>
<td>National Interviewees</td>
<td>2</td>
</tr>
<tr>
<td>External Interviewees</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4.1: Overview of participants in the research
Interviews and Focus groups

There are three fundamental types of research interviews: structured, semi-structured and unstructured[37]. Structured interviews use a list of predetermined questions and are usually very quick and easy to administer as there are usually no follow-up questions. They only allow for very limited participant responses and are therefore of little use if depth is required and are thus, more suited for quantitative studies. On the other hand, unstructured interviews do not use any predetermined and are often initiated by very open questions like "Tell me about your experience of...". Further questions are then based upon the initial response. These interviews can quickly become very time consuming and difficult to manage and to participate in, as there are no predetermined questions to provide guidance. These interviews can be useful when significant depth is required and there is little to no prior knowledge about the subject area.

Within this study, a mix of both structured and unstructured interviews has been used, also know as semi-structured interviews. Semi-structured interviews consist of several key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge in order to pursue an idea or response in more detail[15]. This type of interview provides some guidance for the participants on what to talk about, while also providing flexibility that allows the participants to diverge from the predetermined questions. This allows for discovery or elaboration of information that is important and relevant to the participants, but may not have been thought of before the interview began[15]. Interviews are, therefore, most appropriate where little is already known about the study phenomenon or where detailed insights are required from individual participants[37].

Semi-structured interviews can suffer from the same disadvantages that unstructured interviews have. This means that they can become quite time consuming if one diverges from the key questions to much and to often. These two types of interviews also generate a lot of unstructured data to be analyzed afterwards, as many of the interviewee’s responses are to questions that are not predetermined by the interviewer. This data then needs to be organized to some degree before it can be analyzed in an orderly fashion.

In the interviews we opted for tape-recording instead of taking extensive notes to be better able to focus on the discussion and communication with the users. As a result, most of the interviews and meetings were recorded but not transcribed fully. Instead, timestamps were noted when something interesting came up as to make it possible to transcribe these specific parts in better detail later.
Focus groups, demonstrations and presentations

Some of the interviews involved several participants, we have chosen to look at the interviews with 3 or more participants as focus groups. Focus groups share many common features with less structured interviews, but there is more to them than merely collecting similar data from many participants at once. A focus group is a group discussion on a particular topic organised for research purposes, and exploits the interaction between the research participants. This discussion is guided, monitored and recorded by a researcher (sometimes called a moderator or facilitator)[51][66]. Focus groups are used for generating information on collective views, and the meanings that lie behind those views. They are also useful in generating a rich understanding of participants’ experiences and beliefs[66]. Focus groups can work successfully with as few as three and as many as 14 participants[13].

We decided to use focus groups and semi-structured interviews as our data collection methods as they are both qualitative data collection methods and their purpose is mostly the same. That is to explore the views, experiences, beliefs and/or motivations of groups or individuals on specific matters[37]. Their main difference is the number of participants, where interviews are usually one-to-one and focus groups usually have from 3-14 participants. The number of participants dictated whether we were to conduct interviews or focus groups as there are many conflicting differences in how the two methods are conducted.

Purpose of the interviews and focus groups

The basic theme for our interviews and focus groups were the user-friendliness of the LTA. This meaning things like ease of navigation through the application User Interface(UI), using the available functionality and customizability, and readability of the league tables.

The interviews and focus groups usually started with a brief introduction of the background and concept of league tables for the participants, after which a quick demonstration of the application followed. Some participants were then asked to try using the application with some guidance. Then some questions were asked to start a conversation or a discussion about the LTA.

Some of the common questions the participants were asked include:

• How was it to use the application? was it easy or hard?
• Do you think this could be useful to you somehow?
• Further suggestions?
As tailoring the application to the common needs of the various users was one of the priorities of the study, these questions seek to gain knowledge of how the users experienced the application and their visions and ideas for what it could become or be used for. Semi-structured interviews and focus groups were used, so these questions are there to provide the necessary guidance of the conversation to get the feedback needed to achieve the goals of the study.

The conversations of the interviews and focus groups were all audio recorded and timestamps of interesting parts were noted so they could later be transcribed. This method was chosen, as transcribing entire conversations would become too time consuming, while also developing the application. Audio recording was also done in order to allow the researchers to focus on the conversation with the participants. Taking detailed notes while maintaining a conversation can quickly prove to be quite hard to do while keeping a good flow. So not having a second source of data then would mean that data could potentially become lost as it was not recorded in any way. Audio recordings was also a good source of data to go back to when parts of the conversation were hard to follow due to background noise and how the participants spoke, like for example with varying volume, speed and dialect.

4.5.2 Data Analysis Approach

Data will be reduced by following the ladder of analytical abstraction as seen in 4.5. Firstly, the interviews, observations, discussions and user-tests are summarized. Secondly, themes and trends will be identified in order to map the main opinions and thoughts of the users. We will also be analyzing the potential uses of league tables. Finally, patterns and explanations are made to draw a conclusion of the findings for further research.

![Figure 4.5: Steps of analytical abstraction, after Carney[18]](image)
Chapter 5

App Development

This chapter aims to present the current and final product of the League Tables Application and the technical environment around the app. Furthermore the applicaton’s functionality will be presented and there will be given an insight of the different formulas that calculate the scores in the league tables.

In addition there will be a section describing the different prototypes throughout the project that lead to the final product. Lastly there will be a section covering the technical solutions behind the application.

This chapter will not cover the reasons behind the choices that have been made in regard to the design of the application. Chapter 6 will describe the implementation and feedback from users which ultimately lead to the design choices and the different prototypes throughout the project.

5.1 District Health Information System 2

The LTA was developed for DHIS2 and is used as the HMIS in Malawi. We thus start with this section with describing the system in general and the elements in the system relevant to the LTA. DHIS2 is described as "... the flexible, web-based open-source information system with awesome visualization features including GIS, charts and pivot tables"[28]. DHIS2 is developed by HISP and the primary objectives of the software is collection, validation, analysis, and presentation of aggregate and transactional data[29]. The functionality facilitates decision making in the health sector, as well as supporting integration of fragmented health systems. The software is tailored to integrated health information management and is currently the preferred HMIS in 30 countries around the world in addition to being used at various levels in 47 countries[29], mostly used in developing countries.
DHIS2 is mainly accessed through a web browser with an account, but you can capture data on any type of device, including desktops, laptops, tablets, smartphones and feature phones[28] in addition to having offline functionality for most solutions. The functionality is organised in apps, being extensions which can be added or subtracted from an installation to customize the system as required. Beware that these apps differ from what people install on smartphones in three ways. The DHIS apps are parts of the larger database system, they are stored in the web server, and they can run in browsers in any device[50]. The LTA is another addition to these apps, accessible in the menu of applications as seen in figure 5.1.

Figure 5.1: Accessing the LTA from an DHIS2 instance through the application menu

Because the software is customizable, the various implementations have their organizational and technical differences. As this study is based on the Malawian HMIS, it is natural to have a closer look at the Malawian implementation of DHIS2. The data captured is stored in a central server currently based in the financial capital Blantyre. The data structure of the system is organized in a manner reflecting the hierarchy described in section 3.4.2. Within the data structure there are two concepts; organisation units and indicators that are highly relevant for the functionality in the LTA.
5.1.1 Organisation Units in DHIS2

All the facilities, districts, zones in addition to the national level are represented by organisation units holding an referable unique ID and a set of valuable attributes. Each organisation unit also holds a pointer to it’s underlying organisation units. Together these objects form a virtual representation of the HMIS hierarchy where each zone has their underlying districts and each district has their underlying health facilities.

5.1.2 Indicators in DHIS2

In DHIS2 an indicator is a calculated formula based on a combination of data elements, category options, possibly constants and a factor[19] and are used to analyse data. In short, one can say that indicators in DHIS2 are math formulas used to measure health services. There are two forms of indicators, those with a denominator and those which do not have a denominator[19]. In the league tables, it makes most sense to use the first mentioned form as these indicators are they are "typically more useful for analysis. Because they are proportions, they are comparable across time and space, which is very important since units of analysis and comparison, such as districts, vary in size and change over time"[20]. Without a denominator the indicators yields a result where the type is a raw number, in other words, not being comparable when used to compare units. These indicators would not work well league tables as it would always favor the bigger zones, districts or facilities.

The numerator usually consists of data elements counting incidents while the denominator often is referring to target population data or expected counts. One example is the health indicator ANC 1 Coverage, or Antenatal Care coverage 1st visit. The indicator can be defined as "Total 1st ANC visits by expected number of pregnant women." The indicator yields the estimated percentage of expected pregnant women that attend the 1st ANC visit. A visual representation is given in figure 5.2.

![Figure 5.2: Definition of the indicator ANC 1 Coverage](image-url)
5.1.3 Analytics resource

To access analytical, aggregated data in DHIS2 you can work with the analytics resource[1]. The displayed data in the tables generated by the LTA are retrieved by using the analytics resource. By using a combination of when(period), what(indicators) and where(orgunits) the desirable data are retrieved from the system. The technical details are described more thoroughly in section 5.4.2.

5.1.4 Pivot Table extension

At the moment it is possible to create league tables in DHIS2 through an application called Pivot Table. However, according to earlier work done in Malawi[34] the current functionality is limited. The Pivot Table is a rather general application to create all sort of tables. While it is very powerful, the amount of selections and variations can be confusing as the menu in the pivot table app shows more than 35 options, where the user only needs to use three or four to create a league table[34]. An approach customized to create league tables reducing the perceived complexity of DHIS2 could be more suited for the users needs[34].

5.2 League Table Application

The League Table application is a web-application customized for DHIS2 to administrate league tables and can be inspected at link provided in the appendix. In short, the most important features include viewing, creating and editing league tables. The application is implemented using AngularJS as the framework. The application make use of the existing metadata and data available in DHIS2, so it will use local data in whatever database it is installed. It is strictly an analytic tool generating output data by combining information that is already in the system to create league tables. Because the application is generalized, it is easily transferable to other DHIS2 instances and its data. When it comes to security it is something that the application does not need to take care of. Credentials and other security measures comes with DHIS2 as the application has to be installed within a DHIS2 instance. As a result of the application being customized to work on DHIS2 instances, the league table application would not be transferable to other systems without tweaking major parts of the app.

By being installed in a DHIS2 system, the app also naturally gets access to the DHIS2 Web Application Programming Interface (API). An overview of the relationship between the app and DHIS2 can be seen in figure 5.3.
The app uses HTTP requests from the DHIS2 Web API to get indicator data which is being used in the respective league tables. In addition, the application uses HTTP requests to create, save and delete league tables within the application.

More specifically the app communicates through the `dataStore` component of the API to save and delete user created league tables. Furthermore the app gets aggregated data from the `analytics` component by combining a set period, a list of indicators and a list of organisation units. Lastly information about available indicators and organisation units are fetched from the respective resource endpoints in the API. For the ones interested, the web communication part of the application is described more in detail in section 5.4.2.

**Figure 5.3:** A diagram showing the relationship between the DHIS2 instance, DHIS2 Web-API and League Tables application.

### 5.2.1 Main functionality

As a result of the requirement of simplicity, the app was eventually limited to four main screens; the dashboard page, the create/edit table page, the view table page and the user-guide page. All pages also have the possibility
to go back to the initial dashboard page and back to the DHIS2 instance.

Dashboard

The dashboard page also serves as the landing page of the app. It is mainly there to give an overview over the League Tables available, which is divided into Templates, Community and User tables. The Template tables intended to be official tables provided by the management. The Community tables are tables made by other users and User tables represents the current users own tables. It is also possible to filter/search for a table. In addition to showing the tables, there are buttons leading to all the main functionalities.

Figure 5.4: Screenshot of dashboard page.
Create/Edit table

The process of creating or editing a league table is almost identical, but when editing the information is settings and options are filled in previously. The user also have the choice to delete the table in edit mode. The page lets the user input:

- A table name and eventually a description
- The period the table should get the data from
- A list of health indicators (and reporting rates)
- Selection of which organisation units that will be included

Figure 5.5: Screenshot of create/edit league table page.
**View League Table**

The view table page is where the league table is presented with the calculated rankings. The data from the selected organisation units, indicators and period will be retrieved from the data within the DHIS2 instance. Then, the data will be calculated as described in section 5.3. The columns are sortable and the table itself can be exported to PDF or Excel.

---

**Figure 5.6: Screenshot of viewing of league table page.**

1. **Organisation Units**
2. **Indicators**
3. **Indicator value**
4. **Total score & Rank**
User Guide

The user-guide functions as a FAQ with quick questions and answers.

Figure 5.7: Screenshot of viewing of user guide page.
5.3 Ranking & score calculations

This section describes the formulas used to calculate the total scores in tables created in the LTA. It also describes how weighting and inverting affects the calculations.

5.3.1 Total score (for organisation unit)

An average over the indicator scores is calculated into a total score with the weight taken in consideration.

The formula used to calculate the total score for an organisation unit:

\[
\frac{(weight \ A \times \ indicator \ A) + (weight \ B \times \ indicatorB) \ldots (weight \ X \times \ indicator \ X)}{(weight \ A + weight \ B + \ldots \ weight \ X)}
\]

5.3.2 Weighing indicator scores

Weighted scores are calculated by adding a weight to each indicator as explained in the formula.

Let’s say that you have created a table with 3 indicators, emphasizing the importance the longer out in the treatment the patient has come.

- ANC 1 Coverage, weight: 50%
- ANC 2 Coverage, weight: 100%
- ANC 3 Coverage, weight: 200%

And get the following result;

<table>
<thead>
<tr>
<th>Name</th>
<th>ANC 1 Coverage</th>
<th>ANC 2 Coverage</th>
<th>ANC 3 Coverage</th>
<th>Rank</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bo</td>
<td>136.6</td>
<td>119.1</td>
<td>120.3</td>
<td>1</td>
<td>122.3</td>
</tr>
<tr>
<td>Kenema</td>
<td>93.5</td>
<td>117</td>
<td>86.7</td>
<td>2</td>
<td>96.3</td>
</tr>
</tbody>
</table>

Figure 5.8: Weighted score example.

The score for the organisation unit "Bo" is then calculated:

\[
\frac{(136.6 \times 0.50 + 119.1 \times 1.00 + 120.3 \times 2.00)}{(0.50 + 1.00 + 2.00)} = 122.3
\]

Similarly, "Kenema" is then calculated:

\[
\frac{(93.5 \times 0.50 + 117 \times 1.00 + 86.7 \times 2.00)}{(0.50 + 1.00 + 2.00)} = 96.3
\]
5.3.3 Inverting indicator scores

A feature implemented which proved to be useful was inversion of indicators. Inversion can also be explained as turning something upside down. In other words, indicators should be inverted when the number represents a score that is better the closer it is to 0%, as opposed to 100%.

For example, pregnant women are enrolled in the antenatal care (ANC) program. Common indicators to evaluate this program is coverage, meaning to which extent pregnant women are enrolled and coming to antenatal visits, and dropout rate, which is the proportion of those originally enrolled who discontinue the program during the pregnancy. Typically pregnant women should come for 3 or 4 visits during pregnancy. A well-run program would have high coverage, and low dropout rate. To reflect this in the total score, functionality for inverting scores is needed.

In the application inverted indicator scores is calculated as follows:

$$(100 - \text{indicator } A) \times \text{weight } A$$

**Practical example**

Let’s say that you have created a table with 2 indicators;

- ANC 1 Coverage
- ANC 1-3 Dropout rate, inverted

ANC 1-3 Dropout rate is inverted because a low value should give a better score as patients not dropping out from the program. In Figure 5.9 an example output of a table is given.

<table>
<thead>
<tr>
<th>Name</th>
<th>ANC 1 Coverage</th>
<th>ANC 1-3 Dropout Rate</th>
<th>Rank</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bo</td>
<td>136.6</td>
<td>11.9</td>
<td>1</td>
<td>112.4</td>
</tr>
<tr>
<td>Tonkolili</td>
<td>139.6</td>
<td>51.6</td>
<td>2</td>
<td>94</td>
</tr>
</tbody>
</table>

Figure 5.9: Inverted score example.

The score for the organisation unit "Bo" is then calculated:

$$\frac{(136.6 + (100 - 11.9))}{2} = 112.4$$

Similarly, "Tonkolili" is then calculated:

$$\frac{(139.6 + (100 - 51.6))}{2} = 94$$

Tonkolili got a considerably lower score in this case because their dropout rate is much higher than "Bo" in this case.
5.3.4 Color & trophy distribution

Currently, colors are distributed to the total score and rank columns based on ranks. The top 25% ranking organization units are colored green, the bottom 25% are colored red and the rest are colored orange.

Trophies are used as markers to highlight the best value within each indicator column. By best value we mean the value that will contribute the most towards the score. If the indicator is not inverted, the highest value will be marked with a trophy. If the indicator is inverted the lowest value will be marked with a trophy instead.

5.4 Technical Solutions Description

This section aims to briefly describe the technical solutions that has been used to put the application together. The main topics includes AngularJS as the app framework and a description of the communication between DHIS2 and the League Tables app.

5.4.1 AngularJS

AngularJS is a structural framework for dynamic web apps[96]. There is an emergence of web app frameworks, but in the project Angular was selected as it is well known within the DHIS2 community. The framework allowed for quick development and a responsive application. AngularJS is built upon the Model-View-Controller (MVC) paradigm where the user input, the modeling of the external world, and the visual feedback to the user are explicitly separated and handled by three types of object, each specialized for its task[16].

Displayed in figure 5.10 the Model represents the current state of the application, the View displays the data to the end user and the Controller controls the relation between Models and Views. More specifically, the Model holds the objects used in the application, often represented as JavaScript Object Notation (JSON) objects. The View in AngularJS Applications is in short what the user see on the screen, which technically is generated by HyperText Markup Language (HTML) files. Lastly, the Controller responds to user input and performs interactions on the Model objects, in other words the JavaScript files that handles the logic and operations that modify the state of the data model.

When it comes to the League Table Application the server and database part in figure 5.10 can be viewed as DHIS2. The league tables stored and
manipulated in the League Table Application is stored in JSON objects and holds data about indicators and organisation units in the particular table among other data. These objects can be seen as the Model part of the MVC pattern in the League Table Application. An example of how the JSON objects looks can be seen in figure 5.11

Figure 5.10: Diagram of the Model, View and Controller in an AngularJS application[10]

Advantages

- Easy to set up
- Widely used by DHIS2 devs
- Responsive. You can see what you develop rather quickly.
- Fast development

Disadvantages

- Can be slow compared to competitors, though this is not a problem as the application is relatively small in size.
• You write "angular code" and not JavaScript. This means that developers has to learn how to write angular code even though they may know how to write JavaScript.

• Hard use certain external libraries with Angular

5.4.2 HTTP-Calls

This section will cover the communication between the League Tables application and the DHIS2 Web API. In the descriptions the `baseUrl` part of the API calls are referring to the base url of the DHIS2 instance. For example, on the official test server of the DHIS2 community, the base url would be

• `https://play.dhis2.org/demo`

Furthermore, the calls GET calls are appended with `.json` to get the data on JSON format from the API.

Storage of league tables

The league tables are stored as JSON objects using the `dataStore resource`[2] provided by the DHIS2 Web API. The resource allows users that have access to the given app to also have the rights to store data in the corresponding namespace. In the case of the League Tables application, the corresponding namespace is `leagueTables`. An example on how the tables are stored by JSON files are given in figure 5.11. The simplicity of JSON makes it easy for for humans understand, in addition to being easy for machines to parse and generate. The app distinguishes so-called `user` and `template` tables for a neater presentation of the tables. The endpoints for the user tables are;

• `baseUrl/api/dataStore/leagueTables/userTables`

while the Template Tables are stored at

• `baseUrl/api/dataStore/leagueTables/templates`
Figure 5.11: Excerpt of how league tables created in the LTA are stored in DHIS2 in a JSON format
Fetching indicators

Fetching indicators consists of two steps. The first step is obtaining the indicator groups available from the DHIS2 API. This is done by using a GET request to the endpoint:

-(baseUrl/api/indicatorGroups.json

The request yields a list of indicator groups with various information, but in the application there is only need for the name of the indicator group in addition to its unique ID. In the application the list of available indicator groups are presented by using a dropdown menu. The dropdown menu represents a choice the user have made. In the screenshot in figure 5.12 the dropdown menu can be seen where the selected group is currently ANC.

The second step to use the unique id of the selected indicator group to fetch the indicators belonging to the indicator group. A list of the indicators belonging to the groupid are obtained through a GET request to the endpoint:

- baseUrl/api/indicatorGroups/{indicatorGroupId}.json

Figure 5.12: Visual presentation of indicators in the app
Fetching indicator-data

Fetching indicator data is done by using the analytics resource of the DHIS2 web-API. The indicator data is the data that are being presented in the league tables. The requests to get the indicator data consists of three dimensions:

1. dx, which is the indicator ID’s
2. pe, which is the periods selected
3. ou, which is the organisation units ID’s

In figure 5.13 id’s from the indicators "ANC1 Coverage", "ANC 1-3 Dropout rate" and "ANC2 Coverage" are used. Furthermore the period is "April to June 2016" and the organisation units are "Bo" and "Western Area".

![Table Example](image)

Figure 5.13: Table Example

Fetching organisation units

Start with getting the top-level org unit. Then using the children of the object in recursive manner.

- baseUrl/api/organisationUnits/{organisationUnitId}.json

Reporting rates/Completeness

For the sake of simplicity, Completeness, also known as Reporting rates have been disguised to act like an indicator group. What this means is that Reporting Rates is placed in the same drop down menu seen in figure 5.12. When the user selects Reporting Rates in the menu the application initiates a GET request to the endpoint

- /api/dataSets.json

Instead of one of the indicator groups.
Network slimming

The requests in the application are slimmed down to ease the internet traffic. The technique used is a functionality provided by the DHIS2 Web API where the requests can be tailored to only include the fields that are needed. For example by appending "fields=a,b,c", the request only includes the fields a, b and c instead of a potential of unknown number of attributes that isn’t going to be used anyways.

5.5 Programming detours

This section is aimed to describe the hacky solutions used during development. The solutions allowed to make quick progress and get working prototypes up and running to simply have more material to test to gain more insight during deployment.

5.5.1 Storing tables in DHIS2, pre v2.21

Due to a limitation in DHIS2 instances older than version 2.21 there were used an unconventional solution to store tables as the dataStore resource was not yet implemented. However, there were possible to store data by interacting with the the systemSettings and userSettings resources in the DHIS2 Web API. The endpoints api/userSettings were used to store personal tables and api/systemSettings were used to store template tables by creating new keys. The storage key for both types were prepended with leagueTables resulting in the endpoint

• baseUrl/api/userSettings/leagueTables

for user tables while the Template Tables were stored at

• baseUrl/api/systemSettings/leagueTables

However, the API-endpoints available only allowed the content-type text/plain which was a hurdle. In the application, a hacky solution was used by converting the data to text/plain when writing the data(saving), and converting the data type from text/plain to JSON when reading(retrieving) the tables. The solution worked fairly well, but with a very limiting limitation; normal(non-admins) users could not share league tables as the user only has access to it’s own userSettings. Template tables, which were available for all users to view could also only be created by users with admin access.
5.6 Prototyping

The purpose of this section is to present the development approach used for the league table application both in Norway and in Malawi. The 4 stages of development or prototypes will be presented and will include where and when the development was done. What it was based on, be it earlier work, user feedback, or new ideas. The main goal(s) for each stage will then be presented in addition to what was done, how it was done and new ideas after testing.

5.6.1 Prototype 1

Briefing

Prototype 1 was developed in Oslo, starting early 2015. This development was done in weekly iterations where the essential functionality was implemented earliest and the design of this functionality were changing weekly. The development was based on earlier league table designs[34] done by a master student at UiO. Some user-testing was doing to verify concept and functionality as well as to sort out major bugs in the application. The main goals for Prototype 1 was to implement basic functionality and making it ready for field testing in Malawi.

Changes and Features implemented

- Creating, Storing and viewing league tables.
- Editing league tables.
- Dashboard to view and select already made tables.
- Sortable columns.

Pre-studies

The first prototype of the application was developed little user involvement, but was based on earlier work in Malawi.[67] This work involved making league tables using existing functionality in DHIS2, but a series of shortcomings made it very troublesome for a wide range of users to later customize the tables. Seemingly simple things like adding new indicators to the table was not as easy as it sounded. Doing so would make the total score incorrect, meaning it would need to be redefined to include the new indicators. This was not possible for many users due to not having the
required credentials to edit indicator definitions. Another issue was that such editing can be considered advanced functionality, meaning it would be too difficult for novice users to achieve without any prior training. An application for making League tables could solve this.

**Development**

The application started out as several design drawings or rough sketches for the basic features the application should have. Since the purpose of the application is to be able to easily create and view league tables, we quickly agreed that creating, storing and viewing tables were the most important features. Thus, those features were the first to be implemented in the earliest versions of Prototype 1.

One of the main characteristics we wanted to achieve for the application was to make it user friendly. Much emphasis was put on creating a good flow when using the application, especially when making and editing tables. This includes intuitive navigation and informative feedback from the application to the user.

Figure 5.14: First sketch of the dashboard of the application
Figure 5.15: First sketch of the create table screen
The essential functionality of the application should include

- Basic functionality for creation and storing of league tables.
- Selection and customization of indicators and which organizational units to compare.
- Automatic generation of a general performance score based on selected indicators for each organizational unit.

The main priorities for the first prototype was to make it ready for field testing in Malawi while also making it easy to pick up and use, even with very limited training. This was done by implementing the basic functionality in addition to some extra convenience features like a dashboard for viewing all saved tables, the possibility of editing already made tables and column sorting for each indicator. These extra features were added to enhance the user experience allowing for easier access to tables and more flexible customization by editing already made tables.
Testing

We weren’t able to do much code tests for the first prototype as the structure of the application was changing frequently while we were learning how to best develop the application. Instead we performed a series of manual tests in the UI after each new addition to the application to ensure older functionality remained intact.

We were however able to do a few user tests in Oslo before going to Malawi. These testers include 2 employees from Malawi CMED, a Ghana DHIS2 staff member and an attendee from the DHIS2 conference in Oslo. The user tests included creation, viewing and editing of tables which helped us verify functionality and concept while also giving us suggestions for further improvement. They also helped us detect some major integration bugs that occurred on the Malawi server that would need fixing before the application is ready for field testing.

Issues & Changes

After testing the application, we realised that our way of finding the national organization unit or top level, was not generalized which means selecting organizational units only worked on the DHIS2 demo server. This then required us to get access to the DHIS2 server in Malawi, so we could find a good way of solving this. We also noticed that we were actually only showing 50 of over 700 available indicators in Malawi. After fixing this issue, we ended up with a 100 page list of indicators in our application, making browsing indicators very troublesome. We then made the decision to change the indicator selection process from showing a very large list of all available indicators, to being arranged into indicator groups which would make browsing indicators less overwhelming to the user. The last major issue that became apparent after the user testing was that saving tables was dependent on user credentials. We hadn’t noticed this as we were using an administrator user with full access on the demo server. The problem was that only administrators could create shared tables that was visible to all users, while regular users could only create tables visible to themselves. A new solution to how the stored tables were displayed in the dashboard were then needed to not confuse shared tables with private ones. We ended up the simple solution of splitting the dashboard into two groups, public and private tables, which was later renamed into Templates and My tables.
5.6.2 Prototype 2

Briefing

The second version of the application was developed continuously in many small and very rapid iterations during our stay in Malawi. Meaning that changes, features and error fixes were added daily while testing the application with various end users. The development of prototype 2 was based on the feedback we received from users testing our application in Malawi in addition to observations made. The application was tested by users from various levels within the Malawi health sector such as district, zonal and national level including a number of NGOs. The goal for this prototype was to get as much feedback on as many features as possible while fixing any errors/bugs that may occur, and implementing the most commonly requested changes and features.

Changes and Features implemented

- Visual indicators telling the user the application is working.
- Network optimizations.
- Custom period selection.
- League table templates for users to copy.
- Some design changes to improve the process of creating tables.

Poor network conditions

During our stay in Malawi, we quickly noticed extensive differences in the power and internet infrastructures of Norway and Malawi. Access to Electricity and Internet was not a given in Malawi. Blackouts occurred frequently for various reasons, the most common one being unpaid power bills. Internet access was very limited in the district offices where we tested the application. Paying the internet bills was not prioritized due to their limited resources. When the internet actually worked, the speed of the internet was very slow. This made the application behave in unexpected ways as we had only been testing the application on rather fast internet speeds. One example was being able save several instances of the same table. This was possible because the user was able to click "Create Table" several times before the application was able to load and redirect to the page of the table that was created. To remedy this, we had to make a few changes and add some features to the application. These changes included slimming down the network usage of the application making loading
times shorter, visual feedback in the form of spinners when something is happening and disabling certain buttons when the page is redirecting. All of which seemed to improve the user experience of the application to a very high degree when under poor network conditions. Previously you wouldn’t know if something had crashed or was just loading slowly, this confused some users as things that took time to load, like indicators, weren’t visible. With the addition of these features, learning may be reinforced and disruptive user actions were avoided[71].

Figure 5.17: A district hospital in Malawi.

**Different user groups**

The technical and analytical knowledge of the different users varied immensely. For example, some health workers in the districts barely knew how to use a computer while some of the NGOs wanted visualized league tables in the form of a colored map based on scores, with drill-down functionality etc. Roughly there were two groups of users, those with more and those with less technical and analytical knowledge or in other words, novice and expert users. Expert users were usually giving feedback on which additional features and customizability they wanted the application to offer. These points were all noted but usually not added. This was because most of the health workers in the districts had more than enough with the functionality already added. This included seemingly simple tasks like finding indicators, setting the right period, using percentage indicators
etc. The development of the application quickly became a task to balance usability and learnability to functionality and customizability. This means that we had to be wary of what functionality we were implementing as we wanted to avoid creating additional obstacles for novice users. We also had to make sure the application offered enough features to be of interest to the expert users. Balancing this became the main focus during the development of the application in Malawi. After observing many users and how they used the application, we were able to make some minor changes to the create-table screen, increasing its user-friendliness and functionality. These changes include repositioning of elements like the lists of available and selected indicators, and selecting custom periods instead of predefined ones (e.g., Last month, quarter, year etc.).

**Templates**

After testing the application in the various districts, we had gained a lot of knowledge of how people wanted to use the application. We realised that administrator privileges was not common at all, making the public tables very static and not subject to change. Also, since many users seemed to not know which indicators to select, we decided to rename Public Tables into templates, while adding a “copy”-button that copied the template into "My Tables". The idea behind this was that officials could agree which indicators are important for a certain type of table, and make this template available to the users. The user could then copy these templates into their private tables, where they had privileges to edit. They could then change the organizational unit to their preference and they would then have a finished league table, completely bypassing the intricacies of selecting harmonious indicators. This could potentially increase the usability of the application.
5.6.3 Prototype 3

Briefing

The third version was developed during our last days in Malawi and then continued after returning to Oslo. The development was done in weekly iterations where visual improvements and generalization changes were implemented. This version is based on feedback and observations made in Malawi, this includes the functionality vs usability trend, confusing around indicators as well as some visual updates. Testing of prototype was very limited. It was mainly test done by us, the developers, to ensure that older functionality remained intact after implementing new changes and fixes. The goal for the development of prototype 3 was to increase the user friendliness of the indicator selection as feedback suggested this was a source of confusion for many. It was also a priority to make the application ready to be released in the DHIS2 App Store.

Changes and Features implemented

- Labels on indicators, showing their types to the user as seen in figure 5.18 (e.g. percent, per hundred).
- Indicator telling the user how well the current selection of indicators will work.
- Specific organization unit selection
- Trophies for best indicator values
- Coloring of scores and ranks.
- Generalization changes made to support more instances of DHIS2
Improved visuals

We added features that simplified the creation and readability of the tables and improved customization options without adding more obstacles for novice users to overcome. These features included telling the user how good their selected indicators are for comparison, specific organizational unit selection and not just entire levels, trophies or markers to best indicator values, and coloring of scores based on rank. The colors are currently distributed in a very static manner. The coloring was inspired by ALMA scorecards and works as follows:

- Green: Top 25%
- Yellow: Middle 50%
- Red: Bottom 25%
DHIS2 App Store

Parts of the development focused on getting the app ready to be released in the DHIS2 App Store. This would make it available for anyone to install on their instance on DHIS2. Before we could do this we had to make some changes to the application. It had to be generalized so could work on any other instance of DHIS2. We have not had access to any other instances of DHIS2 than the one in Malawi and the Demo, so knowing for sure whether it will work or not on any instance is not possible for us. The solution to this receiving feedback from users on other servers after the

Thoughts on further development

With the third version of the League Table application, we feel like we have added as much of the requested functionality as we could, while keeping it as user friendly and easy to learn as possible. This means that if one were to add any further functionality to the application, it should be possible for the user to skip it as to not add to the basic complexity of the application. If more functionality and customizability is to be added, it would be advised to add modes to the application. For example a simple and an advance mode where simple mode is the current version and advanced mode has more functionality and customizability enabled. One could also consider adding an options panel for each table that users could access by clicking a button. Here one could customize the settings for each table, like for example rules for coloring, giving trophies, score calculation etc.

Priorities for further development would be to update the application to support DHIS2 v2.21 which makes in-app storage possible. This means that user without administrator privileges are able to share tables with other users within the application.
5.6.4 Prototype 4

Briefing

The fourth and currently last version of the League table application was developed in Oslo after the DHIS2 version on the Malawi server was upgraded to v. 2.21. The focus of development for this prototype was mainly to ensure the league table application supports the new version of DHIS2, but also to utilize the new functionality introduced in this update. This update introduced some changes and optimizations to the API as well as in-app storage. This means that it was now possible to allow for non-admin user-sharing of league tables.

Changes and Features implemented

- HTTP-request changes.
- Community tables. Shared user tables.

Update to v2.21

The change from 2.18 to 2.21 meant that we had to update our HTTP-requests to the DHIS2 Web API. Default requests, which we were using, had been optimized to give minimal data back. To fix this, we had to specify the data we wanted from the server by including some additional parameters in our requests. With the DHIS2 version on the Malawi server now supporting in-app storage, we introduced a third table group called "Community Tables", while the two previous ones were "My Tables" and "Templates". The Community Tables group would now serve as the group for public or shared tables, My Tables would still be a users private tables and Templates would be tables made and shared by administrator users. We chose to keep the two former groups as they still had their unique purposes.

As the application was updated, the new version needs to be re-added to the App-store again. The application now supports a more recent DHIS2 update, meaning it should possible for more countries to test the application as the previous version was made to support a rather outdated version of DHIS2. Again, this might provide us with feedback on how the application behaves on other instances of DHIS2, helping us to generalize the application so it can eventually work on any instance with minimal local customizations.
Further development

Further development of functionality should include the following as these features were commonly requested, but we were unable to implement them in a satisfactory way:

- **Coloring**
  We received feedback suggesting that the current rules for coloring scores would create an unfair representation of the current standings. For example, even if all organizational units have the same score, there would still be "losers" in red and "winners" in green. Finding a fair solution to this problem needs to be done by either coming up with a better formula for distributing colors, implementing a way for users to define their own coloring rules without disrupting the balance of functionality and usability, or coloring based on targets defined by some entity outside the application.

- **Timeliness**
  There is currently no easy way of getting timeliness numbers in regards to reports from DHIS2. However, there are applications that are able to get these numbers somehow. Maybe in the future, this will be a feature supported by DHIS2 making timeliness an available indicator for the league tables.
Chapter 6

App Deployment

This chapter will describe the research findings during the deployment of the LTA. The app was implemented in several cycles using AR as the research framework. The cycles were conducted both in Norway and Malawi, however almost all the findings presented are originating from the cycle in Malawi. The findings is divided into two main categories were the installed base and the league table will be described first. Secondly the themes revolving around the reception of the application will be described.

The app was deployed during the entire month of November 2015 in the Malawi HMIS. As described in chapter 4.5, the data are originating from meetings at four districts, two zonal offices, two departments at the national level and three NGOs operating in Malawi. The meetings included activities such as demonstrating the app, user-testing the application, observing the users, interviewing the users and discussing with the users.

6.1 Installed base and the League Tables Application

There are many components that must be present to maintain an HMIS. To mention a few, the software components of the system itself, infrastructural components, existing management processes, accessibility to the system and available data are all components that can be explained as the installed base that facilitates further evolution of the HMIS. The findings belonging to each category mentioned will be described more in detail in this section. Overall there were many enabling factors facilitating deployment of the LTA, but on the other hand there were also constraining factors.
6.1.1 Infrastructure

Through the project there were uncovered infrastructural challenges emerging when deploying the LTA during the stay in Malawi. Among these, the most immediate challenges were related ICT and electricity.

Internet Connectivity & Electrical Power

Especially when traveling to the different district hospitals in Malawi, it was experienced that the Wi-Fi coverage was limited while the zonal and national offices had better Wi-Fi coverage. In regards of why the internet connection was limited at district level, the health workers informed that it was often not set aside enough budget for internet bills. The problem of unpaid bills described in section 3.2 was also experienced as a common problem in this project. Medical equipment, power and other expenditures bound to medical treatment were prioritized above having an internet connection. However, most districts had installed operable network equipment, usually funded by NGOs. In most cases an internet subscription was the last component missing.

As the LTA is only available through DHIS2, it was also often made unavailable by the lack of an internet connection. During testing of the LTA, mobile data dongles were needed at every district to provide internet connection. A data dongle can be described as a small device that connects your laptop or desktop PC to the internet using mobile phone network[98]. The dongles are usually made to connect to a PC through an USB-port. The dongles in addition to internet subscriptions were quite pricey, meaning that the districts visited in this project could not fit this option into their budget without financial support from donors as all the districts were depended on funding from NGOs to support expenditures like internet bills. A common problem described was that internet funding was bound to specific projects and when the programmes ended, so did the internet funding. The internet speed provided was also often slow impacting the tasks requiring higher internet speeds. On the positive note, the geographical coverage of the GSM signal experienced first hand was impeccable. Mobile internet access was always available, even in remote areas.
At district level in response to carrying out tasks in DHIS2 like reporting and viewing data, one of DHMT members described the situation as: "The connection is not good, it’s always giving us a headache." District staff further explained that there were periods when they had no network over extended periods each month, delaying and disrupting their planned work. When the internet was online, the slow internet speed made the system troublesome to use as even the simplest tasks took excessive amounts of time to complete. The health workers at the districts responsible for data entry to DHIS2 in particular described that the internet connectivity was a big problem for data entry.

Access to power and its reliability and stability was also constraining issues in Malawi. One of the districts in particular had daily outages lasting as much as half of the day at a time. This made developing, deploying and testing the LTA a challenge.

Presenting the application in districts to receive feedback were made more difficult by the power issues. As mentioned, dongles were used to get around internet problems, but power issues were more problematic. Not having access to power in a district meant that the time set aside to demonstrate the app was limited by the battery life of our laptop in addition to not being able to use projectors. In addition, individual user-testing and discussing the app after the demonstration was problematic as there were limited numbers of laptops available and the computers available at district level mostly were desktop pc’s.

The lack of power was more common for those located in the districts. It hindered health workers from consistent usage of DHIS2 meaning it was troublesome to learn and practice the system. To the project, this meant that we were not likely to receive feedback on the application after our visit as people were unable to use DHIS2 with the LTA, be it because of
lacking internet and power sources or due to people forgetting how to use the system.

6.1.2 Accessibility to Malawi’s HMIS/DHIS2

The national server hosting DHIS2 were unstable, being disconnected many times during the project, preventing us from deploying new versions of the application and testing new features with live data in addition to being unavailable at demonstrations. This was naturally a hindrance as the development of these features would have to be put on hold for the duration of the outage. Moreover, the users asked for another unofficial server/DHIS2 instance to play around with. Currently there is only one DHIS2 server available in Malawi and many are uncomfortable trying out new features etc. in fear of doing damage to the data or system in the process.

Although having some technical issues with the set up, the overall status of desktop computers and local area network equipment needed to input data to DHIS2 was relatively healthy at the district hospitals that were visited. The hardware funding and help to set up the networks were mainly supplemented by NGOs operating in the areas. At the same time Programme coordinators reported that much of their equipment were malfunctioning, restricting their ability to use DHIS2. The most prominent challenge seemed to be able to afford the subscriptions for internet as described in section 6.1.1.

When conducting individual testing with the users in Malawi, it was noticed that few had prior experience with DHIS2 and many said they did not have access to DHIS2. A prerequisite to be able to access DHIS2 is to have user credentials. In many cases multiple persons were sharing accounts, missing out on the option to personalize the appearance of DHIS2 among other features. Not having received user credentials was a general issue that occurred at all levels having an impact on an potentially greater user base. In addition users that already had been assigned accounts had problems retrieving credential information. For example if an user did not remember the password, it cannot be recovered by email. Instead, manual work through making a phone call has to be done as seen in figure 6.2. The inconvenience created a barrier for potential users as it creates unnecessary effort to be able to use the HMIS. DHIS2 have functionality for recovering passwords, and the functionality is enabled with ticking a single option in the Settings Application as seen in an figure 6.3.
During user tests at district level it was observed that some of those who were able to access DHIS2 with their own user were not able to view data from all the levels in the system. Furthermore they were often unable to create league tables in the app. After some investigation it was found out that this was due to users having limited read data permissions, not being assigned user roles in the system and only have been assigned read-write permissions for their respective districts. The default user rights were
quite restricted by default discouraging transparency in the HMIS. The missing permissions severely limited the users usability of the LTA and DHIS2 in general as the users were not being able to compare results with other districts. In addition there was also a case where a user had been transferred from another district meaning he only had permission to view data from his prior district and not his new. The user explained this had been a problem for a longer period of time and that he was uncertain on who to be able to solve it. Lastly, the NGOs wanted more user rights to be able to do tasks like creating indicators. Excel was often used instead.

We noticed that many users seemed to lack technical knowledge of IT and DHIS2. When we asked them if they had received training, some said yes but that they had forgotten what they learned due to not being able to use DHIS2 consistently after the training. NGOs contributed to some of the training, mainly with the use of analytical tools such as Pivot Tables and Visualizir available through DHIS2.

### 6.1.3 Status of data in HMIS/DHIS2(Malawi) or Status of HMIS

The use and quality of data in Malawi’s HMIS was poor. There was a lack of cohesion and organization within the system causing confusing for those using it. When testing the league table, it was often the case that we had to select indicators based on availability of data rather than what the health workers wanted to see. This made the tables presented not very informative. The lack of quality data and an organized data system makes using DHIS2 as support for decision-making difficult.

**Data Quality**

When testing the league table application, we found many issues with the data available in DHIS2.

If was often the case that indicators had missing data, making it impossible to use for analytical purposes. It was either due to missing numerator or denominator data. As described in section 5.1.2, indicators often use population data as the denominator. Numerator data was often the number of health related incidents, for example ANC visits, Maternal deaths, Malaria incidents, Fully immunized patients etc. This lack of data quality may be due to many reasons, one of which is most likely lack of usage. For example, we found that population data was missing for 2015 in one of the districts we visited. The fact that this error had not been detected earlier (we visited in November) suggests that the data receives
little use. We also found a multitude of duplicate indicators. Reasons for this seemed to be overlapping health programs and lack of a dedicated training servers. This means that indicators made in training sessions would be put into production server while not being removed afterwards.

Figure 6.4: Poor data quality and missing data are affecting the league tables.

There were also a series of "legacy" indicators that came from discontinued programs, but that had not been removed. Indicators belonging to programs not yet started were also present in the system. The last possible cause for this confusing system of indicators was facilities registered in reporting forms where the facility don’t provide all services, meaning they had no data for many indicators. This rather large selection of faulty and outdated indicators made it very hard to find the "correct" indicators when searching through the system, once referred to as a "jungle of indicators". To know for sure, one had to look at the indicator definitions to see what data they were using. If the indicator used the correct data, it was most likely the correct indicator to use. Many health workers and NGOs seemed hesitant to delete indicators that shouldn’t be in the system. One of the NGOs explained they’d rather rename indicators, putting "official" in the name of the most updated indicators, rather than removing those not in use. Though this was quite interesting, we weren’t able to find out why they were hesitant to delete indicators.

Overall, we found that lack of quality data and organized indicators made the league table harder to use than need be.

Population Data
During deployment there were various issues related to indicators where the most common one was lack of population data. Without the population figures it is difficult to make informative indicators as they will not be able to represent the health status of a population.

When we asked why population data was missing, many said they were unaware of the data being missing from the system. In one district, a health worker suddenly mentions that they actually have population figures for 2015, from the National Statistical Office of Malawi (NSO), which they have gotten from the local offices of National Initiative for Civic Education (NICE). We accompanied the Health Statistician Assistant (HSA) and his clerk to assist them with the data entry. When entering data, we noticed that both the clerk and the HSA were confusing some of the population figures. On paper, they had total population and female population figures. The clerk who was entering data, was about to enter the total population figures when we asked if that was correct. The clerk then responded saying that they had no male population data, so instead they would just use the total population figures. We then had to explain that a male population estimate can be made by subtracting the female population from the total. The fact that this had not occurred to them earlier suggest that data may be regularly entered with errors and that their statistical knowledge is limited.

We also found that the population data had different sources and were generated in different ways. There were projections or estimates from the NSO and collections of headcounts. Headcounts are manually counted people in a certain area. They explained that while headcounts were often more accurate, it was also much more demanding to collect, making estimates more commonly used.

**Usage of data in DHIS2**

Through interviews, focus groups and some comments, we found that very few was consistently using DHIS2. The most common usage seemed to be for data reporting. Of those we asked, the most frequent user accessed DHIS2 "a couple of times a week". As so few were actively using DHIS2 means that the data DHIS2 offers is probably used as infrequently. There were also cases where health workers extracted data from DHIS2 to be used in excel sheets to create graphs and tables instead of using the inbuilt tools in DHIS2. There were also some of the DHOs that had used graphs made in DHIS2 in review meetings though these meetings didn’t seem to happen too frequently or consistently. At most, review meetings were held quarterly as funding was required to hold the meetings due to travel and housing expenses.
Fragmentation of health data

"In the DHIS, it would be great if that would be the central repository for all data in Malawi regarding health. If this would all be linked(health data), all be at a central place it would be easy for decision makers to get informed." (NGO employee)

Through interviews with NGOs and other organizational bodies, we found that health data is currently split into many systems and databases. Communication between those in charge of health programs was limited, thus creating duplicate reports and data. The reason for this seemed to be that there were many independent systems that were yet to be integrated into DHIS2 due to DHIS2 not having data to satisfy current needs. For example, certain relevant maternal indicators were not available through DHIS2, thus outside-indicators were used instead in some performance reviews. Also, data from private hospitals was not present in DHIS2. Interviews with NGOs and some Health workers revealed that communication between levels was lacking. The NGOs talked about coordination between them and Malawi’s government to reduce the amount of duplicate work being done.

Data collection & data entry

Consistent data entry is something that is crucial to having good data quality. Who were responsible for the data entry varied. In some districts, programme coordinators were responsible for entering data related to their program. In others, a HSA was in charge of entering data. Some had clerks available that could do the data entry if the programme coordinators or HSA didn’t have time. However, troubles with internet connection when entering data was a frequently occurring issue. Without a stable internet connection it was difficult, sometimes even impossible to enter data into DHIS2. We also noticed that the hospitals we visited large queues and generally seemed very busy. This might impact the reporting of data as well, as the treatment of patients is prioritized over entering data.

It was explained that before entering data into DHIS2, it had to be collected. In one of the districts, a dedicated data collection team travels between the facilities to collect data. This is a quite challenging task as many facilities did not have reporting forms ready for the teams arrival. This is problematic as facilities could be over 96km away from the District Hospitals where the data is entered. Especially in the rural areas where rain could at worst destroy the dirt roads. So the data collection team couldn’t spend too much time at each facility else the data would become outdated by the time it was all collected and entered into the system.
Indicators

The fieldwork revealed a number of a couple of drawbacks when it came to the current state of indicators.

When it came to the organizational part, the set of indicators consisted any combination of duplicates, non-functional, legacy indicators and indicators created in training sessions. In short, there weren’t really an system implemented for creating and organizing indicators over time. With many separate actors creating indicators for their own needs, the list quickly turned into a "jungle of indicators" which even the most experienced users had trouble navigating in, making it hard to locate the indicators the users were looking for.

The indicators was often also not in the expected category(indicator group). Or if they found an indicator they were looking for, it was often the case that the indicator was out of date or not in use any more. This meant that it either didn’t have data in it or that it was faulty in some way. There was also a lack of naming conventions or standards for indicator names in addition to indicators simply being incorrectly defined in the system.

Different indicator types

Indicators in DHIS2 are of different types, or ratios. They can be raw numbers which are indicators without denominators, percentages, per thousand and so on. We found that comparing indicators of different types often lead to complications with the final score, making it inaccurate. The common theme was that percentages works the best, as the score formula is tailored for percentages. Even though indicators of different types are weighted down to match other indicators, the score will be skewed favouring the lower denominator indicators.

As you can see in figure 6.5, the "Maternal death rate by registered live births" indicator is of type pr 100,000 and has thus very little impact on the final score. The reason for this becomes clear when given the formula used to calculate the score.

\[
\frac{(1 \times 168.2) + (0.001 \times 32)}{1 + 0.001} = 168.233
\]

Here we see that by weighting down the indicator to match the percentage format, it will become so low that it won’t have any significant impact on the final score. Weighting them higher would cause too high fluctuations in the impact they have on the score as the values can vary so much. In this case, there is a 716.16 difference between the lowest and the highest value.
### Figure 6.5: Example of scores with percentage indicator and pr 100,000 indicator

<table>
<thead>
<tr>
<th>Name</th>
<th>ANC 1 Coverage</th>
<th>Maternal death rate by registered live births</th>
<th>Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Area</td>
<td>168.2</td>
<td>32.1</td>
<td>168.1</td>
<td>1</td>
</tr>
<tr>
<td>Bo</td>
<td>146.4</td>
<td>386.2</td>
<td>146</td>
<td>2</td>
</tr>
<tr>
<td>Tonkolili</td>
<td>136.9</td>
<td>169</td>
<td>136.7</td>
<td>3</td>
</tr>
<tr>
<td>Pujeahun</td>
<td>136.5</td>
<td>259.9</td>
<td>136.2</td>
<td>4</td>
</tr>
<tr>
<td>Port Loko</td>
<td>135.2</td>
<td>607.6</td>
<td>134.6</td>
<td>5</td>
</tr>
<tr>
<td>Moyamba</td>
<td>130.2</td>
<td>488.4</td>
<td>129.7</td>
<td>6</td>
</tr>
<tr>
<td>Bonthe</td>
<td>120.6</td>
<td>321.5</td>
<td>120.3</td>
<td>7</td>
</tr>
<tr>
<td>Kenema</td>
<td>113.5</td>
<td>0</td>
<td>113.5</td>
<td>8</td>
</tr>
<tr>
<td>Kambia</td>
<td>112.6</td>
<td>383.3</td>
<td>112.2</td>
<td>9</td>
</tr>
<tr>
<td>Bombali</td>
<td>106.8</td>
<td>213.2</td>
<td>106.6</td>
<td>10</td>
</tr>
<tr>
<td>Kailahun</td>
<td>91</td>
<td>298.8</td>
<td>90.7</td>
<td>11</td>
</tr>
<tr>
<td>Kolnadugu</td>
<td>75.9</td>
<td>716.6</td>
<td>75.2</td>
<td>12</td>
</tr>
<tr>
<td>Kono</td>
<td>62.8</td>
<td>321.5</td>
<td>62.5</td>
<td>13</td>
</tr>
</tbody>
</table>
6.2 Reception of League Tables Application

This section will describe the reception of the LTA during demonstrations and user-tests conducted in Malawi. The section is describes findings directly related to the app.

The limited internet connectivity caused some issues for us during our visits in the districts. There was rarely any districts that had a running Wi-Fi connection, meaning we had to resort to mobile networks through dongles. Our application was not suited to be used in environments with such limited internet speeds from the start. This made using the application quite confusing as it gave little feedback when things were actually happening. We quickly realised this would be an issue during testing. Measures including the addition of "spinners" when loading and reducing its internet usage, were taken to solve the issue.

The implementation of the application was also affected by the power related issues. It limited the time we had to test and receive feedback after our initial presentation and demonstration, as battery life was often a limited resource. These limitations made us unable to collect as much feedback as we wanted, especially when the attention of the demonstrations strayed from the league table and went elsewhere, like for example analysing faulty indicators.

"I think it’s simple, not too hard to use.", "The league tables are user friendly." (DHMT members)

The feedback we received on the usage of the application gave us the notion that it was user-friendly. We received positive feedback on most features including the presentation of the dashboard, league table creation/editing process and the league tables themselves. Most said the steps required to create a league table were many enough to give sufficient customizability, but not so many that the process would become confusing.

"People are not really keen on doing things that take time" (NGO employee)

The process of creating tables was quick and easy to learn. The users that tested the application also understood how to edit their selection of indicators on the fly after learning how to create a table. There was however an issue with the creating and editing of tables that we didn’t fix. When the user accidentally hit a button that would navigate away from the current page, they had to start the entire process again. This seemed to happen quite often. A simple solution to this problem could be to add a dialogue box when the user navigates away from the create/edit page,
asking them to confirm their action.

"I want our districts to hold review meetings. It's something we want to explore, to present the data during the meetings to get them to debate the data. It is a very useful initiative." (NGO employee)

Many said the league tables gave a quick overview of performance. Users also thought that league tables could be included in existing practising management, for example in review meetings. When there were available data present, it allowed them to analyse and compare the performance of their facility to others in their district. Many said this was a tool they could have use for in their work, if only internet and power became more reliable, making it possible to plan work ahead.

The general consensus in the districts was that the application was mostly equipped with the functionality it needed to have and no more. This seemed to be true as some users at district level had issues understanding the basic concepts, especially those related to indicators. Even basic tasks like using the mouse and keyboard seemed harder than expected for some. For example, some users were often looking down at the keyboard rather than at the screen. This was an issue when for example users were looking for certain indicators. The filter box automatically updates per keystroke, and the user did not notice that the app actually updated the results immediately. They would then miss the indicator they were actually looking if they for example made a typo. On the other hand the more experienced users, often NGO employees, was asking for more features and functionality, and more complex customizability. Using and navigating the application definitely seemed to be more natural to them than to some of the district health workers as they probably had more experience using computers. After observing users with varying technical abilities test the application, me managed to do some improvements to the flow of the application. These include sticking components like headers to the top of the table screen and finish buttons to the bottom of the create/edit screens. This made analysing large tables easier and the process of creating and editing tables much quicker. The most wanted functionality that was missing in the LTA was the possibility to add the tables created in the app as a favourite in DHIS2 and having a way to include timeliness of the datasets in the tables.

During our presentation of the application, we noticed that the visual elements of the application became cluttered when shown on low resolutions. This was often the case for projectors. Another issue with the presentation of the application was that the application was often projected on colored walls in lit rooms. This caused the applications subtle color contrasts to cause some issues when showing tables as it was hard to see things like where table cells began and ended.
Selection of indicators

When demonstrating the application, we often asked the health workers present which indicators they wanted to see in a table. Most wanted to see maternal indicators, indicators relevant to one’s health program and reporting rates. For example, a health worker responsible for a malaria program would often suggest malaria related indicators. When we asked which indicators were most important, we were told that their selection of indicators depend on national interests and immediate issues. The health workers explain that a selection of around 15 of the most relevant indicators at the time was common to present at review meetings. In the end, we usually ended up with a selection of indicators that had data rather than indicators the health workers actually wanted as they were missing data.

"If we have enough data in the system it could be useful."
(DHMT manager)

There were confusion about which type the chosen indicators was (percent, per thousand, number or other). In the earlier prototypes of the LTA there was no good way to show the indicator types. This in addition to lack of knowledge about indicators caused confusion on the implications of comparing raw numbers and various ratios to percentage indicators. Even though most said percentage indicators were the most commonly used, frequent requests to include raw number indicators in the tables when demonstrating were made. Some also seemed to have issues understanding why using raw numbers for comparing was a bad idea even after we explain that they would always favour those with larger populations. We didn’t spend much time investigate the reason for this as battery life meant we had limited time.

6.2.1 Ranking performances

The topic of how the scores were calculated came up in every meeting (formula can be found in section 5.3). There was always an interest to know the formula behind the tables to judge its fairness. In general the health workers agreed that the formula was a good way to calculate the scores, although there were comments suggesting that the calculation would not be fair in certain situations. For example, the calculation would produce an inaccurate score when some health centers in a district did not offer certain services included as indicators in the table. The score would then be unable to reflect that a health center did not provide services bound to indicators which was used in the league table. This is because the calculation would count the lack of data as 0, thus giving said health center
a lower score. We were also told that showing blank indicator values for those not providing services was a bad idea as it was easily confused with missing data.

We were never able to come up with a solution to this as it was hard to distinguish between missing data and those who weren’t providing the service through the DHIS2 API as well. NGOs we interview told us that they had the same problem, and further explained that it was quite demanding to keep a map of which health centres offer which services accurate and up-to-date.

### 6.2.2 Colors in the league table

One of the NGOs we interviewed explained that colors made tables easier to interpret and analyse. Early feedback on the application as well as viewing other examples of scorecards and league tables suggested that this was a much wanted feature. We quickly implemented a simple formula for coloring scores based on rank and adding markers to highest scoring indicators so we could test the concept (as seen section 5.6.3). Feedback on the fairness of the color distribution was quite mixed, though most users thought colors highlighting good and bad performances were a good idea. There were those who made strong points arguing that the distribution would more often than not be seen as unfair. It would happen when many of the compared organizational units would have similar scores. The coloring formula would then force someone into yellow and red even though most should be in green. Suggestions were made that coloring be based on national targets or thresholds. This is probably the best way to do it, though DHIS2 does not currently provide these data. We received little feedback on the markers highlighting the best indicator values, only some comments suggesting that they would rather want coloring of indicator values as well.

### 6.2.3 Weighting and inverting indicators

Weighting of indicators was a feature that received some appraisal during the demonstration, though the feature got little attention in our user tests. Feedback suggests that it was important to be able to say that an indicator is more important than others when creating a league table. When doing user tests, these features seemed to cater to those with advanced technical and analytical knowledge. Some gave the impression that this functionality was a solution to problems they hadn’t realised were problems yet, making the features confusing.
Though we implemented weighting with the intention it be used to define the importance of indicators, we discovered it had another use. Weighting can also be used to combine indicators of different types in the same table. This was a good idea on paper, thought it didn’t seem to always work well in practice. The reasons for this is explained further in section 6.1.3.

We received little feedback on the inversion of indicators as well, though people seemed to understand the concept after we explained. During testing we realised that inverted indicators actually reward poor reporting rates. For example, it cannot differentiate between having 0 cases of Malaria and no reported data. The user’s knowledge of the data becomes quite important in these cases to be able to detect similar errors.

6.2.4 League Tables Application as data quality assurance

"It is a good application, it lets us see where we made a mistake."  
(DHMT member)

Using the league tables with faulty data made it quite hard to extract any useful analytical information from it. This is one of the reasons that the LTA can be used as a data QA tool. The LTA functioned well to identify data issues as fields were either blank or showing unexpected values. For example, a health worker used "RHD Births Attended By Health Personnel" as an indicator in his table when testing. He noticed that the value was only about 17% when he was actually expecting it to be around 70%. After some investigation, it turned out that the indicator’s denominator used longer period intervals than the numerator. This caused the indicator to show a value lower than expected. During most demonstrations of the application, this triggered discussions on data quality and started investigations to figure out what caused the issue. Due to this happening during almost every demonstration of the application, we found that low performance scores due to faulty data gave incentive to correct the errors.

We found that the most common reasons for faulty data was through errors in an indicator definitions. This could be due to numerator and denominator having conflicting periods, for example the numerator is measured quarterly while the denominator is measured every 6 months. Other reasons include missing population data or that the service was not provided by said organizational unit.
Figure 6.6: Example of table made by user where abnormal data was quickly identified. The score of 0 indicates that there is most likely an error.
Chapter 7

Discussion

This chapter is divided into three sections. The first two will be discussing challenges and opportunities related to Malawi’s HMIS as well as the LTA respectively. The third section will review the methodologies used in this thesis and our approaches.

The discussion will be about the literature and findings presented earlier in the light of the research question.

- Which factors influence the design, development and implementation of a league table application in Malawi?

7.1 Challenges and opportunities presented by the HMIS in Malawi; the installed base

7.1.1 Data in Malawi’s HMIS

Though also an opportunity or enabling feature for our application, the data stored in Malawi’s DHIS2 server had many weaknesses, where the biggest one was data quality. This affected our LTA by providing it with lacking data giving the tables less credibility and usefulness as there was less to analyse.

Missing data and data quality

Missing data is one of the biggest challenges for the LTA as it requires data to produce an intelligible score. When there is missing data one might not be able to use certain indicators to create a performance score. If indicators with missing data is included, the final score will be better at describing data quality rather than performance. This is because those
who have data get points towards the score, and those with missing data do not. Also, it proved to be quite difficult to distinguish between missing data and organizational units not being part of a programmes which meant they were not supposed to report said data. Users pointed out that it was unfair to rank organizational units based on indicators from programmes they were not part of, meaning their value for that indicator would be interpreted as missing data by the league table leading to a lower score. This is because when for example a district has not reported data for a program it is not part of, the score will still count the indicator in the denominator. This gives an overall lower numerator and higher denominator producing a lower result (see section 5.3 for formula).

Users avoided this problem by simply not using the indicators causing the issue. In a way one could say this worked, but the end result is a less informative score as it is based on fewer indicators. Continuously ignoring and avoiding problematic indicators may lead to them becoming forgotten in the system as it never has data and is never used and thus will never be corrected. This corresponds with one of the common challenges (see 2.2.1) HISs in countries like Malawi face which is poor quality data which receives little use. Because it is not used it remains of poor quality [14, Chapter 9].

We found that much of health worker and NGOs focus was on indicators related to immediate issues and health programs they were currently involved in. Though this is to be expected and is not necessarily a bad thing as league tables can portray specific health performances as well as a broad general status. It is still important to maintain the indicators not currently in focus as these might be important later. Little focus may cause little use of said data thus leading to potential errors not being corrected and the quality of the data is reduced. As described in section 2.2.1, having a limited selection of updated and accurate indicators may lead to issues regarding regular monitoring of health status [5].

The common theme in these challenges seems to be that users would rather avoid problematic data rather than fixing the issues. This could be due to little use of data and a lacking sense of ownership of the systems among the users. This might cause them to feel that it is not their problem, and thus not their responsibility to solve. This agrees with one of the common challenges mentioned in section 2.2.1 regarding achieving quality information and sound use of it. We also found that data entry was often not prioritized. Data was collected and ready for entry, but there were cases where it had been put on hold for various reasons or just simply forgotten. This suggests that those responsible for data collection and entry don’t use data from DHIS2 very often. The fact that those responsible for data collection and entry don’t use the data they collect means that they will most likely not experience problems caused by lacking
reports and delayed entry and thus have no personal interest in solving it. Improving information usage at lower levels closer to the source of the data is definitely important if one is to improve the overall quality of data in DHIS2[14, Chapter 9].

Confusing indicators
Another challenge related to the data stored in DHIS2 was how confusing the indicators were. There are several factors observed that contributed to the confusion. First of all, there was an overwhelming number of indicators available in the system. As of March 2016, there were 783 indicators present in the system. The number doesn’t reflect much on its own, but we found through our research that a high number of these were not actively in use. The main causes for this were a multitude of duplicates, legacy indicators, training indicators and temporary calculations used to define other indicators. Because indicators can be defined with and without denominators, the system opens up for misinterpretations of what an indicator is and what it describes.

What is the purpose of having indicators without denominators one might ask. The most likely purpose is to be able to reuse common calculations, such as the sum of two data elements, in new indicators without having to type them in manually every time. But having these kinds of calculations appear as indicators may cause some confusion as they don’t work well when compared with ratios. If this is going to continue being a possibility in DHIS2, it should support filtering of indicators by type, so that one can at least filter out indicators without denominators. This would help with creating a coherent selection of indicators in the LTA and to avoid using raw numbers.

As mentioned, there were also many duplicate, outdated/legacy and faulty indicators in Malawi’s HMIS. Many of these were the result of DHIS2 training sessions taking place on the production server. The alternative is to use the DHIS2 demo servers, though these do not contain relevant data or organization units. The connection from Malawi to the demo servers was also quite slow, making them more troublesome to use than the server stationed in Malawi. Having dedicated training servers would make it easier to conduct training as one would always know what data is available in the system. This makes it possible to plan which tasks to include in a training session ahead, ensuring that all tasks can be done without technical complications. Cleaning the system afterwards could also be much easier by simply resetting it. Any cleaning done after training sessions on the production server has to be done manually and it is easy to forget about things. This is shown by all the faulty indicators we found in the system while testing and demonstrating the league table app that turned out to be from training sessions.

We observed cases where rather than deleting invalid indicators, be it
because they were duplicates or outdated, health workers would rather rename the indicators to prevent them from being used instead of just deleting them. This is a worrying sign of little communication between those creating indicators as the cause of this is probably them not wanting to delete or change the work of others even though it is outdated and faulty. There also seem to be no standard conventions of how to name indicators, like for example including which programs an indicator belonged to in the indicator name. We observed that this was often the case that there were duplicate indicators from different programs.

To lessen the complexity of the system of indicators or "the jungle of indicators" as it was referred to, some naming conventions and standards needs to be agreed upon. This is important if the expression "indicators" is to remain as loosely defined in DHIS2 as it is today. Else the size of the "jungle" will just continue to grow and relevant and updated indicators will become more and more difficult to find if one doesn’t know exactly what it is called.

Though there are enabling procedures such as review meetings giving opportunity to use data in Malawi’s HMIS, the challenges related to the data in DHIS2 makes it more complicated. Not only are users required to have some statistical and analytical knowledge to interpret graphs and tables made, but also knowledge about the indicators used and a critical view of their values to be able to detect errors and inaccuracies as to not misinterpret results. Particularly on district level there were many signs suggesting that users found it challenging to create an informative league table due to use of raw-number-indicators, faulty indicators and missing data. For example indicators presenting only raw-data such as counts of an incident was often suggested to be included in the tables during presentations of the LTA. These kind of indicators are invalidating the table because these they work poorly as indicators of performance and don’t compare well with other indicators such as percentages and per thousand, etc. When used in league tables, as mentioned earlier they will always favour the highest populations thus giving an unfair representation of current health status. Without a well thought out selection of indicators, the scores the LTA generates will not have much analytical value to the user. If the user is not aware of this being the case, it could potentially lead to them seeing this as an issue with the application itself rather than their selection of indicators. This is a problem as it could steer them away from using DHIS2 and its other useful applications.

While DHIS2 provides opportunity to the LTA by providing it with a storage of data, processes for collecting and entering new data and procedures to use data, it also introduces many challenges as these opportunities or enabling features have many weaknesses and shortcomings.
7.1.2 Functionality supporting backwards compatibility

Functionality supporting "backwards" compatibility was often requested by users. By backwards we mean technologies that existed before our application and provide formats such as excel and pdf. Arguments for backwards compatibility was that it gave opportunity to lessen the gap between the old and the new technology. This is an important aspect in the theory of installed base as the new should be connected to the old making them interoperable as described in section 2.1.3. If the application supports exporting tables to excel and pdf formats, it also allows users to work with tables when offline or even when not near a computer if a table is printed out. In this case, it would allow users to keep using excel for table viewing, manipulation and customization and .pdf for printing and/or sharing tables outside of DHIS2. This is can be advantageous to the concept of league tables as it reduces the barrier of entry for many who are skilled in excel but not so knowledgeable about DHIS2 as they wouldn’t need to acquire new knowledge to be able to work with league tables. Other arguments to support exporting league tables into excel and pdf formats would be functionality we were unable to add such as coloring based on targets and offline usage and sharing.

The fact that many requested the ability to export tables to excel and pdf suggests that many users lack training in DHIS2. It also suggests that DHIS2 is not reliable enough and the functionality and customizability it offers is not sufficient for the users needs. To solve this one could provide more training to the users. As more health workers learn to use DHIS2 effectively its user base will grow and thus its credibility associated with its capabilities. This then leads to the self-reinforcing cycle seen in figure 2.1 further increasing its user base. To increase the chances that health workers who learn it keep using it, DHIS2 has to be useful to them. To be useful it has to be reliable in terms of ICT and power which will be discussed below. It also has to provide at least as much functionality and flexibility as the older formats such as excel does or other unique functionality that excel does not support.

7.1.3 ICT and electricity

Section 3.2 presents the current status of the general infrastructure in Malawi including components most relevant to this thesis which are ICT and power. These are also two of the country’s main challenges concerning their HMIS. The two main issues in these areas are the high ICT costs and the frequent power outages[33]. ICT prices were often to expensive for district hospitals and facilities to afford an internet subscription. The
frequent power outages meant any technology requiring a constant power supply to function, like for example ICT, would become very unreliable. Together, these challenges meant that health workers would have trouble finishing their daily work and delivering reports on time as work could not be planned reliably and was often delayed. We also received comments suggesting the workload could potentially double as systems went down due to internet or power issues. This was because when their systems went down, reporting was done using paper registers and when it was up, the reports then had to be put into the system.

As many had limited resources in terms of finances, hardware such as computers and printers were lacking at district level and below. So to summarize both the lack of internet connections and hardware to utilize it was often lacking due to financial constraints and prioritizations. Those who did have access to the internet and had sufficient hardware were unable to utilize it properly due to power outages. Altogether, this means that it was many obstacles to overcome at the lower levels in order to be able to use DHIS2 efficiently and reliably.

**Lack of access to electrical power affecting the implementation**

The limited access to power in the districts proved to cause some challenges when it came to presenting, demonstrating and testing the LTA. We were often unable to connect our laptops to a power source in the districts due to the frequent power outages. This meant that we had very limited time to do everything we wanted to accomplish. The time we had depended on the amount of battery left in our laptop.

This made us unable to do as thorough testing as we wanted and had to prioritize testing the basics of the application. This may have been the cause for the lacking feedback we got on functions such as weighting and inverting. So a useful tip would be to bring mobile power supplies when doing field work.

We were also unable to do much user training as the formerly mentioned tasks were prioritized in order to get as much feedback as possible.

**Internet connectivity affecting design and development**

These challenges also affected the design, development and implementation of the League Table application. It affected our development approach by requiring the application to be very lightweight when it came to network usage. While testing our application in Norway did not reveal the shortcomings in the app, the tests in Malawi certainly did. In hindsight,
the internet situation in Malawi should have been mimicked before testing the application Malawi. To simulate such environments and testing the application in it before conducting fieldwork would have been very useful as it could have saved a lot of time in development. It could also have allowed us to focus on other aspects of the application during the testing rather than technical details. There are several tools easily available in web-browsers to throttle internet speeds and simulate poor connectivity which later in the project were used. In this project the developer console functionality in Google Chrome was used.

There are probably many optimizations of internet usage to increase network performance that was not done in the LTA. However, in the application, two areas were focused on as optimizations there gave good results.

Firstly, the network usage was reduced by slimming down the application’s size. This is most relevant the first time a user opens the application when all the scripts and contents of the app have to be loaded. In the subsequent openings of the app modern web browsers usually have cached the content to preserve the network usage. One practical measure taken was to use the minified versions of source code the libraries used. In minified code, unnecessary characters like whitespace, newline, comments etc. are removed to make the file smaller in size. Although it makes the code unreadable for most people, it is still fully functional for computers to execute. In the LTA for example, Angular was used as the web framework. The application then had to include the file "angular.js" with a size of 790.4 kB. The size of the minified source code "angular.min.js"mart is in comparison only 108.2 kB. While in Norway this didn’t make much of a difference in loading speeds, though in Malawi this saved a lot of time, often up to half a minute. In addition we believe that there should be a general culture where the developers are aware of preserving space, thus not including unnecessary libraries, images, icons etc as it could have big implications on the applications performance, especially when internet speed is limited.

Secondly, keeping the number of network requests to a minimum is important because every request have an overhead of information required to send data over the network. Furthermore measures were taken to only request and send the minimum amount of information needed. For example, when requesting an indicator, one can specify which fields the server should include in the response instead of just letting it respond with everything connected to the object. In the beginning of our development, this was an issue by default, though after the DHIS2 upgrade to version 2.21, servers responded with minimum information by default. This meant that we had now had to ask for more than default. Combined, the measures taken resulted in a much faster and more responsive app that could
function with slow internet speeds than the first prototype developed.
Some features to improve visual feedback was also added to improve performance in environments with low connectivity, though these will be discussed in the section 7.2.

7.1.4 Summary

The process of designing, developing and implementing the LTA required quality data and indicators, access to an HMIS, a stable internet connection, a reliable power source, functional equipment as well as a knowledgeable user base. The enabling and constraining features of the installed base were thus important factors as they defined how every process could be done.

<table>
<thead>
<tr>
<th><strong>Opportunities</strong></th>
<th><strong>Challenges</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Much data available in DHIS2</td>
<td>Infrastructure</td>
</tr>
<tr>
<td>Routines for data collection and entry</td>
<td>Knowledge and training</td>
</tr>
<tr>
<td>User base with knowledge of DHIS2</td>
<td>Financial resources</td>
</tr>
<tr>
<td>HMIS routines and existing practices</td>
<td>Access to DHIS2</td>
</tr>
<tr>
<td></td>
<td>Lacking data quality</td>
</tr>
<tr>
<td></td>
<td>Messy indicator system</td>
</tr>
</tbody>
</table>

Table 7.1: Summary of opportunities and challenges presented by the HMIS in Malawi; the installed base
7.2 Challenges and opportunities presented by the League Tables Application

One should keep in mind that the application was customized for the conditions and observation made through the stay in Malawi. Although the Malawian HMIS is unique, aspects of the app can be applied to league table design in general.

7.2.1 Potential usages

The concept of using league tables in performance ranking had potential to be incorporated in existing practices. One of the stronger attributes of the LTA was its ability to view much data at once giving an overview of the health status. This was well received as it made use of the data already available in the system. A staff member from one of the NGOs operating in Malawi summarized his thoughts about league tables as follows;

"Its a very good thing this whole league table idea because generally what we have noticed is that people have collected a lot of data, but the biggest challenge has been how to actually promote this data for decision support."

Figure 7.1: One district in particular were very interested in optimizing their processes.

Feedback from the users suggest that the most common usage for league tables would be performance monitoring. This includes measuring one’s own performance and comparing it to peers and higher organizational
levels based on the score generated by the LTA. Furthermore, DHOs explained it would make their work easier as the application quickly shows how well facilities and programs are performing in their district. This would allow them to identify who were doing well and who needed extra support.

A common issue in the HMIS was that even though much data is collected, it was hard to make sense of it and then use it to support management decisions. As league tables are able to quickly present data in a clean way while also attempting to make sense of the data by generating a performance score, it could definitely help with this issue. The process of evaluating performance could be time consuming and use of league tables could make the task easier as described by a health worker at district level:

"It’s able to show who is performing well in which indicators instead of going line by line looking for them."

"We will be able to show, using the league table app, how our facilities are performing based on a couple of selected indicators"

The health worker in this setting is referring to having to go back and forth between pages in reports to compare results to figure out how one was performing.

7.2.2 App design

There were many positive aspects with the design of the application. Developing with the end-users in mind gave good results when it came to different aspects of usability described in chapter 2.4. It was observed that designing the app with few and simple steps worked well regardless of being tested on district level, national level, zonal level or by NGOs as users were able to create tables fairly quick. Besides, having storage of tables and the userguide built in the app worked well as the user had the functionality needed within short reach. These observations may suggest that such design contributed to efficiency as the users navigated through the app with ease. Moreover, the app generally being simple to use without much knowledge beforehand suggests that the application was easy to learn. This could be a valuable attribute as there probably would be a smaller necessity to train personnel to be able to use the app effectively. Also, developing the application with low network usage gave good results towards the app being efficient to use.
The various measures taken to give visual feedback to the user was also fairly successful as the users became more independent and needing less help to use the app effectively. The need for the visual feedback to the user when performing actions proved to be important in the research context, especially considering the conditions of poor connectivity e.g. animations to show the application is loading. In addition, thinking about logically highlighting buttons with colors, respectively green to advance forward, and red for destructive operations seemed to have a positive impact on the user’s ability to navigate through the app as the actions were intuitive.

Furthermore, realising that the tables in the application could potentially be viewed on different kinds of devices such as mobiles, laptops and projectors showed that designing with the actual conditions in mind can be important when developing. Especially projectors did not handle subtle color contrasts in on different surfaces like a white wall, or projector canvases in addition to sunlight disrupting the colors. Such conditions does matter because statistical presentations like league tables will probably be used in review meetings with similar conditions. An idea that we did not have the time to test was to add an option to toggle a "high-contrast" mode, where the coloring scheme of the application could be altered to better support said conditions.

### 7.2.3 Ranking

Using ranking to measure performance had many positive aspects. The majority of the users thought it was motivating as they wanted their
district or facility to perform better and it was many who believed that it could be used in decision making. In other words, it contributed to stimulating competition between similar service providers[6] as described in section 2.3. Most seemed to agree that being placed on the bottom of a league table for anyone to see would motivate them to improve their performance rather than demotivate them. Based on the feedback it is reasonable to assume that the ranking can contribute to a healthy competition among the peers in a way that they push each other to do better promoting both data usage and data collection.

However, the ranking only worked well when data was present in the system, as it was hard to extract valuable information from tables that were missing data. Furthermore, the ranking formula used in the LTA to calculate the total scores in the tables was optimized to operate with percentage indicators. Although, when using other ratios such as per thousand, etc. the rankings would be the same, the scores would have low differences. This makes it difficult to compare performances as everyone seems to perform equally. Combining indicators with different types makes the scores less valuable from an analytical standpoint as higher ratios usually has higher values. This means that they will have a greater impact on the score. Furthermore raw numbers renders the rankings in the tables rather useless, as the ranking would naturally favor the facilities with higher populations.

A challenge that often occurred was when organisation units, e.g facilities did not offer certain health services connected to the indicators included in the league table created as described by one health worker:

"If data is missing, the user should be notified why and if it’s supposed to be there, or if they don’t provide the services."

In such situations, the facility would score 0 on said indicator, lowering the total score for the facility considerably. The outcome of such situations may appear unfair for many. A more fair solution could be to not include the indicator in the calculation of the total score of the organisation unit. Also it could be useful to visually represent this as for example N/A instead of just 0 to show that the score is not applicable.

However, to extract such information along with the indicator data is not possible in DHIS2 when fetching indicator data as far as we know and thus we were not able to develop this alternative as earlier mentioned. One can argue that all health programs should have a list of the indicators included along with the organizational units participating in the program. Such information would allow to detect if an organizational unit should have data for an indicator or not. It could also better map who’s offering which health services.

Some said that indicator values below 0 and above 100(assuming the ratio
used in the league table is per cent) didn’t make much sense and wanted to cap indicator values to 0 or 100. This solution may solve some weird interactions with the score calculation. However, one could argue that this can be seen as manipulating the data which defeats the transparency aspect of league tables.

Indicators having values below 0 or above 100 suggests that there are either errors in the data or indicator calculation. If all negative scores appears as 0% in the application, the data can appear as having no errors hiding the actual state. Furthermore, scores that surpasses 100% can actually be correct as well if an area exceeds its "expectations" by treating additional patients from outside their area of responsibility. This makes league tables work as a tool for validating data quality, though not being the main purpose.

**Inverting**

The immediate advantage of the inverting functionality was that it was very useful in certain situations as it opened up for using a wider array of indicators in the league tables. Also, it now made it possible to rank "normal" indicators together with inverted indicators in the same table. The functionality can contribute to increasing the utility of the application in addition to make use of available data.

However, it requires higher demands to data quality as the formula of the inversion used in the app opens up situations where lackluster reporting are rewarded. This situation can be explained by an example seen in figure 7.3. The functionality thus requires more critical assessment by the users of the application to not believe blindly in unlikely performances. Another limitation with this functionality is that it only works well when using percentages, while higher ratios produce inaccuracies. With the formula described in section 5.3.3, we can see that numbers exceeding 100 will result in negative scores.

![Figure 7.3: Here we see Bo getting a perfect score even though it has no data for ANC dropout rate](image-url)
Weighting

Weighting functionality made it possible for managers to highlight indicators which was regarded as more important than others. Many thought the functionality could be useful in the tables contributing to the utility of the app.

We also found an alternative use of weighting. It could also be used to attempt to combine indicators of different types/ratios by weighting the higher ratio indicators down to match those with the lowest ratios. While this seemed like a good idea in theory, it didn’t work well in practice. This was because when weighting indicators down, their impact on the score lowered as expected. But it also reduced the importance of fluctuations in the values meaning most values basically counted for the same. For example a per hundred thousand indicator weighted down by 1000% or 0.001 times its original weight would mean that a difference of 100 between indicator values only give 0.1 points of variation in the final scores. It was not as straightforward as we thought and it needs to be implemented smarter solutions for it to work properly.

7.2.4 Coloring distribution

One practical measure to simplify the interpretation of scores in the LTA that was implemented was colouring the total scores red, orange and green depending on their ranking. As previously mentioned in chapter ?? the distribution was a strict division (top 25% green, middle 50% yellow, bottom 25% red). Making use of colors to highlight performance in the league tables were received as a good concept among many of the users and were described by a NGO that:

"It gives you an idea of the serious issues in your programme and it is more attractive than all the numbers being presented."

Furthermore people thought it was easier to interpret the data in addition to the motivational factor of the desire to be among the of the top 25%.

However, the implementation did get some resistance as the distribution could be unjust in many cases. One zonal officer viewed the LTA as a motivational tool and expressed that "it’s demoralizing to have very good performance and still have ‘yellow’ performance." Giving red and yellow colors to scores that actually is quite good and close to 100% coverage because everyone else is doing even better in an area can be demoralizing. The zonal officer further explained that in such situations like in the table presented in figure 7.4 "We cannot expect them to do more, because they have been looking after other populations that aren’t belonging to them."
Figure 7.4: Table generated from the DHIS2 Demo server to measure ANC performance where most districts are performing well. Is it fair that Moyamba have a yellow score, even with > 100% coverage on average?

<table>
<thead>
<tr>
<th>Name</th>
<th>ANC 1 Coverage</th>
<th>ANC 1-3 Dropout Rate</th>
<th>ANC 2 Coverage</th>
<th>Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bo</td>
<td>146.4</td>
<td>41.8</td>
<td>159.7</td>
<td>121.4</td>
<td>1</td>
</tr>
<tr>
<td>Western Area</td>
<td>168.2</td>
<td>49.6</td>
<td>138.6</td>
<td>119.1</td>
<td>2</td>
</tr>
<tr>
<td>Kenema</td>
<td>113.5</td>
<td>12.5</td>
<td>133</td>
<td>111.3</td>
<td>3</td>
</tr>
<tr>
<td>Moyamba</td>
<td>130.2</td>
<td>22.1</td>
<td>112.8</td>
<td>107</td>
<td>4</td>
</tr>
<tr>
<td>Pujehun</td>
<td>136.5</td>
<td>40.3</td>
<td>107.4</td>
<td>101.2</td>
<td>5</td>
</tr>
<tr>
<td>Bonthe</td>
<td>120.6</td>
<td>40.8</td>
<td>112.6</td>
<td>97.5</td>
<td>6</td>
</tr>
<tr>
<td>Tonkolili</td>
<td>136.9</td>
<td>54.9</td>
<td>106.8</td>
<td>96.3</td>
<td>7</td>
</tr>
<tr>
<td>Kailahun</td>
<td>91</td>
<td>10.3</td>
<td>99.9</td>
<td>93.5</td>
<td>8</td>
</tr>
<tr>
<td>Kambia</td>
<td>112.6</td>
<td>37.5</td>
<td>99.6</td>
<td>91.6</td>
<td>9</td>
</tr>
<tr>
<td>Port Loko</td>
<td>135.2</td>
<td>56.4</td>
<td>91.8</td>
<td>90.2</td>
<td>10</td>
</tr>
<tr>
<td>Bombali</td>
<td>106.8</td>
<td>44</td>
<td>86.8</td>
<td>83.2</td>
<td>11</td>
</tr>
<tr>
<td>Kono</td>
<td>62.8</td>
<td>27.1</td>
<td>64.8</td>
<td>66.8</td>
<td>12</td>
</tr>
<tr>
<td>Koinadugu</td>
<td>75.9</td>
<td>40.9</td>
<td>57.1</td>
<td>64</td>
<td>13</td>
</tr>
</tbody>
</table>
Using targets instead

One possible solution proposed was to use targets when distributing the colors. Instead of automatically distributing the colors fixed like mentioned, it could be distributed based on targets so that the colors represent if the indicator target is fulfilled (green), moderately fulfilled (orange) or not fulfilled (red). Such an implementation would open up another approach to presenting league tables still having the ranking aspect but also function as a monitoring tool for the status of indicators.

However, such functionality would require the targets to be set by someone. One approach could be that targets are manually set by the creator of the table. Implementing manual target functionality would increase the complexity of the app and requires the user to set suitable target ranges which would could lead to human errors and misleading tables. Targets can also be abused to alter the reality of the health status, so the functionality would also require additional trust from the user.

It was observed that the coloring takes a lot of the initial attention to the spectators viewing the table. At first, users focused more on colors than the actual numbers, but when they wanted to know why they had a certain color, they looked at the numbers instead.

Another approach to set targets could be to extract national targets from DHIS2 to be used to set colors, but at the moment the system does not include targets in the indicators. We believe that applications like the LTA interested in using targets in conjunction with indicators could benefit from integrating target information into indicators.

Another aspect with having colors distributed based on targets is if all the indicator scores should be colored individually in the table, or if the coloring still only should be applied to the total score. The total score threshold could for example be set by averaging the thresholds for all the targets. However, by coloring every indicator score one might lose some of the readability of the table, as it takes away focus and attention from the total score.

7.2.5 Functionality or Usability

A trend where the more expertise a user had in IT and health, the more extra functionality they requested was found while testing in Malawi. Those with less knowledge about either field, be it IT, health or both, seemed to find some of the basic functionality, like the process of indicator selection, quite challenging. This required further development of the application to focus on balancing the scales of functionality and usability.

This dilemma introduced limitations on the functionality we could add to
the application. Adding the additional functionality some requested would require us to sacrifice usability in exchange for functionality. To reference the usability goals describing usability in section 2.4, the addition of more utility may come at the expense of effectiveness, efficiency, and learnability.

Advanced users would often expect to be able to do more in the application than novice users would. Like for example setting targets for indicators that the table would base its coloring scheme on. As novice users didn’t necessarily expect to be able to do this, they may see the additional utility as unnecessary steps to complete a task. Unnecessary steps would make the application seem less efficient and effective to use as well as making it more difficult or time consuming to learn. Thus, increasing utility for advanced users come at the expense of user-friendliness for novice users.

However, the fact that different user had different expectations of the application wasn’t only a challenge. It also allowed us to gain feedback on what the various users wanted to be able to accomplish in the application. We could then implement the features that were most commonly requested from all levels without worrying that we would reduce the usability of the application. It also allowed us to identify steps that could potentially seem redundant to some and then allow for the possibility to skip them. For example, we were able to come up with a concept that allowed users to almost skip the entire table creation process. This was through the addition of league table templates that users could copy into their private tables and then edit if they wish.

On of our goals when designing the app was to allow as many as possible to use it effectively while also providing sufficient functionality to all who use it. The approach we used to achieve this was to only add what was most commonly requested across all levels while being able to implement it without introducing additional steps to the table creation process. In the LTA we opted to keep the weighting and inverting functionality, but helped the users in the table creation process by automating the steps allowing users to skip them.

This left us with many suggestions for additional functionality after finalising the application, like users being able to select targets for indicators, defining a colouring scheme etc. This suggests that it could perhaps be a good idea to have different modes for the application, with a default mode where the application works as is, and an advanced mode that reveals additional options for functionality and customizability. Another idea is to add more automation of certain things, like the application getting and setting targets for each indicator automatically based on national targets.
Figure 7.5: An advanced user can have more expectations than a novice user.
7.3 Review of methodologies

7.3.1 Lessons learned from development

To ensure steady progress in the development of the application, it was important to make continuous deliveries to the client. This allowed for quick detection of any issues, be it bugs or deviations from the original design etc and discussion of said things.

When developing in a research environment involving the end users, it is useful to do so in rapid iterations. This allows for more detailed testing and feedback if with each iteration, at least one new feature is introduced. This is due to the small changes between each iteration, the users can focus on what is new between each iteration and give feedback on it. This allows the developer to detect and resolve most issues around the newly introduced feature as quickly as possible.

When developing with the users, it is important to take all feedback into consideration, even the more obscure suggestions. This allows you to identify the common user and its needs, and implement the most requested features.

When developing using a prototyping methodology, it is important to prioritize making working code rather than structured optimized code as you can only get feedback on the things that actually work. Whether the code is well structured with good commenting and has very optimized speeds (knocking off 1 second on a function) means very little to the user when testing the application. So following the mantra of prioritization "Make it work, Make it fast, Make it pretty"[17] is a good idea.

Reformatting code regularly increases the speed and ease of development later in the project. This is because unless the project that is being developed has been done before, the developers will be learning new things through the process. This means that older code might make it hard to do new things, reformatting the code regularly as one learns new and improved ways of doing things, makes it easier to reuse old code.

7.3.2 Research approach

The research methodology used in this thesis was Action Research (AR) (section 4.2) in combination with underlying methodologies such as prototyping and agile development. Combining AR with prototyping seemed very natural as they both have cyclic processes. The steps of AR can be broken down into Diagnosing, Action Planning, Action Taking, Evaluating and Specifying Learning in their respective order as explained
by Susman et al.[83]. Our process of development happened in four cycles including the steps Diagnosing, Evaluating and Specifying Learning resulting in four iterations of an application prototypes, while the process of deployment included the steps Action Planning, and Action Taking. As mentioned in section 4.3, prototyping work as a pendulum moving us back and forth between application development and deployment to combine the two processes into one larger cycle. Even though the development had four cycles as seen in figure 4.2, it is natural to see them as four cycles within one larger AR cycles. This is because Action Taking is an important step within the AR cycles and arguably, there was only process of action taking done in this thesis and was done in Malawi. We believe that our combinations of methodologies was sufficient in order to provide knowledge for further research within this field as well as realising the concept of league tables allowing further development, testing and discussion on the matter.

7.3.3 Limitations and Shortcomings

Methods used for data collection included demonstrations with group discussions, focus groups and interviews, and user testing with observations. These methods provided us with good insight in how health workers would use the LTA as well as thoughts and feelings related to its use. A shortcoming due to the limited time we had while doing fieldwork was that we were unable to attend a review meeting as there were none scheduled within our timeframe. It would have been very interesting to see how users could utilize the LTA in a practical a realistic setting. This would provide us with much insight in how users utilize analytical tools for decision making in their work.

It would also have been very beneficial for the research to do follow up visits after letting the participants use the LTA on their own for a period of time. This would have allowed us to better define the end users and thus have more confidence to change and implement certain features. Like for example functionality for manual targets for indicators that define coloring rules. This functionality would allow users to color tables as they like though it might be an obstacle for the less advanced users. It would also give us more data to identify certain themes, opportunities and challenges. Unfortunately, we were unable to do this as participants could not fit another visit into their schedule or were unable to use the LTA on their own for various reasons. We were also unable to gather more feedback after our visit in Malawi. This was due to a lack of response to emails, asking if anyone had further thoughts and feedback on the application after our visit. As the application lacked a feature allowing to share tables during our visit in Malawi, we couldn’t manually check if there had been made
any tables after our visit.

Though there were things we could have done to gather more and better data, it was still a challenge of its own to categorize and analyze all the data we gathered. While in Malawi, the focus was to identify the most commonly requested features, implement those and do further testing. The rest of the data gathered was only organized by time and place in Malawi to be further categorized and analysed when we went back to Norway. This means that we weren’t able to do many follow up questions regarding what we found.

Figure 7.6: Loosing a wheel gave us the opportunity to analyze newly gathered data.

The amount of participants in the demonstrations and the following discussions, interviews and focus groups were based on convenience and availability. Even though we had little control of who participated, we still feel we were able to involve many users from various levels giving us a broad perspective. One could argue that we didn’t always use the optimal methods for data collection depending on the user sample. For example there might have been times were focus groups would have been more suited than discussion. Our approach was to do what felt the most natural to do. For example if the demonstration started a discussion, we involved our selves in the discussion rather than forcing the participants to split up in to focus groups even though we had planned to do so after the demonstration. We did this because our goal was to gather as much quality feedback from the available users as possible in the short amount of time.
we had. This meant that as long as the participant were talking and sharing their thoughts and feelings towards the LTA, we were satisfied. As the research takes a qualitative approach with a limited user sample it would be wrong to assume it is 100% generalizable. This is because we cannot say for sure that our findings reflect the opinions of the entire health sector in Malawi. Though it is not fully generalizable, we felt it was sufficient in order to identify the common users.

Our research and the feedback we received on the LTA may have been affected by us being the developers of the application. This may have cause someone to be reluctant to share negative thoughts and feelings about the application. We were also accompanied by members of associated with DHIS2 and the MoH. This might have made some participants reluctant to present their shortcomings as well as critizing DHIS2.

As a last note we were foreign students, with limited knowledge about Malawi and its HIS, HMIS and health related subjects in general. This caused some challenges as we might have misunderstood certain formalities, approaches and contexts and thus needed some time to adjust accordingly.
Chapter 8

Conclusion and future work

The purpose of this chapter is to provide a summary of the discussion in Chapter 7 attempting to answer our research question while providing some reflections on and suggestions for future work.

In this thesis, we have presented our work related to designing, developing, and implementing a league table app in Malawi. In this work, our research question has been:

• Which factors influence the design, development and implementation of a League Tables application in Malawi?

We found that there are both enabling and constraining factors influencing the design, development and implementation of a league table application in Malawi. While Malawi’s HIS had many factors influencing the LTA in an enabling way, it presented more challenges.

The enabling factors were that DHIS2 offered much data our application could use as well as routines for data collection and entry. Existing HMIS procedures, such as review meetings allowed for the possibility for data to supporting decision-making. There was also an established user base with knowledge of DHIS2 which reduced the amount of training required to test the application.

The participants of this research saw potential in the application. They thought the concept of league tables was a good way of viewing much data at once and thought the LTA could be integrated in existing practices and routines. Furthermore the ranking aspect was received as motivating as it stimulated competition. In addition to ranking, the LTA functioned well as a tool for quality assurance of data in the system because it was evident when data was missing in the tables. Using colors to highlight performance was well received as it made the data more attractive and highlighted the level of performance. Moreover, including the ability to invert indicators in the app enabled to make use of more data in the system. Weighting to
highlight importance was found useful as well.

Having the LTA support backwards functionality proved to be useful as this allowed more users to utilize the application how they wanted. Involving users from most levels in the development and testing of the app helped increase its usability and contributed to developing an app that was relatively easy to use for health workers of all skill levels. It allowed us to see what functionality was most important to users so we could avoid adding unnecessary functionality that would reduce usability.

The challenges include missing data in the system making data analysis hard to accomplish. There was also a lack of data quality and usage. This affected many data analysis tools including the LTA to support decision-making in Malawi’s HIS. We found that there was a multitude of duplicate, legacy and training indicators in the system. Besides, there were also many incorrectly defined indicators causing confusion and making the process of selecting relevant indicators for the tables difficult and time consuming. Additionally we found that infrastructure, such as ICT and electricity introduced many challenges with it came to effectively utilizing Malawi’s HMIS.

Moreover, the way the ranking was conducted lead to a couple of challenging factors. The ranking implemented worked best in terms of measuring performance when only percentage indicators were being used and there was data present. Using other ratios was challenging as the results were hard to analyse.

Another challenge with the ranking that needs to be addressed is how N/A scores, (organisation units not providing the service of the indicator) should be presented in the table, how it should count towards the total score and how such information can be retrieved from DHIS2. The ability of inverting opened up for non-reporting organisation units to get an unfair perfect score. Weighting to balance out different indicator types did not work well with the formula used in the app. The basis of the coloring in the LTA was often viewed as unfair because it was a strict division.

Before it is possible to effectively integrate the use of the LTA in existing HMIS routines and practices, further strengthening of Malawi’s HIS and HMIS is needed. An immediate suggested measure to include in the strengthening process is to clean up the indicator system. This would involve the identification and deletion of all training indicators, legacy indicators no longer in use and duplicates. While doing this it would also be beneficial to review the definitions of all indicators to make sure they use the correct data elements in their calculations. To prevent these issues from recurring, increasing health workers understanding of data usage and collection should be pursued as well as the addition of a dedicated training server.
In the future the application could benefit from being tested more extensively to explore its usages, gathering information that could contribute to further development. When it comes to further development specific to the LTA we have set a couple of extensions and improvements that could contribute to the utility and usability of the app. Generalizing the scoring formula to support a combination of indicators with different ratios would be advantageous as it would allow for a wider set of data to be used in the league tables. This should include a smarter solution for taking weighting into consideration to support different ratios being used. Also, there should be implemented a generalized way to invert scores, supporting other data types than percentage.

Further research on ways of utilizing colors in the tables should be done as colors proved to have much potential in helping data analysis as well as motivation and stimulating competition. We suggest using targets to set colors in addition to how the targets should be set. Especially for the LTA, it should be researched how targets can be fetched in conjunction with indicators. Lastly, the matter of N/A scores should be addressed. More specifically, how such information can be retrieved from DHIS2, how N/A scores should be presented in the table and how it should count towards the total score.
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Appendix

Link to bitbucket repository: https://bitbucket.org/tronerud/league-table-application