Dashboards and information overload

Challenges and design guidelines for Health Information Management Systems in developing countries

Joakim Ikiza Amundsen

Thesis submitted for the degree of
Master in Informatics: Programming & Networks
60 credits

Department of informatics
Faculty of mathematics and natural sciences

UNIVERSITY OF OSLO

Spring 2019

Dashboards and information overload

Challenges and design guidelines for Health Information Management Systems in developing countries

Joakim Ikiza Amundsen

Dashboards and information overload

http://www.duo.uio.no/

Printed: Reprosentralen, University of Oslo

Abstract

Health information dashboards are software tools utilized to monitor the performance of health programs, through collections of visualized information within a single screen. Health organizations in developing countries are increasingly adopting these software tools to facilitate well-informed decisions and improved information use. However, what type of presentation formats, the amount of information, or required interactive features a dashboard must possess to facilitate evidence-based decision-making is not yet fully understood. Too much information or interactivity provided by the application will overwhelm the user, resulting in the problem of experiencing information overload. This will ultimately impact decision-making, work efficiency, and productivity. Effectively making the dashboard working against its intended purpose.

This thesis looks into the health information software DHIS2 and its dashboard application. The objective was to explore essential design features that dashboards must facilitate to enable evidence-based decision-making, without causing information overload to users situated in developing countries. Motivated by how a health organization supported decision-making with integrated discussion forums and decision guidelines with the dashboard, I attempted to assess how it could reduce users chance of experiencing information overload. By observing the usage of the dashboard to monitor the performance of two health programs in Zimbabwe, I evaluated limitations and potential improvements.

Findings gathered through a qualitative action case study indicated that assigning decision guidelines to specific visualizations presented by the dashboard reduced the users chance of becoming overwhelmed with information. While the discussion forums produced both positive and negative effects. To address the information overload problem emerging from dashboards, they must provide simple presentation formats and support details on demand through interactivity.

Acknowledgements

First of all, I would like to thank and express my deepest gratitude to my supervisor Petter Nielsen for guiding me through this thesis with invaluable feedback and discussions. I would also like to thank my supervisor Scott Russpatrick for initiating this study, sharing knowledge and ideas as well as arranging meetings.

Secondly, thanks to Cristina Lussiana and Martin Dale at Population Services International's global offices in Kenya for allowing me to conduct this study with their health organization.

Thanks to Aleck Dhilawayo and Jabulani Mavudze at Population Services International in Zimbabwe and their entire branch office for their hospitality and co-operation during my fieldwork.

Lastly, thanks to my family, friends, and HISP UiO for their support and encouragement.

Contents

List of Figures

List of Tables

Abbreviations

API Application Programming Interface.

BI Business Intelligence.

D2A Data-To-Action.
DHIS2 District Health Information Software version 2.

HISP Health Information Systems Programme.
HMIS Health Management Information System.

IS Information System.

MIS Management Information System.

NGO Non-Governmental Organization.

PSI Population Services International.

REST Representational State Transfer.

UN United Nations.

WHO World Health Organization.

Chapter 1

Introduction

1.1 Motivation

Health organizations relies on Health Management Information Systems (HMISs) to facilitate evidence-based decision-making (Lippeveld et al., 2000, pp.2-3). As HMIS have increasingly become more successful in collecting data, presenting the information for data-use has become a bigger issue. Along with all the information made available, information overload has become increasingly recognized (Senyoni and Braa, 2017). Symptoms of experiencing information overload are described as reduced quality in decision-making and work-efficiency, to name a few (Wilson, 2001). To address the information overload problem, organizations are increasingly adopting interactive visualization tools such as dashboards applications (Senyoni et al., 2019). These are software tools designed to centralize important visualized information to monitor performance and facilitate well-informed decisions. However, too much information provided by the dashboard can potentially result in it overwhelming the user and working against its intended purpose.

This thesis was motivated by how a non-governmental (NGO) health organization applied the generic health information software DHIS2 and its dashboard application. To address the problem of dashboard users experiencing information overload; the NGO standardized information use, by assigning decision rules to specific visualizations presented by the application. These decision rules offered a quick assessment of possible actions to take, depending on the visualization's current status. Coupled with an integrated discussion forum available in the dashboard; collaborative efforts were communicated to interpret the information and assist with decision-making. However, the need for these applied work processes and features suggested that the health information dashboard had become a source of information overload in itself.

During my thesis progression, I took part in further development and improvements of DHIS2's dashboard application. I then traveled to Zimbabwe and observed how the health organization applied the dashboard to monitor the performance of two health programs related to HIV and male circumcision. By observing how users interacted with different dashboard layouts and presentation formats, I investigated how the software tool could facilitate decision-making without overwhelming the users with information.

Information overload is not a new phenomenon, but limited research has been conducted in the context of HMIS, especially within developing countries. Further, the literature on dashboards and their essential design features have failed to keep up with the rapid advance of information technologies. With this thesis, I offer insight on how a dashboard can facilitate decision-making without users experiencing information overload. This involves applying simple graphical presentation formats and supporting interactivity that enables details on demand. By following specific design guidelines and utilizing integrated discussion forums, health information dashboards can facilitate decision-making at different levels of the health system's hierarchy for users with different skill-sets.

1.2 Dashboard Applications

Dashboards have been viewed as one of the most useful analytic tool capable of facilitating evidence-based decision-making (Negash and Gray, 2008, p.175). However, clear gaps in the literature have been identified in areas such as the definition of a dashboard, how managers should design their dashboard, and its overall benefits (Pauwels et al., 2009). In developing countries, dashboards have shown to improve data quality through timely reporting and consistent data collection for routine health data (Etamesor et al., 2018). As data collection methods are increasingly improving, dashboard users are required to keep up with more information than previously possible. To make use of all the information; dashboards encode data into graphical representations such as charts. However, presenting too much information can overwhelm the user.

WHO have published best practice guidelines for dashboards intended to monitor health programs such as HIV, malaria, and immunization, among others. These dashboards are recommended to contain visualizations ranging from 2 to 24[1]. Stephen Few (2006, p.39), a highly regarded dashboard designer, strongly emphasize in his book for dashboard design that the application should not display more than the amount that fits the screen boundary. While other renown software vendors such as Tableau recommends a maximum of 3 (Tableau, 2019). There exist many recommendations, and as such, various dashboard solutions.

In addition to visualizations, the dashboard should offer some degree of interactivity to encourage data exploration and assist the interpretation process. However, too much interactivity and feedback can affect the information load and impact decision-making (Wilbanks and Langford, 2014). The application is regarded as a solution to the information overload problem by centralizing important information (Senyoni et al., 2019; Al-Hajj and Pike, 2013). However, information overload is also viewed as a constraining factor to draw out its fullest potential (Wilbanks and Langford, 2014).

[1] See WHO's training instance of DHIS2 with dashboard templates: `https://who.dhis2.org/demo`

1.3 Information Overload

Eppler and Mengis (2002) reviewed information overload across various management disciplines including Management Information Systems (MISs). Through their study, the authors noted that the performance of an individual correlates positively with the amount of information he or she is exposed to, but only to a certain point. Beyond that point, if further information is provided, the performance and decision accuracy will rapidly decline. The classic definition describes that the phenomenon occurs when the information's processing requirements exceed the individual's processing capacities (ibid.).

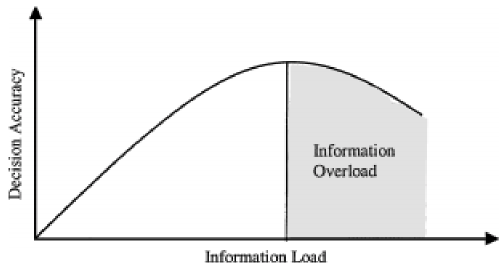


Figure 1.1: Correlation between decision accuracy and information load (ibid.).

It is necessary to emphasize that research related to decision-making in public health is challenging as the process involves multiple factors (e.g., political, budget constraints, special interests) (Lippeveld et al., 2000, pp.36-37). However, information overload have shown to cause other dysfunctional consequences such as *lack of critical evaluation*, *loss of control over information* and *higher time requirement for information handling.*

Potential countermeasures

Multiple different factors can produce information overload when monitoring the performance of health programs in developing countries, but potential solutions have been proposed. These are solutions that can be applied at the organizational level as well as within the dashboard. The most relevant within the context of this thesis are countermeasures proposed by Eppler and Mengis (2002):

Table 1.1: Proposed solutions for information overload.

Task and processes:	Organizational level:	Information technology:
• Defining standardized operating procedures and decision rules.	• Reduction on the sources of information. • Providing incentives directly related with decisions.	• Reduction of alternatives in decision support systems.

1.4 Research Context

This thesis is written in collaboration with the Health Information Systems Programme (HISP). HISP is a global research network aiming to improve health in developing countries through the usage of HMIS. One of HISP's core projects is the development of District Health Information Software version 2 (DHIS2). The software is utilized primarily within the health sector and offers reporting, analysis, and dissemination services of health data (Braa and Sahay, 2012a). An important DHIS2 application for managers and decision-makers is the health information dashboard, a software tool used to centralize multiple indicator-based visualizations (e.g., charts, tabular data, maps). It is intended to enable evidence-based decision-making by monitoring the performance of health programs on a larger scale.

1.4.1 Monitoring health programs in Zimbabwe

The context of the research involving the dynamics between dashboard design and information overload was conducted in collaboration with a health organization called Population Services International (PSI), a global NGO dedicated to improving health through the usage of HMIS. Acknowledging the increasing sources of information that decision-makers were required to keep up with, countermeasures had been implemented. The health organization applied DHIS2's dashboard to monitor health programs with visualizations ranging up to 30 per dashboard, while each health program, in turn, could range up to over 60 different dashboard instances. This study observed the health organization's conduct related to two health programs in Zimbabwe: HIV and male circumcision.

Through DHIS2's dashboard, decision-makers utilized integrated discussion forums. Coupled with each visualization within the dashboard, members at the strategic level of the health system communicated and assessed its values. Additionally, while monitoring the performance of a health program, defined standardized decision templates had been assigned to each visualization, as shown in Fig 1.2 on the next page. These applied countermeasures have been proposed as solutions to reduce the chance of experiencing information overload.

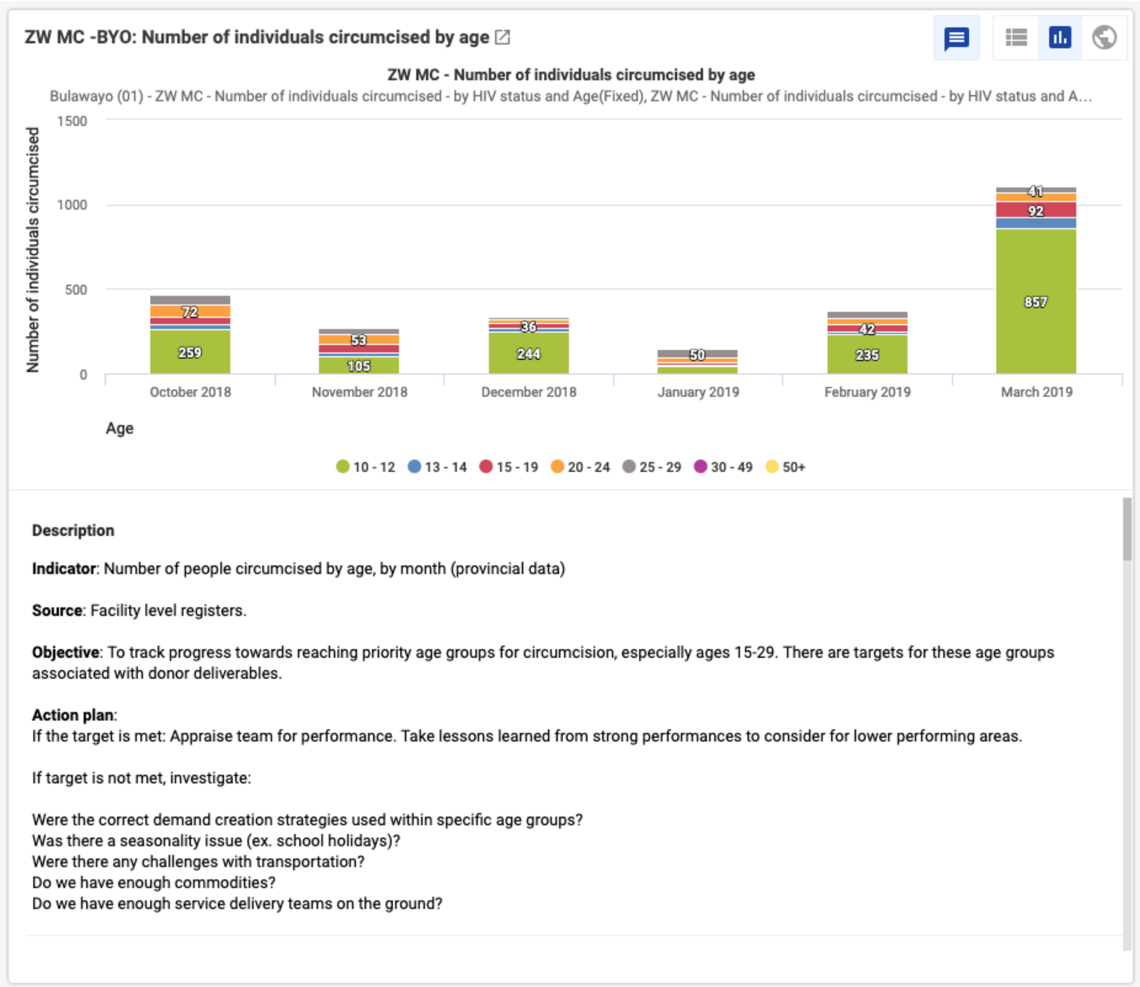


Figure 1.2: Descriptive label with decision rules and incentives.

As shown in Fig 1.2, multiple potential causes must be investigated before arriving at a decision. Due to the reality of limited economic resources and human capacity in developing countries, the margin of error is small before a health program becomes a failure. Thus, decision-makers are required to base their actions upon information that may not be reflected clearly through the visualizations.

Health information dashboards can potentially contain vast amounts of information that already exceeds human capacity for information processing. Further, factors such as the *information quality* and *uncertainty of information* can contribute to users experiencing information overload (Eppler and Mengis, 2002). These are realities that the software application must address, both through its design and its interactive features such as discussion forums to contextualize the quantitative data further.

1.5 Research Aim

The study aimed at exploring essential design features a health information dashboard must facilitate to enable evidence-based decision-making without causing information overload. The health organization that monitored health programs in Zimbabwe argued that their applied work processes addressed the information overload problem. This study attempted to identify design guidelines such as the number of visualizations, appropriate presentation formats, layout composition, as well as the value the discussion forum and decision templates offered to the health information dashboard.

1.6 Research Questions

To gain an understanding of how dashboards, a decision support tool, can maintain a balance between information load and information use; the following research question was asked:

- What essential features must a health information dashboard facilitate to enable evidence-based decision-making, without causing information overload?

In order to answer the research question and capture the scope of the study, I performed the following steps:

1. Investigated literature on the causes and solutions for information overload applicable for dashboard applications.
2. Established agreed concepts and principles on dashboard design.
3. Investigated literature on the process of interpreting visualized information.
4. Performed a quantitative and qualitative analysis of the health organization's dashboards.
5. Conducted an interpretive action case study involving interviews, surveys, and observation of management personnel utilizing DHIS2's dashboard application. With interventions towards dashboard design and applied presentation formats.
6. Performed a case experiment with two focus groups and one control group, involving observations on the usage of different dashboard layouts, presentation formats, and the application's interactive features.

Answering the research question would provide insight towards how a health information dashboard can facilitate information use and balance the amount of information required to be processed in large scale health programs. Ultimately, the research question would be answered by offering a set of essential features a health information dashboard must facilitate. These features are specifically aimed at addressing the information overload problem that can emerge from dashboard applications.

1.7 Thesis Structure

- **Chapter 1 - Introduction:** Describes the motivation for this thesis, offers a brief introduction with the research context, research aim, and research questions.
- **Chapter 2 - Background:** Provides history and technical background on DHIS2, an overview of Zimbabwe's current status and background on Population Services International.
- **Chapter 3 - Literature Review:** Presents relevant literature for information overload, dashboard design, and the process of interpreting visualized information.
- **Chapter 4 - Research Methodology:** Briefly illuminates applicable research methods relevant to the study. Presents the applied research method and describes the research approach.
- **Chapter 5 - Empirical Findings and Analysis:** Presents the findings from an analysis of the health organization's dashboards and the performed action case study in Zimbabwe.
- **Chapter 6 - Discussion:** Offers a discussion on the research topic in light of the findings, literature review, and answers the research question.
- **Chapter 7 - Conclusion and future work:** Provides a conclusion of the conducted action case study and offers suggestions for future work with research directions.

Chapter 2

Background

Before continuing with the research objective, background on DHIS2, Zimbabwe and Population Services International is presented. The first section provides a brief history of the emergence of DHIS2, with an overview of the software's technical background. The second section describes the dashboard application, its interactive features, and available presentation formats. The third and last section provides a brief overview of Zimbabwe's status, PSI and their involvement within the health sector through the usage of DHIS2.

2.1 District Health Information Software

2.1.1 Historical Background

DHIS2 is coordinated by HISP, a global research network initiated by the Department of Informatics at the University of Oslo. HISP is funded by various renowned health-related organizations like NORAD and WHO (Braa and Sahay, 2012a). The initiative started in 1994 between the University of Oslo and the University of Western Cape after the South African apartheid. At that time, the software covered three health districts in Cape Town intending to provide basic information to health workers, such that they, in turn, could provide improved health services to the South African locals. The project development sought to address the extreme fragmentation caused by the segregated health systems that divided humans into racial groups, through a decentralized system of health districts (Braa and Sahay, 2017).

The development process emphasized empowering local management with easy access to health data and analytic tools. After a largely successful implementation in South Africa, the system got quickly adopted by other developing countries. In its early stage, DHIS version 1 was built on top of a Microsoft stack. Excel was used as a reporting tool, and Microsoft Access operated as a database at the back-end.

In 2006, DHIS version 1 was re-built and upgraded, now implemented with the *Java* technology and a relational *SQL* database. The development was performed by students at the University of Oslo and further improved by developers in India and Vietnam (ibid.). Utilizing the Java technology, the system based itself on a free framework using as little dependencies as possible, removing the necessity of additional cost. Furthermore, the Java framework is platform independent and uses object-relational persistence system, which implies that the system will run on any operating system and most database management systems (Øverland, 2006).

Today, DHIS2 is the world's largest HMIS platform as it is utilized in over 60 countries[1]. Taking NGO-based programs into consideration tallies DHIS2's usage in more than 100 countries. Through HISP's action research and educational strategy, students from the health and informatics field have been involved and co-operating with improving health information systems in developing countries. DHIS has provided the empirical basis for students to research and build masters and Ph.D. theses, while also providing a constant stream of evolutionary improvements to the software (Braa and Sahay, 2017).

2.1.2 Technical Background

Data Elements

Recognizing that the environment in developing countries is in constant change required developers of DHIS2 to create a highly flexible metadata model. This approach has been a key factor related to the success of the software (Braa and Sahay, 2017). Data elements in DHIS2 can be defined and modified through the user interface without the need for programming. As such, collected data can be stored and virtually represented as an arbitrary value. The stored data is handled as a singular unit, facilitating easy modification or re-arrangement of potential analytic queries (ibid.) The data is represented through a three-dimensional principle of *what*, *when*, and *where*, where all three dimensions make up the data value:

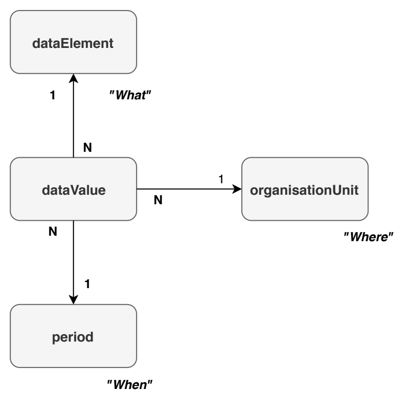


Figure 2.1: The three dimensions of DHIS2 data values.

[1] See `https://www.dhis2.org/about`

As the software requires to capture all potential geographical locations within a developing country implies that the *where*, or organization unit, encompasses health-related facilities from small and simple clinics, to major hospitals, and even zones. This means that in DHIS2, geographic locations such as provinces, or districts, are all represented as an organization unit. A given unit has a unique identifier with arbitrary attribute values and pointers to its parent or child unit. The hierarchy ultimately represents the geographical domain of the HMIS:

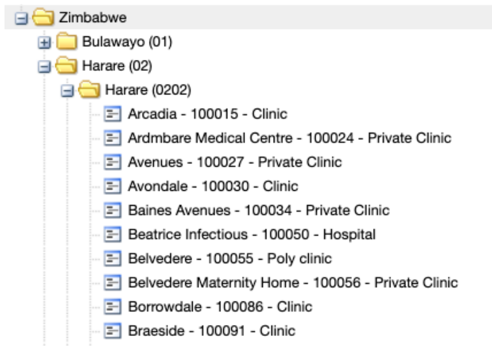


Figure 2.2: One of many organization units in PSI's DHIS2 instance.

The *when* is a date/time attribute that can be fixed or relative, enabling the possibility of relating collected data elements to a specific period. The *what* is the most important and fundamental building block of a DHIS2 database and is the data element that explains what is being collected. The value it represents is defined by the DHIS2 configurator and, due to the flexible manner of the metadata structure, can be any arbitrary value given by its definition through the user interface (DHIS2, 2019b).

Indicators

The software facilitates evidence-based decision-making by utilizing indicators. An indicator is also a fundamental building block for DHIS2 as it promotes actionable data-use when working with aggregated statistics. It is also viewed as a data element but is distinguishable in the sense of it being a formula-based value instead of a raw count. An indicator is typically a mathematical formula in the form of a numerator and denominator. The numerator and denominator can, in turn, be a mathematical expression consisting of multiple data elements, constants, organization units or numeric operators. Indicators represent perhaps the most powerful data analysis feature in DHIS2 (DHIS2, 2019a).

Legends

DHIS2 offers users the possibility to create legends to provide visual cues in visualizations showing tabular data or geographic data points. These metadata objects can be defined with a set of values ranging from low and high with a corresponding color. Legends can, in turn, be assigned to an indicator such that the defined color provides the user with a visual cue in terms of a visualization's relative performance, should the calculated indicator value exceed the defined ranges. The legends functionality is not supported in formats of type charts.

Analytic Requests

Both native and third-party applications communicate with the back-end through a REpresentational State Transfer (REST) architecture. Briefly summarized, RESTful architecture is defined by software that follows a set of *six* constraints where one is optional. The most fundamental principle of REST is that the API is targeted through resources with uniform interfaces (Masse, 2011). Applications that render information retrieved from the back-end server communicates through the REST API via the web with CRUD operations[2]. This is how data-driven analysis is performed, through communication with the API's *analytics* resource:

$$https://baseurl/api/31/analytics$$

The endpoint allows network requests that queries aggregated data belonging to the what, when, and where dimension (DHIS2, 2019c). Through the visualization tools, users can customize requests by specifying which dimensions they want to aggregate, choose a filter parameter, and ultimately receive the data that is calculated by the back-end server. Upon generating a visualization, the back-end responds to the web application through the API, with results based on the request's parameters. The response is in turn fed into the visualization tools that ultimately generates the given format.

This thesis will not go further into the details of the metadata model and the possible variations available in DHIS2 as it is beyond the scope of the context. The remaining sections will instead further focus on the dashboard application and provide a summary of its visualization tools.

[2]Create, read, update or delete functions for persistent storage.

2.1.3 Front-End Architecture

DHIS2 comes with a generic Java back-end server, SQL database, and a set of native applications that are loosely coupled (Roland et al., 2017). The native applications include a web portal with bundled apps free and available for any DHIS2 user to utilize.

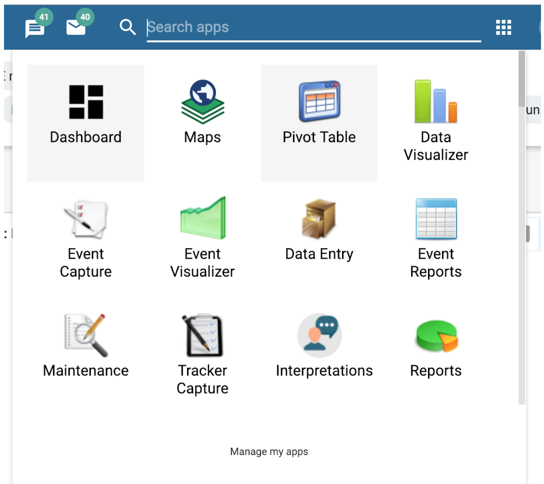


Figure 2.3: A portion of the native applications available in DHIS2.

As of version 2.31, DHIS2 have upgraded multiple web applications that were implemented with pure *JavaScript*, to include the *ReactJS* library developed by Facebook. During my thesis progression, I was involved as a front-end developer with further development of the *Dashboard app*, *Data Visualizer app*, and the *Maps app*. These new applications built with the React library offered users improved interactivity, modern graphical user interfaces, and new features.

2.2 DHIS2 Dashboard

DHIS2's dashboard application has become highly customizable through the software's continuous development of open generification (Gizaw et al., 2017). This development process involves users acting as both customers and designers to identify and report local needs through participatory design, such that DHIS2's core developers can provide features applicable on a global level that serve a broader user group. However, despite its generic solution and a wide variety of use cases, the dashboard is utilized for the same purpose: Monitor performance to conduct strategic planning and facilitate evidence-based decision-making.

The dashboards can become quite large as health programs may cover an entire country. There is no limit on the number of visualizations it can contain. Its generic solution has focused on flexibility that can support innovation in the local context to customize it further for improved usability. However, this flexibility can produce challenges that require competency for designers such that it serves useful in the local context (Nielsen, 2017). Without sufficient knowledge on dashboard design, its flexibility can result in users creating dashboards that work against its intended purpose. The tension between developing a design that can facilitate customization, and design that reduces the chance of experiencing information overload, by limiting the possibilities, are challenging to realize.

2.2.1 User Interface

The visualizations imported to the dashboard can be an object created by an external application, or an object created by one of DHIS2's visualization tools. Each dashboard can be labeled with a descriptive name with additional detailed information to further contextualize its collection of indicator-based visualizations. The dashboard has two modes in view or edit, where edit enables users to reconfigure their dashboard by adding or removing objects, or reorganizing the structure of its contents. All user-designed dashboards can be shared with other DHIS2 users after being configured.

As the dashboard can contain multiple objects of aggregated data, a filter mechanism based on organization units is supported. To encourage balance on the information load; multiple dashboard instances can be created. These dashboard instances can be organized with collections of visualizations from districts, facilities, countries, or other arbitrary categories. The view mode, as shown in Fig 2.4 below, displays the dashboard according to the configured layout and provides users with an extra toolbar of buttons attached to each visualization.

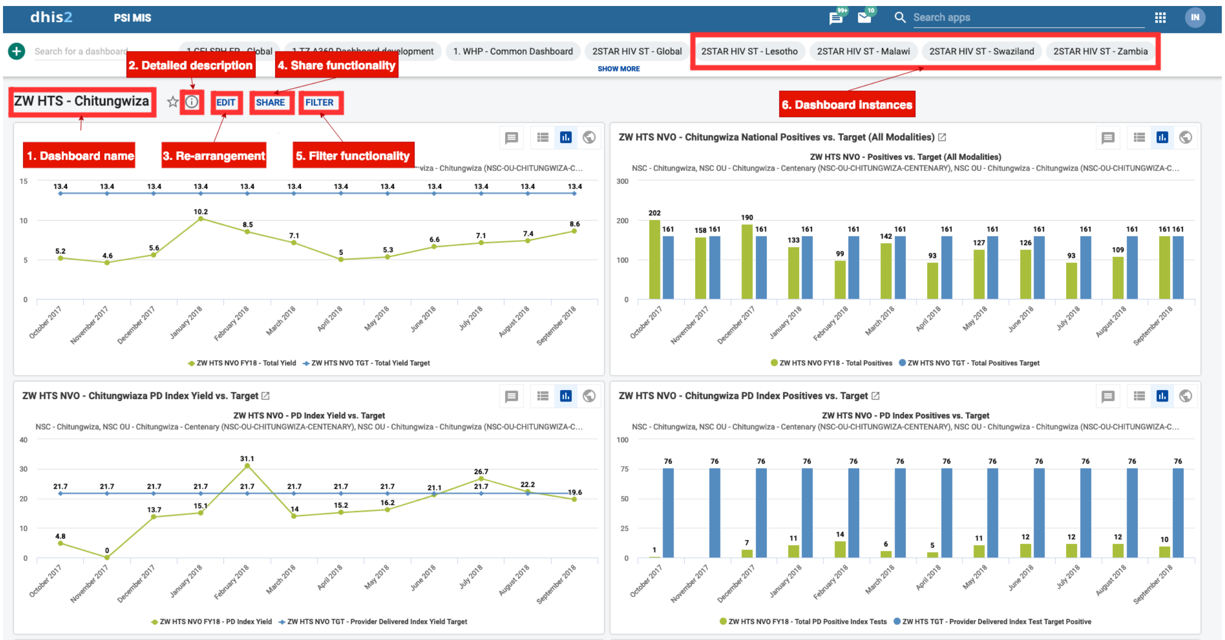


Figure 2.4: The dashboard in view mode.

Grid Layout

As the dashboard is implemented with React means that each visualization is rendered into separate components. To organize the arrangement, a third party library called *React Grid Layout* separates the components into a grid system. The grid can be manipulated by the user such that each component's height and width are structured according to the user's preference. To further organize visualizations into groups, an empty *spacer item* can be added to increase the space between visualizations.

Interactive Features

The toolbar buttons, as shown in Fig 2.5 below, enables a degree of interactivity by toggling the visualizations through different presentation formats or redirection to specific visualization tools. The available presentation formats include tabular, charts, or geographic maps with data-points. The last interactive feature enables users to expand a drop-down panel to engage in discussion.

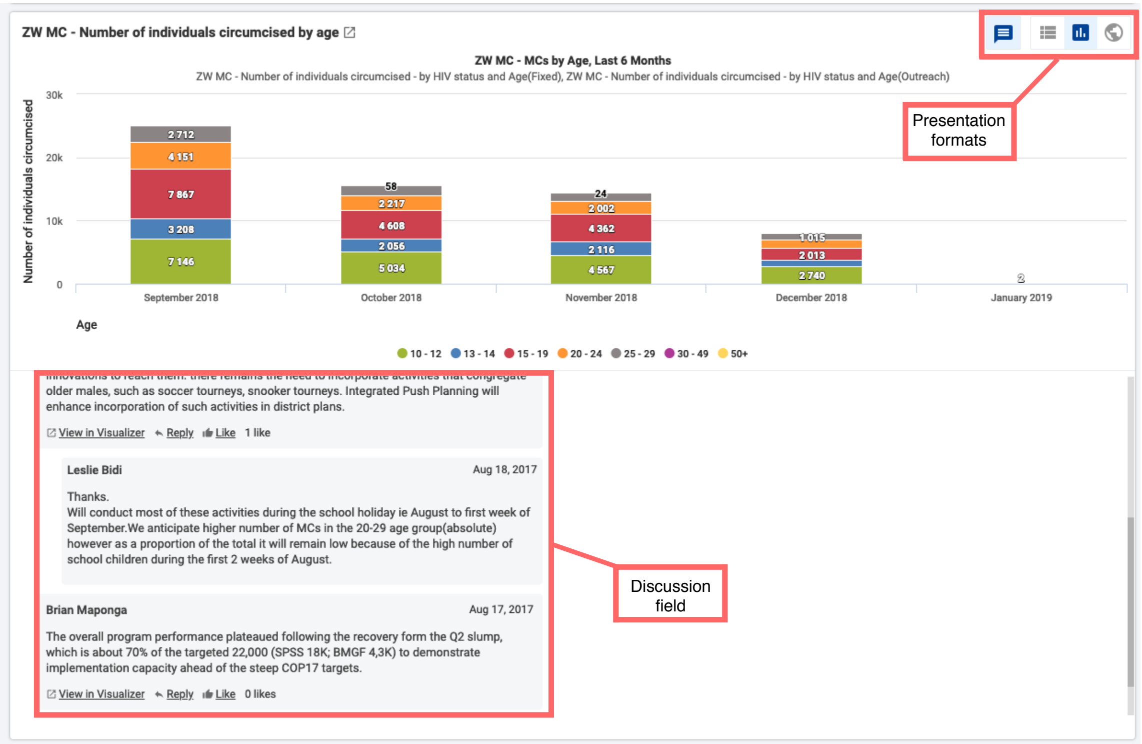


Figure 2.5: Interactive features for individual visualizations.

Integrated Discussion Forum

Through the dashboard, decision-makers and managers within the health system can communicate their effort and provide input on the aggregated data. The discussion forum serves as a tool to centralize valuable information related to the performance of health programs. Through dialogues, colleagues can periodically offer insight on actions that can or have been taken as well as identifying incidents related to data quality. This feature enables users to document their interpretations, post periodic updates, and permanently store it with the visualization. In DHIS2, this capability is termed the *interpretations feature*:

$$https://baseUrl/31/api/interpretations$$

As shown in Fig 2.6 below, visualizations retrieved from the back-end server can contain information that could potentially be lost through meetings, e-mails, or other mediums involved in an organization's work processes. These interactive features assist managers and decision-makers to interpret the information to make well-informed decisions.


```
- interpretations: [
   - {
        lastUpdated: "2018-06-17T14:50:32.735",
        id: "aPiukE4CHzf",
        href: "https://staging.psi-mis.org/api/25/interpretations/aPiukE4CHzf",
        created: "2018-06-12T14:16:33.420",
        name: "aPiukE4CHzf",
        displayName: "aPiukE4CHzf",
        publicAccess: "--------",
        type: "CHART",
        externalAccess: false,
        text: "Bulawayo fell short of reaching the monthly target in May because the schools were reluctant to
        release schools boys for VMMC as there are involved in different sporting activities, we have since lined
        up a number of Mr Smart Fun Days to target the out of school males and we are in the process of engaging
        with schools to support their sporting events and get an opportunity to circumcise those that are not
        involved in sports",
        likes: 1,
      + user: {…},
      + chart: {…},
      + likedBy: […],
        translations: [ ],
      - comments: [
         - {
              lastUpdated: "2018-06-12T14:20:43.234",
              id: "vAxALvTpPb0",
              text: "Well noted, please indicate your requests for additional resources. ",
            + user: {…}
           },
         - {
              lastUpdated: "2018-06-12T14:21:11.291",
              id: "fGYikqamBnW",
              text: "Kindly share how you have managed to set up high performing teams in Bulawayo province",
            + user: {…}
           },
         - {
              lastUpdated: "2018-06-12T14:30:01.354",
              id: "Nl4K4gTA9JC",
              text: "Perhaps your next step would be to have an average of clients done on a single MR SMART
              FUN Day and then work on how many of these events you might need. Also in view of your high
              performing teams.",
            - user: {
                 id: "LY7R0cxIJyR",
```


Figure 2.6: JSON data for a stacked bar chart containing interpretations.

2.2.2 Presentation Formats

Generating a visualization in DHIS2 may be of value to other users. As such, saving the graphical representation will store its configured dimensions and enable sharing of the presentation format by referencing a unique identifier stored in the data warehouse. It can then be imported to the dashboard, downloaded to a local folder or exported to other applications. In DHIS2, charts are rendered by the third party JavaScript library *HighCharts*. Tabular formats are rendered by DHIS2's internal JavaScript library *d2-analysis*. The dashboard is reliant on the visualization tools to generate graphical representations of collected data.

The visualization tools offer drill-down features. Drilling on aggregated statistics means that users can, for instance, create a table with aggregated data within the *last quarterly year*, and drill-down to the last month or last week. With organization units, decision-makers can create spreadsheets with an organization unit that represents the whole country and drill-down to the specific cities or facilities that indicates deviation or any values of interest.

Tabular data

Tabular data are generated through DHIS2's *Event Reports* and *Pivot Tables* application. It enables DHIS2 users to work with spreadsheets of all available dimensions displayed as numeric values. In these visualization tools, aggregated data can be organized into rows and columns with a filter dimension. The Pivot Tables and Event Reports app targets the *analytics* resource to display aggregated statistics in unique ways defined by the user. For instance, by specifying a group of organization units as a dimension, users can perform aggregated analysis of metadata grouped as *Clinics*, to offer more pinpointed aggregation and analysis.

Charts

Charts are generated by DHIS2's *Event Visualizer* and *Data Visualizer* application, by applying the HighCharts JavaScript library. Charts are often utilized to ease the understanding of quantitative data, and the relationship between the data points as graphical representation can be read faster than tabular formats. HighCharts generates the visualization on the client-side, making the library a suitable tool for slow and intermittent connection that occurs in developing countries. The specific formats that DHIS2 offers are:

- Column & bar chart.
- Stacked column & stacked bar chart.
- Line chart.
- Area chart.
- Pie chart.
- Radar chart.
- Gauge chart.

Maps

DHIS2 has its own Geographic Information System (GIS) application that renders data points on geographical maps. With the GIS app, data in the form of counts from facilities, districts, or data captured through events can be rendered and represented through thematic layers within a given country. The application is integrated with Google Maps API, which enables satellite imaging, hybrid or default visualizations.

2.3 Zimbabwe

Figure 2.7: Map of Zimbabwe.

Zimbabwe is a country located in the southern part of Africa. The population is registered to roughly 16 million people, with 16 official languages where English is one of them and commonly used. The country has a Human Development Index score of 0.535, placing it as the 156th out of 189 at the lower parts of least developed countries on Earth (UN, 2018). In 2006, an association of doctors called for assistance to improve health services as life expectancy was decreasing, registering the average man to live to 37 and women to 35[3]. Due to the country's economic hyperinflation, the health system has more or less collapsed as major hospitals are unable to afford basic medicine and have shut down[4]. The population are experiencing diseases such as HIV, cholera, waterborne disease, and infant mortality to name a few.

The country has been affected by frequent protests and civil unrest due to the authoritarian regime of their past President Robert Mugabe the past two years. In 2017, Zimbabwe's President Emmerson Mnangagwa was appointed, and the country's status has arguably not seen any improvements in the standards of living. As hyperinflation and corruption have persisted through the governmental changes, the country is facing considerable challenges and remain as one of the poorest developing countries in the world.

The nonprofit global health organization PSI has collaborated with Zimbabwe's Ministry of Health to improve health with local and international partnerships. The NGO focuses on HIV/AIDS prevention through measures such as condom distribution and HIV testing services. In recent years, these health programs, among others, have been ongoing to empower families to lead healthier lives (PSI, 2016).

[3]See `https://www.smh.com.au/world/in-zimbabwe-life-ends-before-40-20060410-gdnc3b.html`

[4]See `http://news.bbc.co.uk/2/hi/africa/7714892.stm`

2.4 Population Services International

PSI applies DHIS2 and have integrated the interpretations feature with their work processes. The organization adopted DHIS2 in 2011 after using different MISs across different countries. Their legacy systems involved makeshift solutions with the use of Microsoft Excel, Microsoft Access, and various other tools. As a result, data engagement and data-use were tedious in order to enable evidence-based decisions due to inconsistencies and complexity. PSI chose to migrate over to DHIS2 due to its flexible ability to collect, manage, and visualize information. As one of the earliest NGO adopters of the software, the organization has become experienced DHIS2 users with substantial knowledge of its features and limitations (PSI, 2016).

2.4.1 PSI's utilization of DHIS2

At the operational level, PSI has field workers collecting data in rural areas with paper-based forms, cell phones, and tablets. Furthermore, the NGO have clinics, hospitals, and pharmacies that collects patient-data in the larger districts. At the strategic level, Monitor & Evaluation (M&E) personnel evaluates the collected data through the health information dashboard and visualization tools, and communicates their assessment through the interpretations feature with program managers and evidence directors. Potential actions that are suggested by the M&E workers based on the operational level's conduct, as well as strategic decisions higher up in the hierarchy are communicated through DHIS2's integrated discussion forums.

Experiences of information overload

The organization utilizes one global DHIS2 instance across their respective countries, which allows the containment of vast amounts of health information data from different programs in one database repository. As the instance has increasingly obtained more information, information overload has started to become apparent. Members at strategic levels have been suspecting that users are viewing DHIS2 as a simple database. The average user views the platform similar to Microsoft Excel, where the main purpose is to insert values to store data. The NGO's vision is for its users to view DHIS2 as a data warehouse with the power of analyzing and acting on the stored data, through data collection and visualization tools. Before my case study in Zimbabwe, I traveled to Nairobi and spoke with the NGO's global director, which emphasized his view related to the true meaning of the platform:

> *"One thing that should come into mind when using DHIS2, is that the platform exists as an interface for acting on gathered data. Moreover, the interface should be utilized to provide a better health outcome for the average citizen. As users are being overloaded with information, I fear that we are becoming unable to use it sufficiently. PSI's DHIS2 users are gathering information just for the principle of collecting more. This is why PSI has started to introduce a framework for standardized procedures."*

2.4.2 Standardized Decision Templates

While monitoring health programs, the NGO applies a standardized framework termed *Data-To-Action* (D2A). It was developed to assist dashboard users to interpret data and assist with decision-making. The framework emerged after receiving feedback from users being overwhelmed with data when logging in to the dashboard or attempting to use the visualization tools. When being presented with the data, more questions were raised than answered through the analysis and visualization aspect for the average user. The NGO attempted to mitigate this with the D2A framework and integrate it with DHIS2 by assigning possible actions and procedures to take to specific visualizations. As shown in Fig 1.2 on page 5, the framework provided users with additional context with a detailed description of indicators, objective, and possible actions to take in order to get there. The NGO argued that the more clear the problem statement was, the more effective would the problem-solving process become. By inserting the contextual description right next to the visualized data, more insight was given to the user. In addition to this, immediate access to the integrated discussion forum promoted data engagement and discussion that could further bring enlightenment around the data.

Data-To-Action framework

The D2A follows a standardized framework of possible actions to dispatch. The objectives, justification, and possible actions to take follow the same pattern across the different visualizations related to the health program:

- **Indicators:** The applied indicator expression for the visualization.
- **Justification/Objective:** Description on what the intended accomplishment is.
- **Data inputs:** The data elements aggregated through the analytic calculations.
- **Action planning:** Potential actions to dispatch depending on the visualization's current values.

By assigning decision templates, PSI's visualizations explained the following to the user:

- What you were looking at.
- Where the information was coming from.
- Why you were looking at the analyzed data.
- And ultimately what type of action that should be performed.

Through standardized indicators; justification and actions across different programs could be defined, tracked, and acted upon. The NGO states that the users have reported to experience an easier approach as to what they should ask themselves when the targets are not met when applying the D2A framework. Quoting PSI's global director:

> *"The standardized procedure triggers the use of information already available in DHIS2 and promotes data engagement in a positive manner. It is almost unnecessary to use visualizations unless well thoughts are included. To build further upon this; it is required to rationalize how much visualization is needed in order to supply the intended effect of data-driven decision-making."*

Overwhelming health information dashboards

By tracking large health programs, users can potentially see up to 30 visualizations within a dashboard, whereas one or two will be thoroughly analyzed. The NGO argued that one cause of this, may be that the context around the data is missing with the visualization - it needs to promote interpretation and offer some sort of visual cue.

A big part of PSI's workflow involves downloading charts, and start a mail correspondence and engage in discussion through meetings. The arguments emerging from these aspects contain relevant insight which should be present with the data. As in, all things related *to* the data, should be *next* to the data. This way, the NGO argues, identifying the narrative around the visualizations and how it fits together will become more clear and easier to process for the user. The large dashboards have become intimidating to use due to the overwhelming amount of information. To promote further use of the dashboard; the discussion forums and decision templates are applied to address the information overload problem.

Chapter 3

Literature Review

The purpose of this chapter is to introduce the literature deemed appropriate to use as a theoretical background for this thesis. First, I present literature on the concept of information overload and how to address the problem. Next, I draw upon extant literature to define a dashboard and conceptual features that identify appropriate dashboard design, before continuing with the process of interpreting visualized data. Based on the findings, I provide recommendations towards how a health information dashboard can balance the information load while still facilitate evidence-based decision-making. I do this by proposing essential features, and recommended use-cases for the available visualizations in DHIS2. The chapter ends with a summary.

3.1 Information Overload

Research on the concept of information overload has been ongoing for quite some time. The problem has become increasingly recognized and more serious towards the end of last century (Noyes and Thomas, 1995). More information has been created in the last 30 years than the previous 5000 years (Ruff, 2002). As mentioned in section 1.3, there exists multiple names for information overload where *analysis paralysis* or *information fatigue syndrome* are some (Edmunds and Morris, 2000). The definitions varies from that it can represent a subjective experience of failure to process *"high quality"* or *"value-added information"* from the large amounts of information possible (Hall and Walton, 2004). Alternatively, the perception of the flow of information associated with work tasks being greater than one can manage effectively (Wilson, 2001). This thesis applies the classic definition stated in section 1.3 on page 3.

Similar to the concept's various names and definitions, multiple sources have been identified to cause information overload. Ruff (2002) stated that with little or no information, the individual would, in turn, have little or nothing to process and consequently, will make poor decisions. More information can lead to better judgment, but only to a certain point. Beyond this point, the information will effectively become noise, and reduced decision-quality and various other dysfunctional behaviors will eventually emerge (Hwang and Lin, 1999).

Overwhelmed by information

Eppler and Mengis (2002) reviewed literature on information overload across different management disciplines including MIS. The authors found reports highlighting that individuals were experiencing symptoms such as loss of control over information, negative effects on work, reduced efficiency, and reduced productivity. Interestingly, a limited amount of research on information overload within the context of HMIS was identified. Hall and Walton (2004) furthered this notion when reviewing information overload in health care but emphasized that the problem has become more apparent for health workers and that the underlying issues are critical to the health domain. Solutions such as information technologies with filter mechanisms were proposed to counter the individual health worker's finite processing capabilities.

Wilson (2001) published a paper related to the implications of information overload for the health care services and postulated that organizations need to institute policies on the appropriate use of technology, and the information it provides, to limit its damaging effects.

Klerings et al. (2015) identified three main factors related to why health care personnel experience information overload: lack of time, lack of skills to search effectively, and lack of integration of the information process into the workflow. As a technological solution, the authors proposed to integrate social media into the work process to cope with the overwhelming amount of information through co-operation.

Both individuals and organizations adapt and attempt to deal with this matter in different ways. Edmunds and Morris (2000) argued that technology is a tool to reduce information overload, not a driver, and that the key to realizing it is through improved information literacy. This thought was also somewhat concluded by Ruff (2002), as he argued that the solution to information overload is - more information.

Research framework for information overload

Eppler and Mengis (2002) classified *five* categories of causes and solutions, and *four* categories of symptoms related to information overload. As a contribution, a research framework related to information overload was offered. Ruff (2002) reiterated this framework and noted that since information overload is a complex matter, we must recognize the symptoms and admit that it is a serious problem. Further, that the framework serves as a cyclical measure and reminds us that no single factor will eliminate the information overload problem. It requires a continuous cycle of improvement and refinement. An illustration of the research framework is presented on the next page.

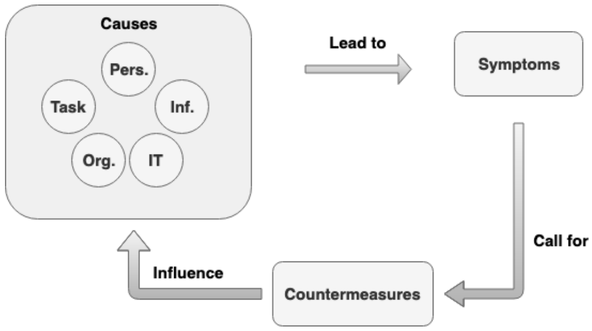


Figure 3.1: Information overload research framework proposed by Eppler and Mengis (2002).

The point at which the symptoms are experienced is not fixed. The stage of which an individual's or the organization's capacity is reached is influenced by factors such as motivation, education, training, organizational design, or the organization's specific conducts (ibid.).

3.1.1 Causes of information overload

As shown in Table 3.1 below, multiple instances in organizational settings have been identified to cause information overload. In the context of this study, several are relevant that can potentially originate from usage of the dashboard itself, or related work processes. Ruff (2002) emphasized that although the concept can be broadly deconstructed into five categories, it is important to note that information overload is the result of a combination of overlapping factors. He continued with expanding upon the work of Eppler and Mengis (2002) with additional causes. I summarize five of each category plausible to identify through the usage of HMIS and dashboards in developing countries:

Table 3.1: Causes of information overload.

Personal factors:	Information characteristics:	Task and process parameters:	Organizational design:	Information technology:
Limitations in the individual human information-processing capacity.	Uncertainty of information.	Task interruptions for complex tasks.	Lack of standard operating procedures.	E-mails.
Inability to maximize technology and software functions.	Information quality, value, half-life.	Tasks are less routine.	Collaborative work.	Introduction of more technology than is required.
Personal traits (experience, skills).	Diversity of information and number of alternatives.	Complexity of tasks and tasks interdependencies.	No internal communications strategy.	Overly complex/poorly designed information systems.
Decision scope and resulting documentation needs.	Overabundance of irrelevant information.	Simultaneous input of information into the process.	New information and communication technologies.	Vast storage capacity of the systems.
Creating monotony by performing same tasks in same way.	Ambiguity of information.	Inability to recognize when the task is complete.	Accumulation of information to demonstrate power.	Intranet, extranet, Internet.

3.1.2 Symptoms of information overload

In order to alleviate these causes, the symptoms must be recognized and countermeasures enforced for us to diminish or at least cope with the emerging issues (Ruff, 2002). Multiple symptoms can occur and be identified when users are potentially overwhelmed by the information a health information dashboard can contain. Four categories of relevant symptoms are classified as follows:

Table 3.2: Symptoms of information overload.

Limited information search and retrieval strategies:	Arbitrary information analysis and organization:	Sub-optimal decisions:	Strenuous personal situation:
Search strategies through information sets become less systematic.	Higher time requirements for information handling.	Decision accuracy/quality lowered.	Greater tolerance of error.
Identification and selection of relevant information becomes increasingly difficult.	Lack of critical evaluation.	Decision effectiveness lowered.	Sense of loss of control leads to breakdown in communication.
Limited search direction.	Loss of control over information.	Inefficient work.	Stress, confusion and cognitive strain.
Move from compensatory search patterns to non-compensatory search patterns.	Ignore information and be highly selective.	Potential paralysis and delay of decisions.	Demotivation.

3.1.3 Countermeasures for information overload

Multiple countermeasures is further proposed by Eppler and Mengis (2002) and Ruff (2002), these can be proactive or reactive. For a health information dashboard to facilitate decision-making towards users situated in developing countries, countermeasures must alleviate the information load that originates from the collection of visualizations. As the presentation formats have limitations in terms of how effective they convey information relative to each user, supplementary aspects can be included. Be it proactive countermeasures in terms of capacity building to prevent information overload from happening, or reactive in terms of filtering out information through the dashboard's interactive features once it occurs. The relevant countermeasures that this study focused upon are countermeasures that can be applied through the available features of DHIS2's dashboard, or by the users utilizing the application. These are summarized into five of each category on the next page:

Table 3.3: Countermeasures for information overload.

Personal factors:	Information characteristics:	Task and process parameters:	Organizational design:	Information technology:
Filter out information.	Visualization, the use of graphs.	Standardize operating procedures.	Offer decision-making models.	Integrate decision support systems.
Limit information by not thinking more is better.	Brand names for information.	Contextualize information by defining specific, clear goals.	Standardize communication.	Intelligent information management.
Training programs to augment information literacy.	Compress, aggregate, categorize and structure information.	Provide incentives that are directly related with decisions.	Prevent broadcasting of messages to all employees.	Offer technology training.
Improve personal time management skills and techniques.	Raise quality of information by defining quality standards.	Bring decisions to where information exists.	Coordination by goal setting, hierarchy and rules.	Information quality filters.
Systematic priority setting.	Simplify functionalities and design of products.	Install process enablers for cognitive support.	Reduce divergence among people through socialization.	Prefer push to pull technologies.

To enable its intended purpose of facilitating evidence-based decision-making, the choice of presentation formats and interactive features are important aspects.

Presentation formats and Interactivity

Diamond and Lerch (1992) found through their study on data presentation that applying graphical formats reduced the effect of experiencing information overload compared to text-based. Umanath and Vessey (1994) interestingly found through their study on cognitive fit theory with different display formats, that graphical representation reduced the effect of information load, but their results indicated that decision-accuracy increased when users were exposed with an increase of information load through tabular data.

Inconsistencies in decision-performance for specific tasks when choosing between different visualizations (e.g., tabular vs. charts) have been identified in previous research. The inconsistencies suggest that presentation formats and decision performance are not always influenced by the user's problem-solving skills, information processing capabilities, or the format itself (O'Donnell and David, 2000). As such, other aspects of the decision-making environment such as interactive feedback have been proposed as valuable directions to study in order to understand the nature of presentation formats, information load and decision-making (Saxena and Lamest, 2018).

These empirical findings suggest that the appropriate presentation formats are somewhat dependant upon the specific user and task. However, to further balance the information load regardless of the user applying the dashboard; interactive features that encourage data exploration have been proposed. Thus, multiple causes, as well as various countermeasures, can address the information overload problem that may emerge when users apply dashboard applications.

3.2 Dashboard Applications

Dashboards have become increasingly popular, but as mentioned in section 1.2, clear gaps in the literature have been identified in areas such as the definition of a dashboard, how managers should design their dashboard and its overall benefits (Pauwels et al., 2009). Yigitbasioglu and Velcu (2012) argued in their review of extant literature on dashboards in the organizational setting that, knowledge towards the extent of their effectiveness is limited in terms of what type of graphical user interface and visualization format works best for the given task or user. Moreover, as researchers view dashboards as one of the most useful analytic tool for decision-making (Negash and Gray, 2008, p.175), there is no agreement on standardized conceptual features describing what a dashboard should look like and what it should do. A limited amount of research articles provides tangible key principles related to dashboard design and guidelines in terms of how they can be evaluated (Wilbanks and Langford, 2014). The most notable author who provides such information is Few (2006) in his book for dashboard design.

3.2.1 Dashboard Literature

The term dashboard originates from the motor vehicle's dashboard, which displays the most important status and metrics that the driver needs to know. The purpose of a dashboard is to efficiently monitor the information needed to achieve one's objectives (Few, 2006, p.26).

Definition of a Dashboard

There is multiple definitions of a dashboard, this thesis will apply the definition stated by Yigitbasioglu and Velcu (2012), which builds upon the definition offered by Few (2006, p.26):

> *"A dashboard is a visual and interactive performance tool that displays on a single screen the most important information to achieve one or several individual and/or organizational objectives, allowing the users to identify, explore and communicate problem areas that need corrective action."*

The authors offered this revised definition as dashboards are becoming more interactive.

Features of a Dashboard

Two types of design features fit the definition of a dashboard outlined above (Yigitbasioglu and Velcu, 2012):

- **Functional features:** Relates indirectly to visualizations, but directly describes what the dashboard can do.
- **Visual features:** Refers to the principle of visualizing data, i.e., how efficiently and effectively information is presented to the user.

As dashboards are regarded as data-driven decision support systems providing information in particular formats, they should be evaluated according to their design features and the way users interact with them to make decisions (ibid.). Few (2006, p.31) classifies dashboards into three categories in terms of visual design roles and interactive capabilities:

- **Strategic:** Provides a high-level overview of the most important metrics on business performance and predictive measures for the future, with static snapshots of weekly, monthly or daily measures, with low interactivity and low context.
- **Analytical:** Static snapshots but with rich context through comparisons, showing extensive history. Analytical dashboards should contain drill-down features to investigate data further.
- **Operational:** Dynamic context with real-time updates. It applies simple display media. Often used at manufacturing sites monitoring valves or assembly lines.

Features in Public Health Dashboards

Previous research in the context of HMIS in developing countries have identified drill-down capabilities as a key functional feature to balance the information load (Concannon et al., 2019). Further, filtering mechanisms, and zooming in on specific visualizations have shown to reduce the chance of becoming overwhelmed, when interpreting presentation formats visualizing public health indicators. These interactive features can improve the interpretation process by increasing the user's information processing power (Zakkar and Sedig, 2017).

Additional functional features that have been proposed to improve the dashboards ability to facilitate decision-making is social interaction (Al-Hajj and Pike, 2013). Interpreting visualizations and translating the knowledge into well-informed decisions are often performed through social collaboration (Heer and Agrawala, 2008). The concept of integrating discussion forums to dashboards have been postulated as a valuable functional feature, as human interpretations contextualize the visualizations and subsequently deepens understanding (ibid.).

Simple graphical presentation formats have been emphasized as a necessary visual feature in order to not overwhelm the user with information (Senyoni et al., 2019; Al-Hajj et al., 2013). Additional information displayed when hovering the mouse over charts encourage data exploration (Zakkar and Sedig, 2017). By following simplicity, details on demand through interaction will reduce overall information load (Concannon et al., 2019). In order to convey simple graphical formats, visualizations are recommended to possess natural color coding. An example is to explicitly use green color to indicate good values, red to indicate bad and yellow for medium (Wilbanks and Langford, 2014).

To obtain well-designed dashboards, designers are required to work closely with the dashboard users and adhere to their needs (ibid.). Further, as appropriate presentation formats vary depending on the task and user, supporting multiple simple visualization types with color coding can improve the dashboard's ability to facilitate decision-making (Dowding et al., 2015).

To a large extent, well-designed dashboards depends upon its visual features through its visualizations. However, its functional features in terms of interactivity are also important when assessing its value. Ultimately, as extant literature have identified a lack of conceptual frameworks to evaluate dashboard design; how they can be evaluated depends upon the user, how they interact with the dashboard and the quality of their decisions.

Common mistakes and usability guidelines

Chrysantina and Sæbø (2019) examined user-designed DHIS2 dashboards that visualized public health indicators in Indonesia, and defined problem categories by applying common design mistakes presented by Few (2006). Stephen Few have worked with information technology in over 25 years, focusing on the practical use of data visualization that presents quantitative business information. In Table 3.4 below, the common mistakes and recommendations when designing dashboards for usability are summarized:

Table 3.4: Stephen Few's common mistakes and usability guidelines.

Common mistakes:	Usability guidelines:
• Providing inadequate context. • Using poorly designed display media. • Encoding quantitative data inaccurately. • Showing excessive detail. • Highlighting important data ineffectively. • Using meaningless variety. • Arranging data poorly.	• Organize information to support its meaning and use. • Maintain consistency for accurate interpretation. • Design for use. • Test design for usability.

3.2.2 Best Practice Guidelines

The literature provides a set of key design features in terms of dashboard functionality. However, guidelines describing dashboard layout and composition are arguably lacking. To establish a clear picture of what a well-designed dashboard should look like, I draw forth the best practice guidelines from the top four most popular Business Intelligence (BI) software vendors. Each vendor had some common principles on what the designer should look out for. As such, I will only reiterate the strongly emphasized guidelines as they agree with these principles while summarizing their unique practices.

Microsoft: Power BI

Microsoft recognizes that users will scan information from left to right and top to bottom. The most important visualization should, therefore, be placed at the dashboard's top left portion. Important elements should be larger than others or be included with clear bold text or arrow symbols. White space can help with sectioning the dashboard and clarify the story that the designer wants to convey, but it should not dictate the space-availability of the page. Elements can be aligned symmetrically or asymmetrically, as long as it is done intentionally.

At Microsoft, a well-designed dashboard is a page that is stripped of all clutter and unnecessary visual styling objects. This way, information is conveyed quickly and cohesively, supporting the data-to-ink ratio principle defined by Tufte (1983). Telling a story is emphasized to draw the user's attention from the starting point to the end. This is achievable by adding visual cues, bold text, borders, and colors. Furthermore, Microsoft states that the use of colors within the dashboard has shown that a higher contrast between colors increased the speed of comprehension. Lastly, some level of beauty is recommended as users will first react emotionally to a web page before logically processing information. Unorganized or confusing dashboards may affect cognitive processing (Microsoft, 2018).

Tableau

Tableau recommends limiting the number of visualizations per dashboard to a maximum of 3, as too many reduce visual clarity and overloads the user with information. Instead of adding more than the recommended visualizations, users should create additional dashboard instances. Further, dashboards with scroll-bars must be avoided as hidden visualizations make the user think that the information is unimportant. Designing a dashboard without a scroll-bar will also help with optimizing performance by reducing the number of network requests performed.

Designers should promote interactivity as it encourages exploration. Filter functions or highlight features that can draw forth given visualizations within dashboards will provoke the user to know more and continue with drill-down features. At Tableau, a well-designed dashboard is one that is well organized, with condensed information consisting of summaries and exceptions. The dashboard is oriented towards its audience and the objective of the story it tries to tell (Tableau, 2019).

Sisense BI

Sisense BI emphasizes that a good dashboard might look different for any given user. Nonetheless, it should tell a clear story and provide the relevant information in about five seconds. A well-designed dashboard makes the complex simple. It displays the most significant insights at the upper part of the web page, trends in the middle, and granular details at the bottom part. A dashboard should contain no more than 5-9 Visualizations.

Ideally, a dashboard does not contain a logo or header bar, as this takes up valuable real estate and will also be processed first by the user. If a logo must be present with the dashboard, Sisense recommends that it is placed at the lower right part of the dashboard. Lastly, as a rule of thumb of identifying a well-designed dashboard, the organization applies a five-second rule: Basic questions on the most important information must be answerable within 5-7 seconds (Sisense, 2018).

Figure 3.2: Inverted pyramid-scheme originating from journalism and how news reports structure their articles.

QlikView

QlikView recommends consistency with placements of visualizations; an organized dashboard will be easier for the eye when processed. The objects should be aligned horizontally or vertically and be uncluttered with irrelevant information. Users should not be able to switch between more than ten dashboards. Light color choices are recommended, emphasizing natural colors for cross-cultural consistency (Qlikview, 2011).

Summary of best practices

Summarizing the best practice guidelines from the renown BI software vendors; multiple design guidelines can be taken into consideration. A dashboard should tell a clear story, by arranging the most important visualizations starting from the top left and contextualizing the information with bold text or symbols. Users should be able to retrieve the most important information in about five seconds. Ideally, no user should be able to switch between 10 dashboard instances. Colors are recommended to provide visual cues, but unnecessary styling should be left out to balance the information load. If possible, a dashboard should support drill-down features and be able to move or hide the header bar and logo.

3.3 Interpreting Visualized Information

We have established that dashboards can be evaluated according to how users interact with its functional features, and how effective its visual features present information to the user. However, how this can be achieved requires knowledge on the concept of data visualization. After examining user-designed DHIS2 dashboards in Indonesia, Chrysantina and Sæbø (2019) observed poor visualization competence, and noted that knowledge of data visualization was one of the challenges related to optimal dashboard design. Thus, as dashboards draw its use from visualizations, applying inappropriate presentation formats can result in sub-optimal dashboards that can potentially be subject to misinterpretation, which affects the outcome of decision-making processes. Further, the information processing requirements can increase and subsequently produce information overload to the dashboard user. In the following section, by drawing upon data visualization and cognitive science, I will define what visualization is, how humans interact with them, and what concepts that can be applied to obtain effective visualizations.

Information Visualization

Ward et al. (2015, p.1) defines visualization as *"the communication of information using graphical representations."* Spence (2001, p.1) states that visualization is a *"cognitive activity that humans engages in, where the information process is facilitated by a computer's visualization tools."* Further, he classifies visualization into two categories:

- **Information visualization**: Involves abstract quantities such as baseball scores, electrical voltages or the number of malaria cases within a country.
- **Scientific visualization**: Represents something physical such as geographic images, the flow of water or 3D objects.

Information visualization can be defined as *"the use of computer-supported, interactive, visual representations of abstract data to amplify cognition"* (Spence, 2001; Card et al., 1999). In DHIS2's health information dashboard, decision-makers interpret abstract quantitative data, meaning that information visualization is the relevant category. This section will, therefore, focus on the theory and principles of information visualization and will not provide additional details towards other aspects as it is outside the scope of this thesis.

The definitions outlined above provide insight towards decision-making when interacting with a health information dashboard. It involves multiple processes, where a subset is the process of interpreting visual representations in problem-solving activities through cognition.

Before users interpret a visualization, the raw data are encoded into a graphical format. This process is performed by a computer and defined as the *externalization* of data (Spence, 2001, p.12). After the externalization, humans browse the visualization to form an internal model that is based upon experience and previous knowledge of the visualization. This internal model is thereof interpreted through perception and cognition.

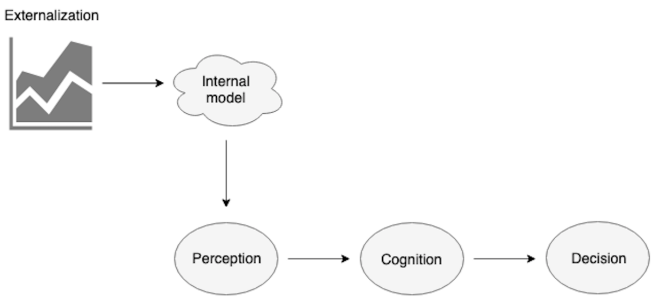


Figure 3.3: Simplified overview of the decision-making process (Spence, 2001, p.99).

3.3.1 Interpretation Process

The interpretation process involves perception and cognition; these processes are complex and not well-understood (Spence, 2001, p.99). However, if the goal is to convey information through graphical representations accurately, it is essential that perceptual abilities be considered (Ward et al., 2015, p.35). The process of visually perceiving information can be divided into two broad categories overlapping each other: *Pre-attentive* processing and *attentive* processing.

Visual perception and Cognition

During the interpretation of externalized information presented by the dashboard, users will first perform pre-attentive processing (Ward et al., 2015, p.36). A high-performance subconscious procedure that occurs in the human mind by identifying differences in, for instance, color, texture, or spatial grouping. Harnessing the power of pre-attentive processing when interpreting large amounts of information through dashboards can be performed by understanding how we perceive objects. The Gestalt principles are a defined set of laws that attempts to achieve this. Forsgren (2015) argued in his study on designing dashboards for managers that the most useful Gestalt laws to follow are:

- **Proximity:** Objects closer together will be seen as belonging together.
- **Enclosure:** Objects with a common border or background color will be seen as grouped.
- **Similarity:** Objects that are perceived similar will be seen as grouped.

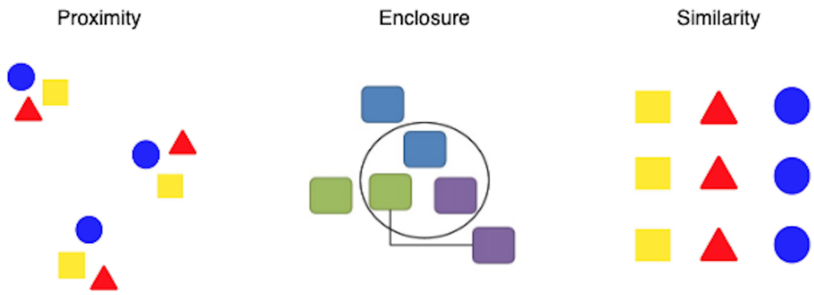


Figure 3.4: Following Gestalt laws can amplify cognition and balance information load.

During the process of perception, the pre-attentive aspect is uncontrolled and uses working memory. After locating a specific visualization that potentially shows deviations in its result, *attentive* processing occurs. It is performed sequentially and uses long-term memory (Ward et al., 2015, p.36). Through attentive processing, users will assess the visualized information based on prior knowledge, experience, and expectations to reflect upon the types of values that have changed. At this stage, additional instructions or visual cues facilitate how to arrive at a decision through cognition.

Cognitive processes are highly complex and will not be discussed thoroughly in this thesis. Decision-making is the last step of the cognitive process, as noted by Patterson et al. (2014). In their study on cognition and information visualization, the authors presented a framework for effective interpretation of information visualization. Briefly summarized, this framework offered a set of leverage points where the relevant ones include:

- Provide memory cues.
- Minimize distracting information.
- Provide visualizations with strong groupings to minimize the working-memory's limitations.
- Aid reasoning with mental models to facilitate the use of long-term memory.

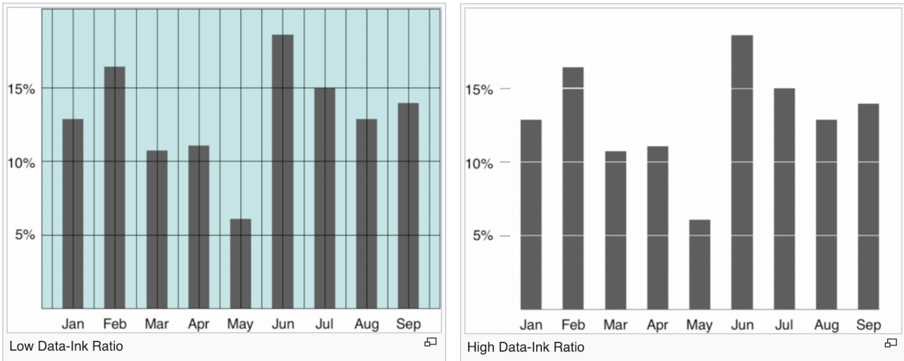
3.3.2 Visual Cues

Visual cues can be applied to presentation formats to reduce the information processing requirements during the interpretation process.

Consistency

Ward et al. (2015, p.142) states that visualizations are efficient if the maximum amount of data is perceived in a minimum amount of time. Further, the authors argue that effective visualization formats require a good balance between visual complexity and information utility. Repetitive and uniform patterns, as well as existing knowledge of the objects in the scene, reduce visual complexity.

Patterns through consistent color coding have shown to improve the process of interpreting visualizations. Additionally, supportive features to assist visual perception by guiding the eyes with grid-lines have been argued as both a positive and negative factor for cognition (Huerta and Jensen, 2017). However, Tufte (2006) noted that too much or redundant color coding might increase the complexity and increase the information load. Too much may increase complexity, but color-coded visualizations are recommended as long as it is applied with a maximum data-to-ink ratio (Tufte, 1983):



(a) (b)

Figure 3.5: Picture (a) Column chart with low data-to-ink ratio. Picture (b) Column chart with high data-to-ink ratio.

Data-to-ink ratio

The concept of data-to-ink ratio originates from Edward R. Tufte, who is viewed as one of the most important pioneers and researchers within data visualization. It involves allocating minimum ink to the information that does not directly present the data while allocating as much ink as necessary to the actual data. In Fig 3.5 above, picture (a) is a sub-optimal visualization as the border around the graph, the background color and the grid-lines are all unnecessary data ink. While picture (b) maximizes ink to the actual data, and minimum to the non-data (i.e., the percentile and month labels). Tufte (1983) states that by following this principle, the viewer's attention is effectively drawn to interpreting the intended, which facilitates optimal cognition. It is worth to mention that this concept has received criticism as a study consisting of 87 students as participants were provided a graph with low data-to-ink and one with high data-to-ink and asked which they preferred. The majority of students did not prefer the graph with high data-to-ink that followed Tufte's principles (Inbar et al., 2007).

3.3.3 Data visualization in public health

Health information dashboards mainly consist of collections of indicator-based visualizations. This section provides recommendations on data visualization offered by WHO and United Nations (UN).

Recommendations from WHO

WHO have published best practices for data visualization and dashboard design specifically for DHIS2. The organization emphasizes that HMIS are largely data-rich but information-poor without effectively communicating the evidence by presenting a story to the user. In addition to dashboard design, standardized guidelines for creating indicator-based formulas are provided. To facilitate interpretations that can be translated into knowledge, recommended presentation formats are presented[1]:

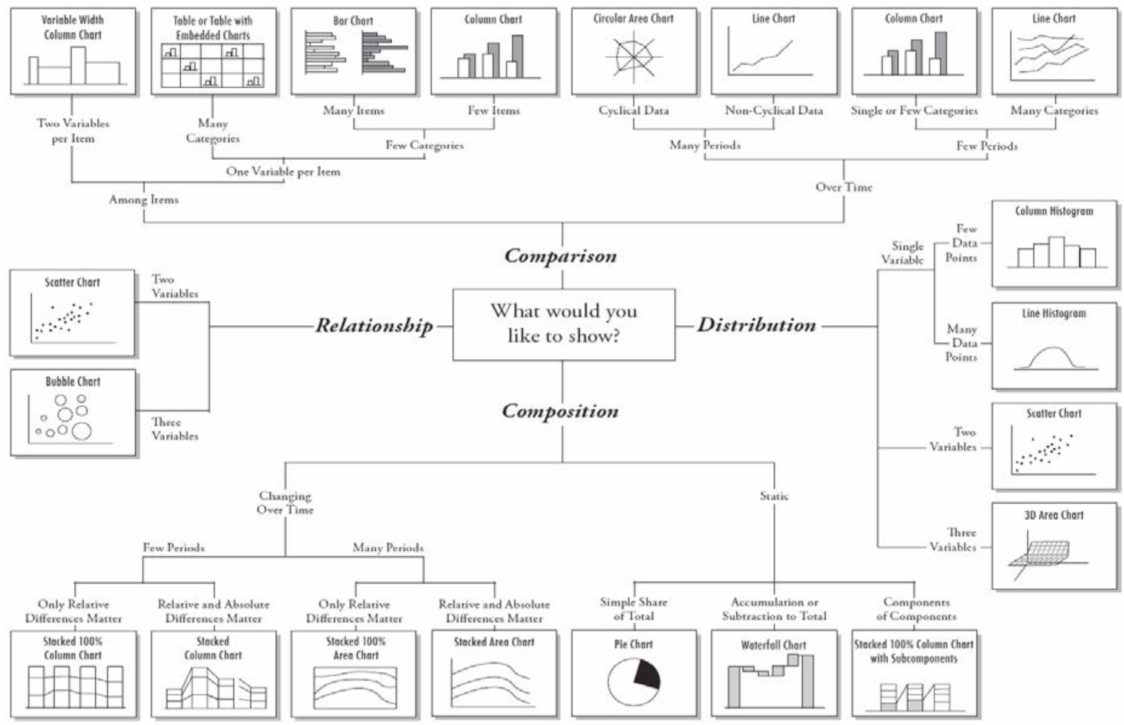


Figure 3.6: WHO's recommended presentation formats.

Further, ten key rules for presenting visualized information have been published. Relevant information for the health information dashboard is summarized and paraphrased as follows:

- Every visualization needs a caption, specify months and year on reports.
- Pie charts: Useful for depicting the rations of a whole.
- Tables: Useful for precise analysis, but difficult to interpret for the user.
- Maps: Useful for quick assessment for regional disparities in key indicators.
- Line charts: Useful for showing a trend over time.

[1] See WHO guidelines for analysis and use of data: `https://www.who.int/healthinfo/FacilityAnalysis_GeneralPrinciples.pdf`

Recommendations from United Nations

UN provides a guide for visualizing health data in a meaningful way that target the audience[2]. This section provides a brief summary.

UN emphasizes in their checklist for designing useful visualizations that the target group must be considered. Different presentation forms may be needed for different audiences. The format chosen for the dashboard must be considered if it should be the focal point. The designer should also not rely on color alone; the presentation format should be understandable if no color is present. The dashboard must also be consistent. Colleagues or end-users should test visualizations in case of misinterpretation occurring.

- **Well-designed table:** Consist of table title, column headers, row stubs, footnote, and a source line.
- **A well-designed chart:** Grabs the reader's attention, presents information simply, clearly and accurately. It does not mislead and displays data in a concentrated manner (i.e., line chart). It facilitates data comparisons and highlights differences and trends while illustrating messages, themes or storylines in the accompanying text.

3.4 Design guidelines for Health Information Dashboards

In this section, I will draw upon findings from the literature review and provide my recommendations for dashboard design. The recommendations will be based upon my understanding of the health information dashboard, its use-cases, and applicable features that fit the nature of the application.

3.4.1 Proposed Functional Features

Health information dashboards can be evaluated in terms of how users interact with them to make decisions through their functional and visual features. This implies that a well-designed dashboard may vary depending upon the user. Decision-makers use the application at various levels of the health system's hierarchy (e.g., national, province, district) with varying skill-sets, but also different needs on the data and its details (AbouZahr and Boerma, 2005). At the higher levels, strategic dashboards with low interactivity are suitable, while at the lower levels, analytical dashboards are more appropriate. This suggests that a health information dashboard must cater to different requirements.

[2]See UN's guidelines for data visualization: `http://www.unece.org/fileadmin/DAM/stats/documents/writing/MDM_Part2_English.pdf`

Given that the appropriate presentation format largely depends upon the user and the task, suggest that enabling toggling between multiple presentation formats should be supported. Excessive components or styling should not be present within the dashboard. Simple graphical representations are recommended as the application can potentially contain large amounts of visualizations. Offering simplicity with intuitive color coding will reduce the chance of overwhelming the user.

Drill-down features, details on demand and additional filtering should be supported if the users are required to examine the values more closely, this is more likely to be true at the lower strategic levels. Spacing and grouping to harness visual perception through the Gestalt principles are necessary to balance information load. Zooming capability that enables users to focus the visualization and increase its size will assist attentive processing on trouble areas. Lastly, as too much interactive feedback will increase the information load, a dashboard should have limited capabilities in terms of functional features. However, what a dashboard should do depends largely upon its user-base. This means that defining functional features requires the designer to engage in discussion with the end-users.

Upon finishing the review from literature and best practice guidelines related to dashboards, I conclude that a basis for essential functional features, where additional capabilities depend upon the users' needs, are:

- Ability to switch between presentation formats.
- Drill-down and filter features.
- Focus capability to expand and increase a visualization's size.
- Re-arrangement capabilities.
- Zooming capability to focus on specific visualizations.
- Possibility to contextualize information through dashboard titles and descriptive labels.
- Spacing and grouping capabilities.
- Display a warning when users attempt to add more than ten visualizations.

The renown BI software vendors, as well as Few (2006, p.42) recommends that dashboards should not contain a scroll-bar. However, taking into account the vast amounts of health statistics that can potentially be categorized into different granular parts of an entire country, dashboards without a scroll-bar will often not be achievable. Further, as a user should not be able to manage more than ten dashboard instances, dividing these visualizations is somewhat impossible should an organization have limited human resources. Lastly, my proposal of ten visualizations as a maximum is taken from WHO's recommendation for HIV dashboards for national coverage.

3.4.2 Proposed Visual Features

A well-designed dashboard conveys a story to the user; this is achieved through its functional features as well as its visual features such as descriptive labeling. A user should be able to retrieve important information within five seconds. Further, the story should be interpreted from top left to bottom right, guiding the user's cognitive processes through visual cues.

The visual features of the presentation formats should contain high data-to-ink ratio, grid-lines, and follow consistent color coding. If possible, tooltips should further explain the values when hovering the mouse over a visualization. To balance interactive feedback; a delay in displaying the tooltips can be implemented. The colors used should be natural, but the visualizations should be able to be interpreted correctly without the use of colors as well.

Upon finishing the review from literature and best practice guidelines, I argue that essential visual features are:

- Intuitive color coding with natural properties.
- Maximized data-to-ink ratio.
- Simple presentation format.
- Low amount of excessive clutter and styling.
- Grid-lines.
- Title and description for improved context.
- Tool tip capability when hovering the mouse over a visualization's value for detailed information.

3.4.3 Visualizing Information

Few (2006, p.102) states that the correct display medium will always be based on the nature of information, nature of the message, and needs and preference of the audience. Spence (2001, p.12) noted that humans form an internal model when interpreting the externalization. Further, he identifies short-term memory and working-memory as limitations of the cognitive process. I would argue that the challenge of achieving an effective visualization lies with the different user's knowledge of data literacy and cognitive abilities. This is where the standardized decision templates and integrated discussion forum could serve as a powerful tool for users situated in developing countries.

Assist perception and cognition with decision rules

In terms of visual perception, attentive processing can benefit from assigning goals and decision rules to specific visualizations as memory cues. Ward et al. (2015, p.412) notes that additional information like labels are essential for effective interpretation. During the interpretation process, decision-makers could potentially reduce the complexity of the cognitive process to arrive at a possible decision. This will subsequently reduce information processing requirements and reduce the users' chance of experiencing information overload. I would argue that standardized decision templates are valuable, as long as the proposed actions have been defined thoroughly. In developing countries, there exist multiple factors that could affect the visualizations values. Blindly following the proposed decisions could cause a negative impact if the performance decrease is caused by other factors not defined by the decision templates.

To achieve useful visualizations, Tufte (1983) argues that high data-to-ink ratio must be applied. However, as it exists, studies that contradict this concept implies that defining clear guidelines that fit every type of user and task is challenging. This argument could also be strengthened by the field's different opinion on color-coded visualizations (Dowding et al., 2015; Tufte, 1983; Inbar et al., 2007). At least, a rule that should always be followed is thorough research of the dashboard users and the audience that will ultimately interpret the visualizations and interact with the application.

Enable collaborative interpretations

Interpreting the information and translating it into well-informed decisions are often performed, and improved, through co-operation and social activities (Braa et al., 2012; Heer and Agrawala, 2008; Al-Hajj and Pike, 2013). The health information dashboard's integrated discussion forum could serve as a tool to aid memory through visible documentation of previous occurrences and updates. Further, it can assist decision-making through social interaction and collaboration. As such, I argue that strengthening the dashboard with a discussion forum surely has the potential to improve decision-making, while also reducing information processing requirements.

Recommended use-cases

As previous research has identified poor visualization competency as a constraining factor for optimal dashboards (Chrysantina and Sæbø, 2019), knowledge on appropriate presentation formats for the given task is essential. Before ending this chapter with a summary, recommended use-cases for DHIS2's presentation formats are provided.

- **Bar charts** have values displayed in a thick horizontal line. Along with column and line chart, it is one of the most common visualizations used in dashboards and has its best use-case when looking at a specific value across a nominal or ordinal scale (e.g., organization units) (Few, 2006, p.113).

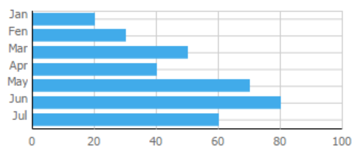


Figure 3.7: A simple horizontal bar chart.

- **Line charts** are commonly used and recommended when showing performance trends over time or other interval scales with intrinsic order. It facilitates high data-to-ink ratio, reduces visual clutter in its simplicity and is therefore suitable to be used in a dashboard.

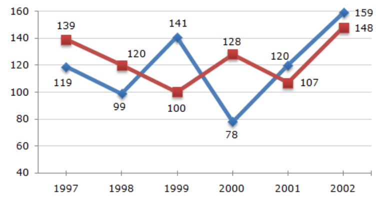


Figure 3.8: A simple line chart.

- **Pivot tables** are processed sequentially and have both positive and negative use cases. Tabular data is best used in dashboards with visual cues that can indicate performance increase or decrease to amplify pre-attentive processing. In DHIS2, this can be achieved by applying legends.

Sierra Leone - ANC 3rd visit				
Period / Facility Type	CHP	MCHP	Clinic	CHC
March 2018	2 294	5 467	440	3 558
April 2018	2 520	5 667	502	3 952
May 2018	2 636	6 749	500	4 159
June 2018	2 809	6 257	603	4 608
July 2018	2 717	5 937	617	4 101

Figure 3.9: A text based pivot table without legends.

- **Gauge charts** are best used in the dashboard with additional visual cues to contextualize the current value further. This involve providing context that can compare the value and describe if the performance are good or bad.

(a) (b)

Figure 3.10: Picture (a) displays a sub-optimal visualized gauge. Picture (b) displays a suitable gauge.

- **Column charts** is applied when the user wants to compare similar data across categories. Stacked column, and stacked bar charts are best used when comparing multiple values or categories to illustrate correlation. The visualization is recommended to use within a dashboard if it applies high data-to-ink ratio and consistent color coding. However, Few (2006, p.116) notes that stacked charts should not be used to display single series of part-to-whole data. UN stresses caution with applying stacked column chart with multiple items as it will be difficult to interpret the differences. A common column chart can replace stacked charts.

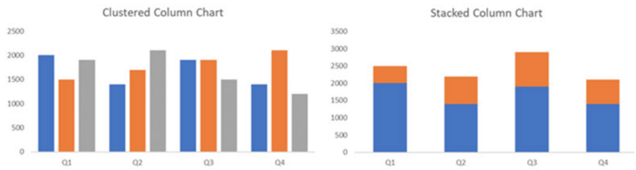


Figure 3.11: A column chart (left), an stacked column chart (right).

- **Area charts** are not suitable to use with the dashboard as it occludes the values, hides supportive grid-lines and are visually challenging to interpret due to its utilization of data-to-ink ratio.

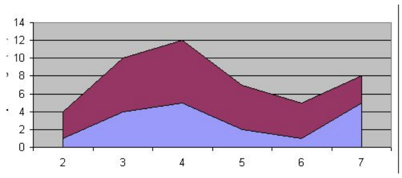


Figure 3.12: An Area chart.

- **Pie charts** are best used when the user wants to see what contributes to a whole, but is not recommended when applying more than three rations. It is noteworthy to mention that Few (2006, p.47) as well as the top BI vendors recommend users to apply a different visualization (e.g. column chart) rather than pie charts in dashboards, as the rations may confuse the user while it also is sub-optimal to visualize quantitative data.

(a) (b)

Figure 3.13: Picture (a) displays a badly visualized pie chart. Picture (b) displays a suitable pie chart.

- **Radar & Spider Charts** is not recommended to be used with the dashboard as it facilitates poor pre-attentive processing capabilities, requiring users to process the values thoroughly through attentive processing. It is only recommended using this visualization when the categorical scale is related to hours within a day as it can resemble a clock. A bar or column chart is more suitable in most occurrences.

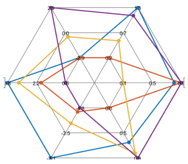


Figure 3.14: A radar/spider chart.

- **Geographic Map** is recommended to be used with the dashboard. The presentation format should be applied with legends to assist pre-attentive processing during interpretation.

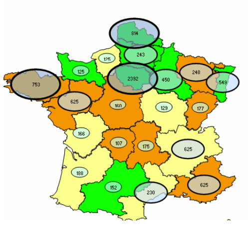


Figure 3.15: A geographic map with data points and legends.

3.5 Summary

Information overload can be caused by multiple factors in the organizational setting (e.g., personal factors, organizational design, or the characteristics of the information). The point at which it occurs is not fixed and varies relative to the individual. Multiple symptoms have been identified, as well as potential countermeasures to cope with the information required to be processed. These countermeasures can be proactive or reactive. It involves measures such as standardized operating procedures, capacity building, or integrating information technologies such as dashboards. However, poorly designed dashboards will, in turn, make the application act as a source of overload. It is important to note that information overload occurs from several sources. Meaning that multiple factors within a dashboard can produce information overload, but also multiple factors within the organizational setting.

Dashboards can be evaluated according to their functional features, visual features, and how users interact with the application. It should facilitate filtering and drill-down features to balance information load and encourage data exploration. Given the nature of information overload, a well-designed dashboard is only achievable through a cycle of refining and adjustments should they be perceived as overwhelming. Further, as the dashboard draws its use from presenting visualized information, knowledge on data visualization is required in order to apply appropriate presentation formats.

To provide visualizations that can be interpreted effectively through a health information dashboard, simple graphical representations are required. Visual cues should be facilitated that improve pre-attentive processing. High data-to-ink ratio will help users focus on the intended data that will be interpreted, while grid-lines will assist further. Color coding and grid-lines can help with reducing the visual complexity, but also increase the information load. To maintain a balance, consistency, and some degree of interactivity will reduce the chance of overwhelming the user.

Chapter 4

Research Methodology

The purpose of this chapter is to introduce the research approach and research methodology. First, the goal of the study is reiterated with applicable research methods, along with my reasoning behind the chosen method. Thereof, an overview of the research phase is given, before continuing with how the data collection and analysis were performed. The chapter ends with a reflection on the limitations of the applied research method.

4.1 Research Approach

4.1.1 The Goal: Insight and Understanding

The goal of the study was to gain insight on essential features and design a health information dashboard must facilitate to maintain a balance between information load and information use. To reach this goal; the following research question was asked: *"What essential features must a health information dashboard facilitate to enable evidence-based decision-making, without causing information overload?"*. A quantitative, qualitative, or mixed approach could potentially help gain understanding to answer the question. Quantitative research focuses on examining the relationship among variables, primarily through real numbers and statistics (Creswell, 2014, p.32). Qualitative research focuses on exploring and understanding the meaning that individuals or groups ascribe to a social or human problem. Mixed methods combine both approaches to provide a more complete understanding of the research problem than either approach alone (ibid., p.32).

The benefits of adopting a quantitative approach could involve improved ability to generalize theory, with consistent and precise results. However, a purely quantitative approach could potentially limit my ability to contextualize social characteristics involving the different ways users interact with the dashboard during the decision-making process. Further, as users can experience information overload at different points suggested that omitting subjective feedback could potentially lead to insufficient understanding. A qualitative approach would have strengths towards capturing the context of the information overload problem and offer multiple data collection methods that could provide more detailed information and reduce misinterpretation. Whereas limitations of a qualitative approach involve a reduced possibility to generalize theory.

As DHIS2's dashboard are applied by users with varied skill-sets, I argue that a qualitative approach was well suited to capture the social and technical aspect and ultimately answer the research question. The social aspect would involve the different approaches users applied to interpret visualizations, enforce decisions, and their individual information processing capabilities. The technical aspect would involve the features that the dashboard offered and their ability to balance information load during the decision-making process.

As mentioned in section 3.2.1 on page 27, dashboards can be evaluated in terms of how users interact with the application to make decisions (Yigitbasioglu and Velcu, 2012). This argument implied that observations on how PSI utilized the dashboard would provide results to assess potential limitations and improvements. As such, in-context research that focused on the different dashboard users was called for. Given that multiple factors within the organizational setting can cause information overload suggests that the scope can potentially become large. To limit the scope down to manageable parameters; the study focused at causes and symptoms of information overload mentioned in section 3.1 on pages 23-25, and countermeasures applied with the dashboard (i.e., filter mechanism, decision templates, and discussion forum).

Qualitative case studies

Yin (1994) notes that case studies are applicable when control over behavioral events is not needed and where there is focus on contemporary events. Denzin and Lincoln (2000, pp.443-450) states in their handbook of case studies that, the context of a given case which the researcher chooses to study, does not define whether or not it being qualitative or quantitative. Rather, it is the data the researcher gathers from the results that ultimately defines a study as quantitative or qualitative.

Qualitative case studies are characterized by researchers spending extended time on site, in contact with activities and operations while reflecting upon it. It emphasizes experiential knowledge as data sources, involving subjective feedback from the research subjects. These arguments suggested that by collecting experiential knowledge and feedback from the different dashboard users would help ensure that the results were of qualitative nature. Additionally, the study's fieldwork duration would span one month such that I spent extended time on site.

4.1.2 The applied methodology: Action Case

Braa and Vidgen (1999) argues that IS research methods can be broadly categorized into two parts, namely *positivist* and *interpretivist*. The positivist assumes that the phenomenon can be observed objectively and with detail through reduction and minimal intervention to maximize predictability.

Walsham (2006) notes that interpretive studies aim at *"...producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context."*

To answer the research question, the study focused upon gaining understanding through observations and retrieving subjective feedback, with potential interventions through small changes to the dashboard layouts. With an emphasis on observation without continuously changing the dashboard design, users could familiarize themselves with the layout. By not interfering with the natural setting, observing that symptoms such as *loss of control over information* was a cause of information overload, and not as a cause of users having to familiarize themselves with the design, could become more plausible. Additionally, as I worked with further development of the dashboard application, my interpretations would be based on prior technical knowledge in addition to findings from the literature. Thus, I argue that the *action case* was a fitting framework to adopt while conducting the qualitative case study. It is a hybrid IS research method that crosses the intended outcome between an interpretive and intervention approach, with emphasis on collecting data to offer insight towards a situation. The action case uses components from the cyclical *action research* method for desired changes, and participative *case study* to provide understanding of the research question in an organizational context (Braa and Vidgen, 1999). One advantage of adopting an action case methodology with minimal interventions include active participation in the workplace, without affecting the natural setting to the same extent as action research. Fig 4.1 below illustrates the intended outcome of methods applicable for IS research. As the study's context involved features that were well integrated with the dashboard and the health organization's work processes, meant that implementing a prototype or following the action research cycle with continuous changes, could mean that users required longer time to familiarize themselves with the dashboards.

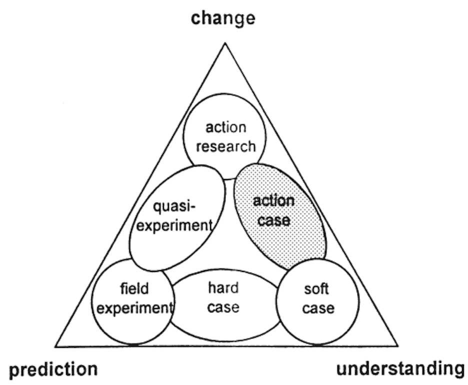


Figure 4.1: IS research triangle with intended outcome (ibid.).

A focus group experiment was also performed similarly to a field experiment approach. This involved observing a group of dashboard users that did not use the decision templates and discussion forums. The experiment was performed to observe potential differences in the decision-making process related to information overload to gain insight on the potential value they added.

4.2 Research Phase

Meeting with PSI: Feedback from users

Before the action case study, an exploratory visit was initiated to PSI's global offices in Nairobi, Kenya, through a five-day stay from 21.05.18 to 26.05.18. I took part in meetings where PSI's global director described how the health information dashboard was applied in their work processes. At this stage, initial interviews with dashboard users were conducted to retrieve feedback on challenges, limitations, and potential improvements. The feedback served as a basis for my implementation changes, which were mainly related to the discussion forums.

Before returning from Kenya, PSI, me and my supervisor concluded to build my research around the value the decision templates and discussion forums offered, to explore their effect on dashboard-use and information overload. Upon my return, I was granted access to the health organization's DHIS2 instance to assess their dashboards and create my own dashboard instances.

As the applied research method would involve performing small interventions on the decision-makers' dashboards; literature related to dashboard design was reviewed. Given that PSI had designed their dashboard layouts themselves, a chance of them not following recommended design guidelines was plausible. However, if I was to intervene with actions that could improve the situation, they were required to be based upon established principles. This formed the start of my literature review.

Literature review

Literature related to dashboards were collected and reviewed by querying Google scholar with the keyword strings "Dashboard design," "HMIS dashboard," "Dashboard review," "Public health dashboards" and "Dashboard developing countries." Scholarly articles consisted primarily of guidelines related to dashboard implementation. There was a limited amount of research articles that investigated design guidelines or the effect of dashboard-use or within the context of HMIS in developing countries. Due to lack of research papers closely related to my context, I expanded my literature review to include dashboards applied within health care or MISs.

As health information dashboards draw its use from presenting visualized information required knowledge on what type of presentation format was appropriate for a given task. The literature on the concept of data visualization was collected by querying Google scholar with the keyword strings "Public health data visualization," "Information visualization," and "Visual analytics public health." I limited my review on research papers and scholarly books involving studies on information visualization, and presentation formats that visualized quantitative data.

Lastly, I investigated literature on information overload to identify potential causes and solutions. Google scholar was queried with the keyword strings "Information overload dashboard," "Information overload HMIS," and "Information overload public health." Through the review of this stream of literature, I found that multiple authors argued that minimal research had been conducted within public health or HMIS (Hall and Walton, 2004; Eppler and Mengis, 2002). The interdisciplinary study from Eppler and Mengis (2002) was primarily used as the authors offered a research framework and had categorized factors that could be related to the effect of applying dashboards with large amounts of information.

Public database search of renown BI vendors

The literature offered a small handful of research papers on dashboard design. To further improve my understanding, an extensive Google search for renown BI software vendors was performed. I queried Google with the strings "Top visualization tools," "Top business intelligence performance tool," and "Top performance dashboard vendors." The results provided public review and user-stories, ranging from specific or collective reviews of software vendors. From the results, I noted the frequency of each vendor on the first three tabs, where one tab contained ten matches. The four vendors with the highest frequency from the three tabs were the ones I investigated further, by retrieving their documentation on best practice guidelines and recommendations for dashboard design and usage.

4.3 Data Collection

There were several instances of data collection from multiple sources during the thesis progression used for triangulation. Triangulation is a process of using multiple perceptions to clarify meaning, verifying repeatability of an observation and reduce the chance of misinterpretation (Denzin and Lincoln, 2000, p.454). The empirical basis of the study consisted of documentation, observations, interviews, and surveys.

4.3.1 Layout composition of user-designed dashboards

Data was collected from the health organization's DHIS2 instance related to their dashboard design. Specifically, the number of dashboard instances that were used for the HIV and male circumcision health program was documented. Within each dashboard instance, the number of visualizations along with the type of presentation formats was noted, while also assessing the usage of decision templates and discussion forums. A similar approach had been performed by Chrysantina and Sæbø (2019), to examine user-designed DHIS2 dashboards in Indonesia. Their work was adopted as a conceptual framework to analyze the dashboards. I categorized dimensions relevant to the study and how PSI applied the health information dashboard.

To summarize, the following dimensions within each dashboard instance were assessed:

- Administrative level (e.g. national, province, district).
- Number of standardized decision templates defined.
- Number of discussion forums used (i.e more than 0 comments posted).
- Number of presentation formats.
- Type of presentation formats.
- Captured period range of visualizations (fixed and relative).

The results were later reflected upon and discussed in terms of dashboard composition after receiving feedback from the users in Zimbabwe. The specific findings are provided in chapter 5 and further discussed in chapter 6.

4.3.2 Field Work

The case study in Harare, Zimbabwe, lasted one month from 15.01.19 to 16.02.19. As access to PSI's DHIS2 instance had been granted, modified dashboards were prepared. The dashboards were based on design principles from literature and best practice guidelines from the top four BI software vendors. Before the action case study, the health organization and their dashboard users had been informed and contributed to users' preference for the modified dashboard design. Four users were assigned as my test subjects such that I could sit in the same office room and observe their work processes related to evidence-based decision-making and how they interacted with the health information dashboard.

After communicating the preferred design layout, the composition largely remained the same, but each dashboard had a reduced amount of visualizations. Following my proposed recommendations after reviewing the literature, I suggested a maximum amount of ten visualizations per dashboard. This was increased to 15 per users' requests during the case study. Additionally, a spacer item on each row was applied to group related visualizations according to Gestalt principles. An illustration of the dashboard design is presented on the next page.

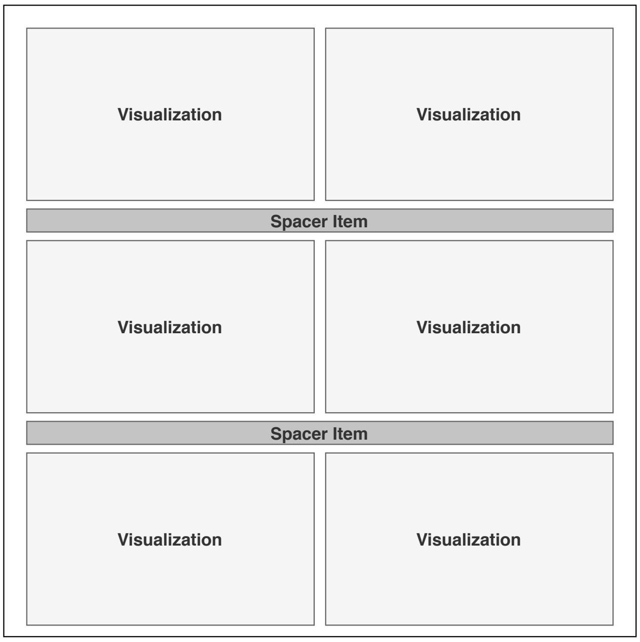


Figure 4.2: Illustration of modified dashboard design.

Observation

Crang and Cook (2007) notes two types of observation: Passive, or detached observation, and participatory observation. With passive observation, the researcher aims to not interfere with the test subjects by observing from a distance. In participatory observation, the researcher takes part and work among the test subjects' workplace.

During the action case study, participatory observation of the users' work processes and their interaction with the dashboard and visualization tools were performed. The observations involved duplicating the users' computer screen to a TV which I monitored. Instead of, for instance, sitting directly behind the user, this particular observation mode was performed in an attempt to reduce the chance of affecting the natural setting. The small interventions consisted of modifying the dashboard design, such as reducing the number of visualizations or changing the type of presentation formats, which were justified by feedback from the users. The feedback was thereafter documented and used for analysis. Primarily, data collection through the action case study originated from participatory observation with the dashboard users without performing any interventions.

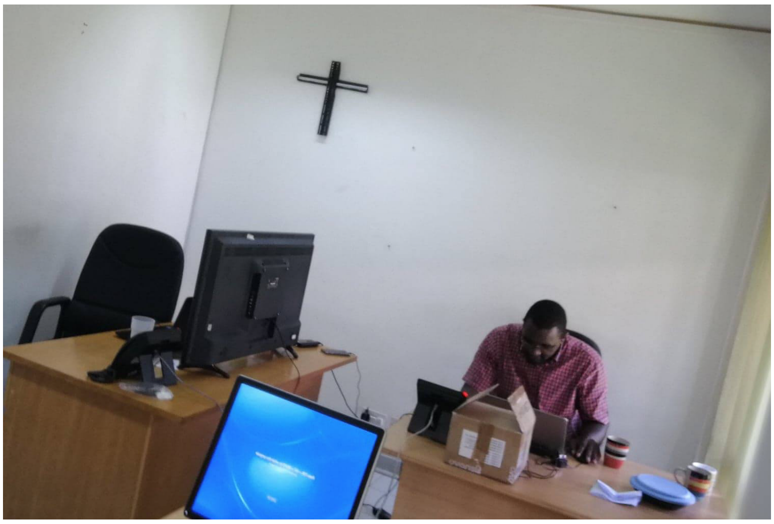


Figure 4.3: The DHIS2 dashboard users duplicated their computer screen.

Interview and surveys

In addition to observations; surveys and informal interviews were initiated at the end of each week. Interviews can be categorized into structured, semi-unstructured, or unstructured (DiCicco-Bloom and Crabtree, 2006), and is a key way to access interpretations of informants in the field (Walsham, 2006). The interview and survey questions for this study followed an unstructured scheme to provide qualitative answers through guided conversations. As Braa and Vidgen (1999) states: *"Surveys can also be designed to collect qualitative data and be analyzed using idiographic methods, placing them in the understanding/interpretation area of the IS research framework."* To ensure that the surveys followed idiographic methods, questions were structured such that users answered subjectively, based on personal experience. Some examples of the questions asked are:

- How does the decision templates reduce your information processing requirements?
- What type of presentation format do you prefer?
- How does the discussion forum help you with decision-making?
- When do you perceive dashboards as overwhelming?

Focus Groups

In week three, dashboard users were assigned into focus groups. This experiment was conducted to observe any differential value of applying the decision templates and discussion forum with DHIS2 applications. The three groups consisted of four persons in total and were divided as follows:

- **Group 1:** Applied DHIS2 applications *with* the support of standardized decision templates and discussion forums (1 person).
- **Group 2:** *Did not* apply decision templates and discussion forums with DHIS2 applications (1 person).
- **Group 3:** Control group with no interventions or any changes with current work processes (2 persons).

Group 1 and 3 focused on the HIV program, while group 2 focused on the male circumcision program which included more collaboration and communication, due to the size of the program. These users, in turn, communicated with other DHIS2 users according to their assigned instructions. As a result, other communication medium was used for group 2 (i.e., e-mail or phone) while also requiring to interpret visualizations and arrive at a decision without assisting themselves with the decision templates. The control group did not apply modified dashboards with reduced number of visualizations or spacing items. While observing the different groups, field notes were used to document notable incidents such as information overload symptoms in search patterns, processing time requirements, and decision-making with or without decision templates and discussion forums.

Field Notes

In addition to observing how the users interacted with the dashboard application, field notes were taken continuously. This included field notes from meetings in Nairobi, Kenya, and Harare, Zimbabwe. The field notes were reflected upon several times during and after the case study. This provided a deeper context to the data collected through observations and feedback from the test subjects' experiences with the action case study.

4.3.3 Meetings and E-mail

E-mail was used to communicate with the health organization as well as collecting data. PSI forwarded documentation on how the standardized decision templates were defined and used. Several meetings throughout the thesis progression were also conducted. These meetings provided technical and administrative information on PSI's DHIS2 instance and work processes. Both meetings and e-mails were used to communicate my intentions with the dashboard design and the goal of the study in Zimbabwe. Table 4.1 on the next page provides a summary of the data sources and data collection methods.

Table 4.1: Summary of data collection methods.

Data collection methods:	Description:
Surveys & Interview	• 4 Unstructured interviews (8 participants). • 2 Surveys (8 participants).
Field notes	• Documented incidents from participatory observation and feedback.
Meetings	• 2 Meetings in Nairobi, Kenya, related to PSI's usage of DHIS2. • 3 Meetings in Harare, Zimbabwe, related to strategic planning and decision-making. • 2 Skype meetings with PSI global offices. • 2 Skype meetings with PSI Zimbabwe. • 8 E-mails exchanged with PSI global offices, related to decision templates and access to DHIS2 instance. • 11 E-mails exchanged with PSI Zimbabwe, related to decision templates and preferred dashboard design.
Focus groups	• 2 Out of 4 weeks (4 participants).
Dashboard composition	• Male circumcision program: 64 dashboard instances. • HIV Program: 17 dashboard instances.

4.4 Data Analysis

4.4.1 Analysis of User-designed Dashboards

All dashboard instances within the HIV program and male circumcision program were quantitatively analyzed. The intention was to use the results for triangulation with the empirical evidence gathered from the field. The results offered an indication of the typical amount of visualizations that a health information dashboard contains when monitoring health programs. Further, it offered insight towards how often the decision templates were defined as well as how often the discussion forums were used at the different levels of the health system. In terms of presentation formats, it illuminated what type of visualization that was commonly applied based on the frequency. The assessed dimensions are specified in section 4.3.1.

The qualitative analysis was performed on two dashboards in each respective health program that users pointed out as overwhelming during the case study. The dashboard instances were evaluated by taking common design mistakes identified through the literature review into account. In addition to applying design principles from extant literature, user feedback and observations were taken into consideration. For instance, charts applying fixed periods without visualizing the recent or relevant months were considered sub-optimal, along with visualizations with misleading labels, or line charts visualizing data not in an interval scale. The evaluation was performed with respect for users' preference in four steps:

1. Compare the dashboard's arrangement with similar levels (e.g. national, province, district).
2. Evaluate the configuration of visualizations (e.g. indicators, target line).
3. Evaluate the applied visualization types (e.g. formats, configured periods).
4. Evaluate visual cues (e.g. labels, decision templates, excess visual clutter).

Similar to Chrysantina and Sæbø (2019), the results were ultimately categorized into problem categories. However, these categories were slightly modified to capture limitations from DHIS2's dashboard as well as potential design mistakes:

Table 4.2: Qualitative analysis problem categories.

Problem category:	Description:
Dashboard design	Problems with dashboard layout of similar instances such as inconsistent placement. Or exceeding the amount of visualizations based on users' preference.
Visualization technique problem	Problems related to inconsistent configuration of presentation formats. Or visualizations with misleading labels.
Data quality problem	Problems related to dashboards containing visualizations with incomplete or no data at all.
Dashboard limitations	Problems related to limitations of the dashboard due to lack of features.

4.4.2 Thematic Analysis

Thematic analysis is a foundational method for qualitative analysis and serves as a flexible tool to identify patterns and themes (Braun and Clarke, 2006). Either through an inductive or a deductive approach. Inductive analysis tends to be data-driven and involves coding collected data without trying to fit it into a pre-existing coding frame. Deductive analysis tends to be analyst driven and involves coding data for a specific research question with a pre-existing coding frame. Coding of themes is a subjective process to some extent, as the researchers choose concepts to focus on (Walsham, 2006).

Before the case study, themes were defined after reviewing literature. As the usage of decision templates and discussion forums could be viewed as potential countermeasures for information overload, some assumptions were taken into account. Additionally, themes for dashboard design and dashboard limitations were created that potential findings could be categorized into. Thus, particular questions during the unstructured interviews, surveys, and feedback were aimed to capture these themes. With this approach, the thematic analysis followed a deductive manner. This particular form of analysis can provide a more detailed analysis of particular aspects but reduces the ability to make rich descriptions of the overall data (Braun and Clarke, 2006).

Qualitative data analysis ideally coincides with data collection (DiCicco-Bloom and Crabtree, 2006). During the case study, field notes were reflected upon and initially labeled according to the themes. After the case study, field notes were re-read and reviewed. When performing the data analysis, the research framework proposed by Eppler and Mengis (2002) was applied as a lens to evaluate the dashboard application through the users' interactions related to each defined theme. The framework shown in Fig 4.4 below categorizes causes originating from factors in the organizational setting, that can produce observable symptoms. Identifying the symptoms calls for countermeasures that in turn, can alleviate the causes. For instance, filtering information can alleviate causes originating from the information characteristics, tasks and processes, or personal factors.

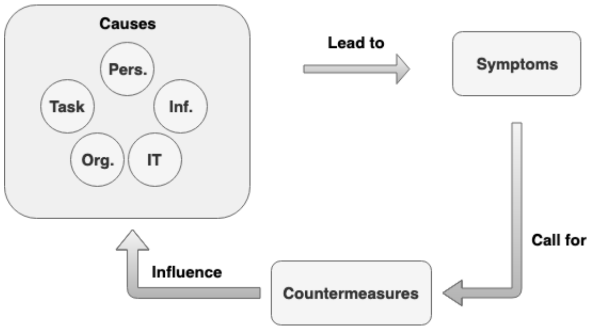


Figure 4.4: Cyclical nature of causes, symptoms and countermeasures of information overload (ibid.).

To see if, for instance, a reduction on the number of visualizations per dashboard alleviated the symptom *loss of control over information*, key findings related to dashboard design was noted. Usage of the decision templates and discussion forums was also noted in terms of their value of improving the dashboard's ability to facilitate evidence-based decision-making. An overview of the main findings is presented on the next page:

Table 4.3: Thematic analysis of qualitative data.

Categories:	Main findings:	Description:
Dashboard design	• Inconsistent arrangement. • Initial impression affects information load. • Upper limit of visualizations.	• Arrangement of most important visualizaitons should be consistent. • Dashboards initially displaying crowded numeric values overwhelmed the user. • Upper limit of maximum amount of visualizations reported to be 15.
Information characteristics	• Dashboards with partial data.	• Visualizations exhibiting incompleteness, or displaying no data at all resulted in increasing the chance of experiencing information overload.
Standardized decision templates	• Inconsistent availability reduced its value.	• Standardizing decision-making processes is difficult to realize when procedures are not always defined.
Integrated discussion forums	• Lack of functionality reduced its value. • Inappropriate use increases information load.	• Not receiving notifications resulted in users moving back to traditional communication streams. • Irrelevant updates increased information processing requirements.
Presentation formats	• Simple presentation formats are preferred. • Tabular data is sub-optimal in dashboard.	• Line charts and column charts are primarily preferred. Toggling between these formats was highly requested. • Tabular data was considered an appropriate format for dashboard as long as it applied legends.
Dashboard limitations	• Lack of interactivity. • Sub-optimal filtering.	• Not supporting drill-down features resulted in users not applying the dashboard. • Current filter mechanism did not remove irrelevant information.

4.5 Limitations with applied method

Applying a methodology towards the *change/understanding* direction of the IS research frameworks presented by Braa and Vidgen (1999), such as the action case study, will often translate into qualitative methodologies. Qualitative case studies can produce limitations that may affect the results.

Generalizing findings from context-specific study

Empiric generalization of the results can be difficult as the findings will come from context-specific situations and personal opinions. However, Greenwood and Levin (1998) argued that general laws must apply to particular cases. As such, the study's particular case could potentially verify the general laws that may emerge or have already emerged related to the use of interactive dashboards and experiences of information overload. The findings could nonetheless be considered valuable as empirical generalization must take context into account in order to improve general theory, related to both dashboard design and information overload.

Identifying information overload through decision-making

The applied lens proposed by Eppler and Mengis (2002) encompasses a broad aspect of the organizational setting. Empirical evidence from observation of potential information overload sources identified from the dashboard may result in originating from a different source than noted. Observing information overload by assessing the decision-making process is a challenging task. To illustrate the complex nature of how the use of HMIS affects decision-making, I draw forth the process illustrated by Lippeveld et al. (2000, p.37):

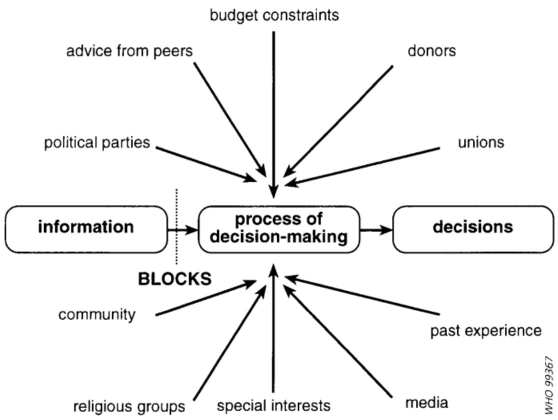


Figure 4.5: Variables of the decision-making process (ibid.).

The decision-making process includes variables that interact in the mind of the decision-maker, involving mental processes that cannot be measured directly or scrutinized through observation (O'Donnell and David, 2000). However, as mentioned in section 1.3 on page 3, other dysfunctional behavior occurs where increased processing time-requirement is one example. As such, the study focused on identifying causes and symptoms of information overload, instead of focusing on decision accuracy.

My role as a researcher and developer

Walsham (2006) argues that *"we are all biased by our own background, knowledge, and prejudices to see things in certain ways and not others."* As such, my observations could have been focused on identifying information overload symptoms that may otherwise be normal behavior. To reduce the chance of misinterpreting how users interacted with the dashboard; feedback was requested to verify or refute behavior that could be identified as valid symptoms.

Further, as I introduced myself as a developer for the DHIS2 software, the data I gathered from interviews and surveys may have been affected such that the test subjects provided positive answers towards the use of discussion forums and decision templates, which the organization view as a valuable DHIS2 feature. To reduce the chance of users potentially providing positive answers, I emphasized that the research did not necessarily imply further improvements for the discussion forums. Further, my implementation changes during the thesis progression addressed some of the limitations reported during my initial trip to Nairobi, Kenya.

Changing organizational context

Testing different dashboard layouts, performing minor interventions, and assigning focus groups with specific roles affects the organization's natural setting. Findings through observations will also be affected to some degree. To reduce the chance of affecting the natural setting; the modified dashboards were prepared before the case study which the users familiarized themselves with. Thus, by following the action case study, minimal interventions were required that could reduce the chance of affecting the organizational context.

Chapter 5

Empirical Findings and Analysis

This chapter presents the empirical findings gathered from the analysis of the health information dashboards and findings from the case study in Zimbabwe. The first section presents results from a quantitative analysis of the health organization's existing dashboards covering the HIV and male circumcision programs. Then, results from a qualitative analysis of the two most used dashboards that was pointed out by users as overwhelming. The second section provides findings based on the categorized themes *dashboard design*, *information characteristics*, *decision templates*, *discussion forums*, *presentation formats* and *dashboard limitations*. The chapter ends with a summary.

5.1 User-designed Dashboards

HIV Pogram

Due to the magnitude of the HIV program's coverage, following guidelines from Few (2007, pp.138-146) or renown software vendors to keep visualizations within the screen boundary was not possible. As the health organization had limited personnel and monitored multiple health programs, dividing dashboards such that no person applied more than ten different instances were also not possible to achieve as recommended by Qlikview (2011).

National level dashboards had an average of 16 visualizations. Out of all visualizations for this level, only one decision template was defined, and nine visualizations registered usage of discussion forums. The visualizations showed information from the last month, up to a yearly coverage. These dashboards were not used as extensively compared to dashboards at lower levels. Decision-making at the national level primarily occurred *"...through meetings with multiple strategic personnel after review with stakeholders."* The number of visualizations, decision templates, and usage of discussion forums for each visualization is summarized on the next page.

Dashboards at province and district level contained an average of 26 and 24 visualizations respectively. At this level, visualizations covered the same period range from the last year, down to the last month. National level dashboards aggregated data from provinces or zones, and was intended to serve as a strategic dashboard with low interactivity and summaries. The lower levels were intended to be used more frequently as analytical dashboards, by analyzing granular data from clinics, enforcing actions to ensure sufficient health commodities and timely reporting, and engaging in discussions to interpret the data.

Table 5.1: HIV program: Number of dashboards, visualizations, decision templates and discussion forums.

Level:	Number & percentage of dashboards:	Total number of vis. & avg. number per dashboard:	Total number & percentage of vis. with decision template:	Total number & percentage of vis. with discussion forum used:	Period range (fixed and relative):
National:	4 (23.5%)	66 avg: 16.5 low: 2, high: 31	1 (1.5%)	9 (13.6%)	Last year to last month
Province:	2 (11.7%)	52 avg: 26 low: 23, high: 29	6 (11.5%)	10 (19.2%)	Last year to last month
District:	5 (29.4%)	122 avg: 24.4 low: 19, high: 30	19 (15.5%)	16 (13.1%)	Last year to last month
Facility:	2 (11.7%)	12 avg: 6 low: 1, high: 11	0	1 (9.0%)	Last 12 weeks to last month
Other:	4 (23.5%)	70 avg: 22 low: 4, high: 36	3 (4.2%)	6 (8.5%)	Last year to last month

As shown in Table 5.2 on the next page, over half (58%) of the dashboard instances across the different levels contained more than 19 visualizations. Column charts were the most used presentation format, with line charts as second most. These formats were interchangeably applied to visualize trends over time and, according to user feedback, was the most preferred graphical representation.

Table 5.2: HIV program, frequency and types of visualizations.

Frequency of visualization counts per dashboard:		Frequency of visualization types:	
• 0-4:	3 (17.6%)	• Column chart:	172 (53.4%)
• 5-9:	2 (11.7%)	• Line chart:	58 (18%)
• 10-14:	1 (5.8%)	• Bar chart:	23 (13.5%)
• 15-19:	1 (5.9%)	• Stacked bar chart:	22 (6.8%)
• > 19:	10 (58.8%)	• Pivot table:	10 (3.1%)
		• External text item:	6 (1.8%)
		• Gauge:	5 (1.5%)
		• Stacked column chart:	4 (1.2%)
		• Map:	2 (0.6%)

Male circumcision program

The male circumcision program was considerably larger than the HIV program. In total, it consisted of 64 dashboard instances and covered additional districts compared to the HIV program. At the province and district level, the number of visualizations ranged from 4 to 18 and monitored performance of the last month down to the last week. Province and district-level dashboards were frequently used and required more close supervision to ensure timely reporting from operational level.

Table 5.3: Male circumcision program: Decision templates and discussion forums.

Level:	Number & percentage of dashboards:	Total number of vis. & avg. number per dashboard:	Total number & percentage of vis. with decision template:	Total number & percentage of vis. with discussion forum used:	Period range (fixed and relative):
National:	6 (9.2%)	96 avg: 16 low: 3, high: 31	0	26 (27%)	Last year to last month
Region:	5 (7.6%)	61 avg: 12 low: 4, high: 17	12 (19.6%)	20 (32.7%)	Last year to last 6 months
Province:	11 (16.9%)	154 avg: 13.9 low: 5, high: 18	19 (12.3%)	95 (61.6%)	Last month to last week
District:	43 (66.1%)	400 avg: 9.5 low: 4, high: 11	193 (48.2%)	190 (47.5%)	Last month to last week

Compared to the HIV program; province and district-level dashboards for the male circumcision program registered increased usage of discussion forums and assigned decision templates. Each dashboard had an average of 13 and 9 visualizations per instance respectively. However, the increased usage was reported not to be a cause of dashboards containing fewer visualizations. Rather, it was due to the complexity of tasks and possible actions to take in specific areas and communities. A large portion of the male circumcision visualizations focused on outreach, and community engagement. While the HIV program focused on self-testing services and static sites.

As shown in Table 5.4 below, nearly half (46 %) of the male circumcision dashboards contained less than 14 visualizations. Only national level dashboards contained more than 19 visualizations. Across all instances, the applied presentation formats followed the same pattern as the HIV program. Column chart and line chart were commonly applied to visualize trends over time. Stacked column charts were used to capture the different age groups and visualize parts-to-whole.

Table 5.4: Male circumcision program: Frequency and types of visualizations.

Frequency of visualization counts per dashboard:	Frequency of visualization types:
• 0-4: 4 (6.2%)	• Column chart: 332 (46.6%)
• 5-9: 16 (25%)	• Line chart: 117 (16.4%)
• 10-14: 30 (46.8%)	• Stacked column chart: 106 (14.9%)
• 15-19: 13 (20.3%)	• Bar chart: 70 (9.8%)
• > 19: 1 (1.5%)	• Pivot table: 57 (8%)
	• Stacked bar chart: 28 (3.9%)
	• Map: 1 (0.1%)

5.1.1 Dashboard Design

HIV Program

A dashboard covering Chitungwiza was reported as overwhelming by the user in group 1. Primarily due to its size with a total of 28 visualizations shown on the next page:

> *"The Chitungwiza dashboard is often used, but primarily as an intermediate step to redirect ourselves to the visualization tools. It contains a lot of visualizations."*

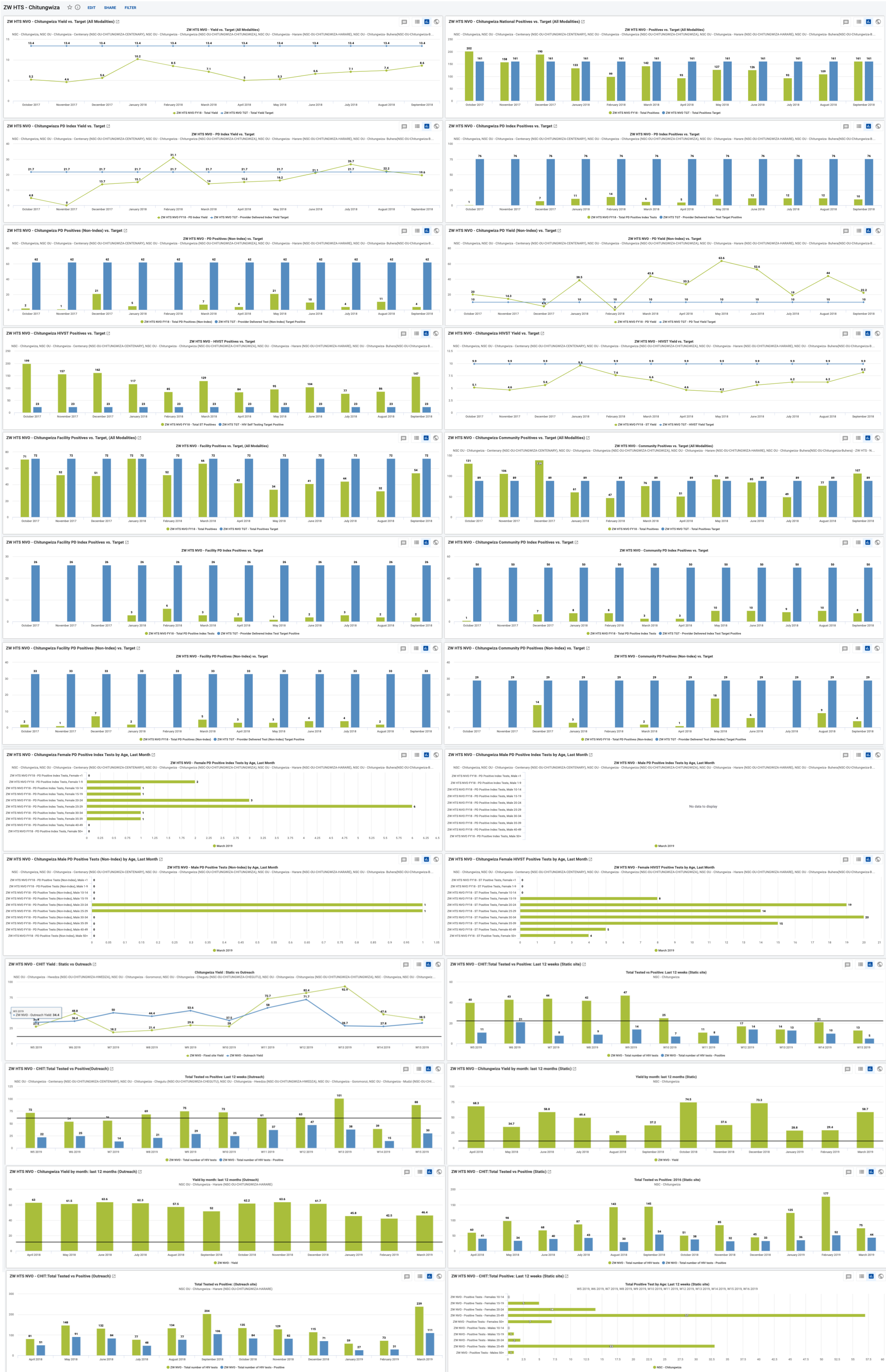


Figure 5.1: Zoomed out picture of the average HIV district dashboard.

Information overload sources from the dashboard

Comparing the layout with similar district-level dashboards showed that the design followed inconsistent placement of the visualizations. Within the HIV program, the number of visualizations varied from each dashboard instance. This behavior indicated to be a common nature for the health program. Some areas have bigger density, with facilities and individual private clinics requiring additional visualizations to monitor performance. However, the first four visualizations were considered the most important by the users. These visualizations were available in all instances but arranged inconsistently. This could result in users experiencing symptoms such as *loss of control over information* when alternating between the dashboards.

Evaluating the applied indicators revealed limitations emerging from DHIS2. To reduce overall information load, I suggested that assigning a target line could provide improved pre-attentive processing, instead of an additional indicator (i.e., blue dimension in Fig 5.2 below). A target line applies a higher data-to-ink ratio in its simplicity, but exhibited limitations. Users were not able to assign a descriptive label, and the black line was not rendered if the values were considerably lower than the target. The column chart at the top in Fig 5.2 was reported to provide a more clear context: *"Each point can be compared more easily. I can also interact with the chart to remove the indicator."* The calculated indicators could also be dynamically updated based on its mathematical expression, but the target lines had to be manually reconfigured.

Figure 5.2: Visualization with indicator as a target (top), and with a target line (bottom).

The third step involved evaluating the dashboard's visualization types. 14 out of 28 visualizations applied fixed periods that had not been updated to include the recent months, effectively visualizing irrelevant information. This resulted in users requiring to redirect themselves to the specific visualization tools and modify the x-axis to see the recent periods. Multiple column and line charts also conveyed the same information by visualizing a trend over time. In a sense, this can be viewed as meaningless variety (Few, 2007, p.51). However, these visualizations were consistently applied across different dashboard instances. Both types are also viewed as an appropriate format to visualize values on an interval scale, when an emphasis on individual values rather than the overall trend is preferred (ibid. p.114). WHO, however, recommends line charts specifically when visualizing data through multiple periods.

The fourth and last step involved evaluating visual cues from labels. The visualizations' assigned name and chart title rendered the same string, which can be viewed as a design mistake of cluttering the display with useless decoration (ibid. p.58). Moreover, due to the amount of aggregated organization units, additional excess clutter was perceived and challenging to read, as shown in Fig 5.3 below.

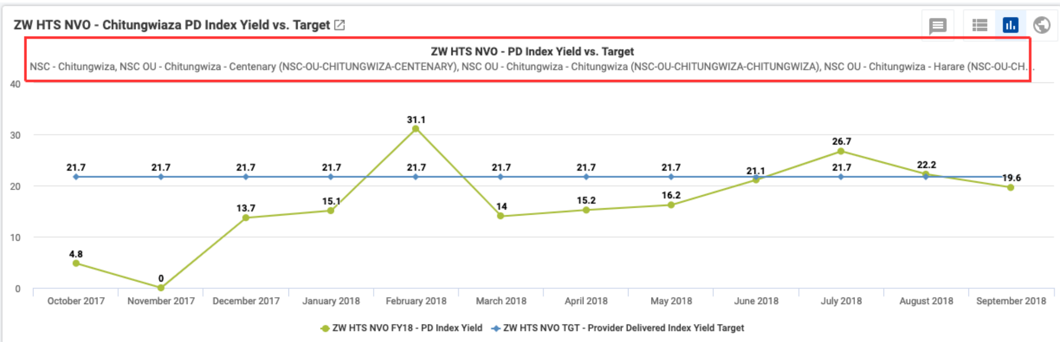


Figure 5.3: Visual clutter in aggregated organization units.

Additionally, one visualization applied a relative period without conveying it through the chart title. The dashboard also contained one visualization that showed no data, and had not been registered new data for the last three months. Interestingly, the discussion forum had not been utilized extensively, with only 3 out of 28 visualizations having at least one periodic update, and 3 out of 28 decision templates assigned as well.

Summarizing the results from the qualitative analysis, the findings were categorized into problem areas. Some areas could be related to sub-optimal design originating from the user, but also limitations from DHIS2 as well. The visualizations had not been updated, in addition to being arranged and configured inconsistently. The dashboard's limitations in displaying excessive information contributed with increasing the information processing requirements, by affecting pre-attentive and attentive processing.

Table 5.5: HIV: Qualitative analysis result.

Problem category:	Description:
Dashboard design	• Inconsistent placement of the most important visualizations. • Exceeding users preference on the amount of dashboard items (max: 15).
Visualization technique problem	• 14 Visualizations with fixed periods, without including recent relevant months. • 1 Visualization with relative trend, without conveying it in the chart title. • Inconsistent use of target line and applying indicators as target. • Visualizations showing the same string for name and chart title.
Data quality problem	• 1 Visualization not registered any new data the last three months.
Dashboard limitations	• 14 Visualizations concatenating multiple organization units, resulting in unreadable long string. • No ability to assign descriptive target line label.

Male circumcision program

A dashboard covering the eastern region was reported as overwhelming by the users in group 2, with a total of 17 visualizations shown on the next page:

> *"The eastern region dashboard displays a lot of information right away, it takes time to digest."*

Figure 5.4: Zoomed out picture of the Eastern region dashboard.

Information overload sources from the dashboard

Following the same procedure, dashboards of similar level were compared. Interestingly, the layout was identical, while also facilitating consistency with the applied presentation formats. In this instance, the reported challenge originated from the dense information by the visualizations' crowded values displayed at the upper part on the previous page.

As shown in Fig 5.5 below, the recommendation proposed by WHO in applying a line chart to display a trend over time, with multiple periods could have been a more appropriate format for the first four column charts, to reduce visual complexity. Reconfiguring the visualizations such that the values were only shown through interaction could reduce the overall information load. However, this was reported as a *"tedious procedure and not always possible because of access rights."* As an alternative, the ability to interact with the chart within the dashboard to toggle the values were highly requested.

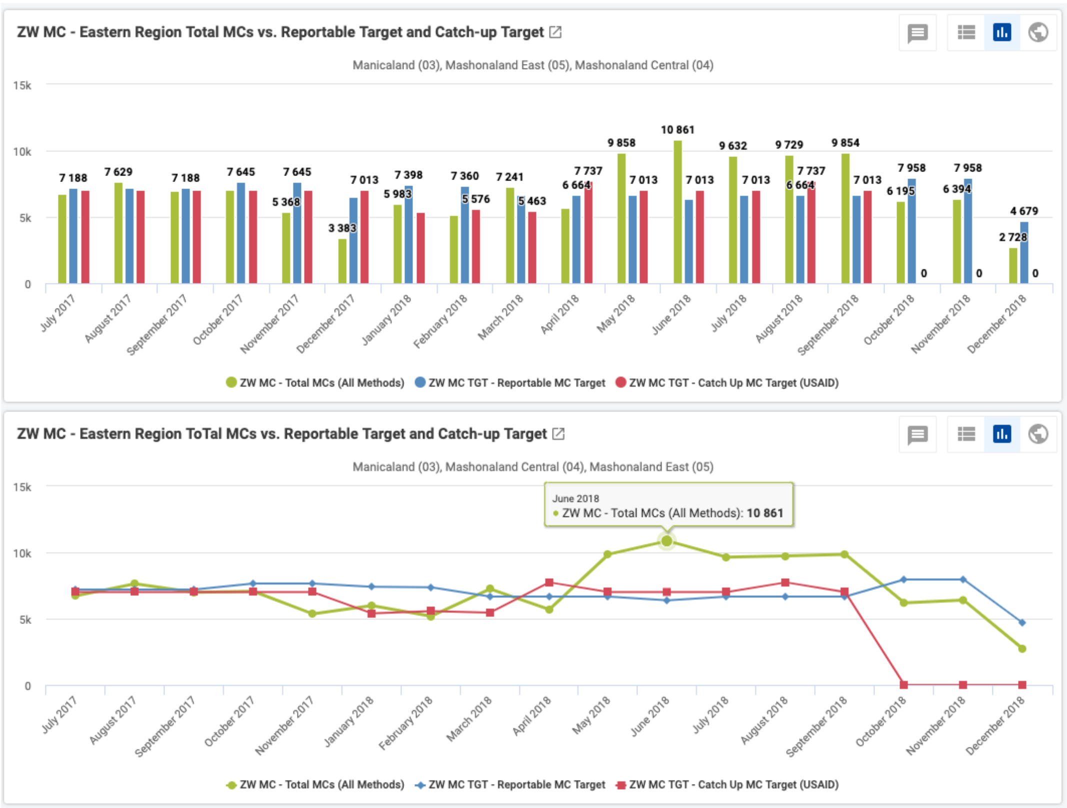


Figure 5.5: Column chart with numeric values (top). Line chart without numeric values (bottom).

The dashboards also contained four visualizations with tabular data and multiple empty values, where only one applied legends to display visual cues. Tabular formats received negative user feedback when multiple cells were empty. One line chart had not been registered data for the last three months. Additionally, four visualizations also applied fixed periods without displaying recent months. By applying fixed periods, users had to navigate to the specific visualization tools and update the visualization for further assessment. Two visualizations applied relative periods without conveying it in the chart title. As the dashboard did not facilitate sufficient filtering or drill-down features, users reported that these visualizations provided somewhat irrelevant information. Summarizing the evaluation:

Table 5.6: Male circumcision: Qualitative analysis result.

Problem category:	Description:
Dashboard design	• Exceeding users preference on the amount of dashboard items (max: 15).
Visualization technique problem	• 4 Visualizations visualizing fixed period without being updated. • 1 Stacked column chart with minimal spread of parts-to-whole correlation.
Data quality problem	• 1 Visualization not registered any new data the last three months.
Dashboard limitations	• 4 Visualizations concatenating multiple organization units, resulting in unreadable long string. • 3 tabular formats with large amounts of cells displaying no data. • 4 Visualizations initially showing crowded values, without possibility to toggle numeric values.

The results could illuminate how the dashboard overwhelmed the user by increasing the information load by displaying excessive details. Moreover, a lack of the dashboard's functional features reduced users' ability to perform evidence-based decision-making from the dashboard directly. The findings are further discussed in chapter 6.

5.2 Thematic Findings

The following section provides findings from observations, feedback, interviews, and surveys. The findings are categorized into the themes mentioned in section 4.4.2 on page 54. By applying the framework proposed by Eppler and Mengis (2002), the findings were analyzed to identify how the applied countermeasures succeeded or failed to alleviate information overload causes. Further, the decision template and discussion forum was evaluated in terms of their role in the decision-making process.

5.2.1 Dashboard Design

The number of visualizations could contribute with the dashboard becoming a source of information overload, as a cause of an *overabundance of information*. At the district-level for the male circumcision program, each dashboard contained a maximum of 11 visualizations. While the HIV program had visualizations at the district-level ranging from 19 to 30 (avg. 24). When comparing the user in group 1 that applied the smaller HIV dashboards; the user in the control group showed symptoms in *limited search directions*, *loss of control over information*, and *higher time requirements for information handling*. In multiple occurrences, instead of utilizing the dashboard, the control group applied the visualization tool to locate charts that was initially available in the dashboard. A countermeasure was performed, by reducing the number of items to a maximum of 15 per instance. This resulted in more control of the information:

> *"It was easier to locate visualizations when the dashboard contained fewer items. The male circumcision dashboards are more user-friendly and less intimidating than the HIV dashboards."*

The two groups who applied the modified dashboards with a maximum of 15 items, used visualizations at the bottom part more frequently, without the need to use visualization tools. By applying a countermeasure in *limiting information, by not thinking more is better*, the symptom of *loss of control over information* was arguably alleviated. The observation confirmed extant literature's principle related to scroll-bars, in that visualizations outside the display screen becomes less valuable and unimportant.

The large dashboards that contained more than 19 visualizations were not used to their full extent. This was observed through the control group that did not apply modified dashboards. In rare occasions, visualizations located at the lower parts of the dashboards were assessed:

> *"When dashboards become too large, it is easier to use the visualization tool and search for the specific chart you want to see. Too many charts are distracting."*

By using the visualization tool, a reactive countermeasure was performed in *filtering out information*. However, the filtering capability of the dashboard was rarely utilized. As these visualizations were present in the dashboard, the symptom of showing difficulties with *identifying relevant information* was observed, and the dashboard's filtering mechanism failed as a countermeasure.

The modified dashboards had the same layout as the users originally applied. Starting with three visualizations in one row; the design largely ended up as it originally was but with a reduced number of visualizations and a spacing item to group related visualizations. Applying some space between related visualizations received positive feedback, acting as a proactive countermeasure:

> *"Increasing the space between the visualizations made it easier to focus on the charts. But this does increase the dashboard size."*

A notable incident after discussing the dashboard layouts with the control group was that the modified dashboards were considered an improvement. Further, the users agreed that the chance of double-checking discussion forums and decision templates would be more likely in dashboards with fewer visualizations.

5.2.2 Information Characteristics

The *uncertainty of information* and *information quality* was additional causes that could contribute to causing information overload. Several dashboard instances had visualizations with incomplete, or no data to display due to network outages and intermittent loss of connectivity. However, some visualizations still showed updated data. This resulted in users assuming that all visualizations could be incorrect and not using the dashboards at all. Indicating symptoms such as *lack of critical evaluation* and *ignore information and be highly selective*:

> *"If a dashboard contains visualizations with no data, I feel the need to double-check with local servers. If it occurs often, we start to doubt if the values are correct."*.

Unfortunately, due to the unstable situation in Zimbabwe, I was not able to initiate a countermeasure for this incident. A proposed alternative was to completely remove the visualizations that did not show any data from the health information dashboard. Although, as this was a common occurrence, the users requested to leave the dashboard design as it was:

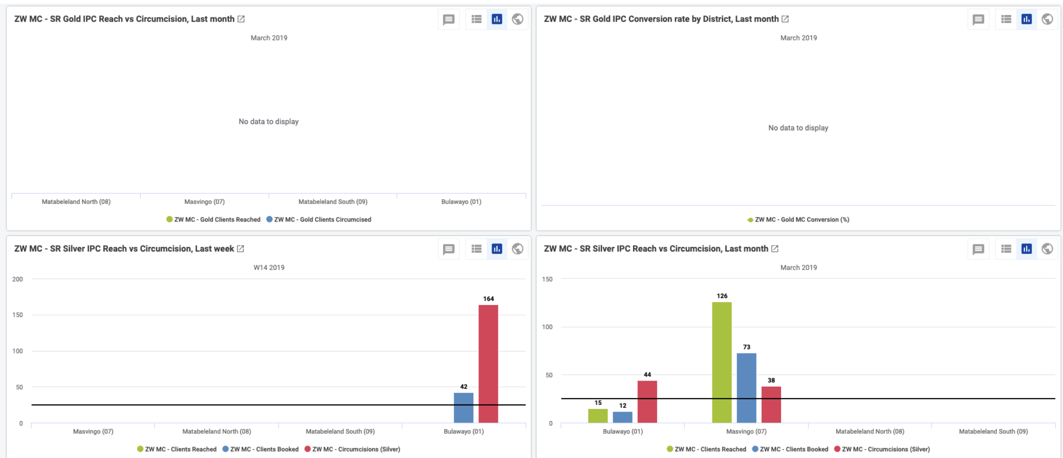


Figure 5.6: Dashboards with partial data.

5.2.3 Usage of Standardized Decision Templates

The standardized decision templates were intended to work as a proactive countermeasure for the large dashboards, as well as a countermeasure for the information quality. Interestingly, users rarely assisted decision-making with the assigned templates, despite showing indications of being overwhelmed. As the result from the quantitative analysis showed, many visualizations did not contain any defined procedures for the user to take. The inconsistent availability of the decision templates had resulted in users not supporting themselves with this countermeasure to reduce the information processing requirements:

> *"Many visualizations does not have any procedures defined. Since they are not always there, it is easier to find possible actions through other means."*

Different opinions were received. The majority of users stated with honesty that they often did not read the templates and discussion forums. The decision templates were reported to be valuable, but the potential alternatives were, to a large extent, considered to be known:

> *"The templates enables us to quickly assess the required actions to take, it varies a lot across different districts and the field workers out there, but we basically know what to do."*

This was confirmed by observing the control group who rarely looked at the decision templates and discussion forum. However, as the users were familiar with the visualizations and procedures on beforehand might suggest that known actions to take were already understood.

Another factor that reduced the potential value of the decision templates was the untimely upgrade of the health organization's global DHIS2 instance. Their previous DHIS2 version had different approaches in terms of formatting rich text and displaying the descriptive label compared to the newly upgraded version. Due to the downtime of network connectivity; priorities of troubleshooting critical equipment within the health system were higher than updating the visualizations that contained a decision template. As a result, when connectivity was re-established and the upgrade complete, these templates were unreadable:

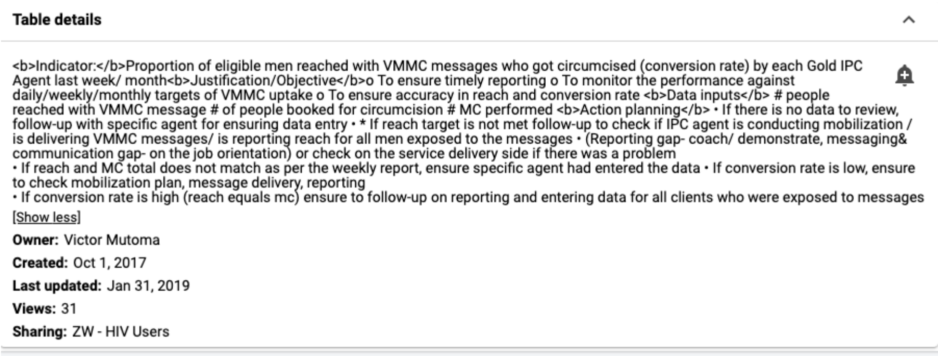


Table details

Indicator:Proportion of eligible men reached with VMMC messages who got circumcised (conversion rate) by each Gold IPC Agent last week/ monthJustification/Objectiveo To ensure timely reporting o To monitor the performance against daily/weekly/monthly targets of VMMC uptake o To ensure accuracy in reach and conversion rate Data inputs # people reached with VMMC message # of people booked for circumcision # MC performed Action planning • If there is no data to review, follow-up with specific agent for ensuring data entry • * If reach target is not met follow-up to check if IPC agent is conducting mobilization / is delivering VMMC messages/ is reporting reach for all men exposed to the messages • (Reporting gap- coach/ demonstrate, messaging& communication gap- on the job orientation) or check on the service delivery side if there was a problem
• If reach and MC total does not match as per the weekly report, ensure specific agent had entered the data • If conversion rate is low, ensure to check mobilization plan, message delivery, reporting
• If conversion rate is high (reach equals mc) ensure to follow-up on reporting and entering data for all clients who were exposed to messages

[Show less]

Owner: Victor Mutoma
Created: Oct 1, 2017
Last updated: Jan 31, 2019
Views: 31
Sharing: ZW - HIV Users

Figure 5.7: Unreadable decision template.

Ultimately, this resulted in producing more visual clutter. As one of my interventions, I spent time updating the templates with the health organization. Although, after this had been corrected, users in the control group did not assist themselves with the decision templates, aside from the user in group one who was instructed to do so. A notable incident related to the user who applied the decision template was that a symptom in *higher time requirements* to process information was observed. However, this could imply that decision-making was performed more thoroughly, and subsequently improved the decision quality.

5.2.4 Usage of Integrated Discussion Forums

The integrated discussion forum offered both positive and negative results in the decision-making process. During the planning meetings, decision-makers went through trouble areas. Through the meetings, decision-makers assessed the discussion forum and initiated capacity building for field workers instead of dispatching additional human or medical resources due to a specific comment:

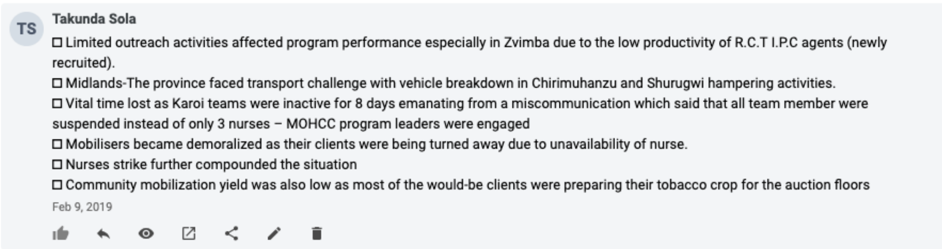


Figure 5.8: Periodic update with helpful information.

These updates helped contextualize the information to facilitate well-informed decisions. Additionally, some periodic updates related to data inconsistencies and incompleteness were also identified. The updates enabled the decision-makers to quickly locate the root cause from data entry instead of lack of resources or efforts in the field:

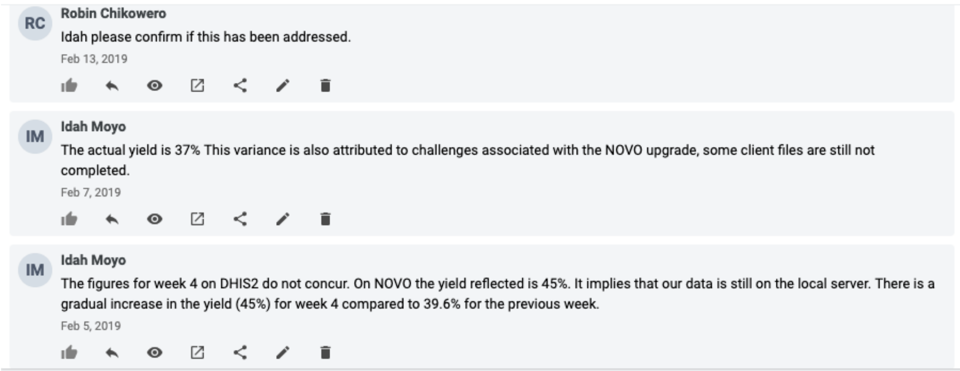


Figure 5.9: Update related to data inconsistencies.

Data collection was significantly reduced during the first and second week due to national demonstrations. The discussion forum served as a key functionality to document these types of incidents with the data. The ability to document sudden changes in close relation to the visualizations enabled users to clarify the root cause in a later period:

"This is one of the reason we are using it. In later events, the updates will explain the performance decrease. Without it, it can be challenging to see."

Some negative results were also observed. The organization had started an internal competition, where the user that had the highest amount of updates posted would be offered a trip to their main offices in Washington. The intention was to encourage data engagement with the DHIS2 software. The competition had started a trend of users documenting irrelevant interpretations and multiple updates with the same content. This could contribute to increasing the dashboard's information processing requirements with an *overabundance of irrelevant information*:

Figure 5.10: Inappropriate use of periodic updates.

As the functional feature had previously lacked key functionalities to enable fluid communication, users had started with traditional communication streams. E-mails and phone calls were still used instead of documenting their discussions within the DHIS2 platform. On several occurrences, when the dashboard users contacted field workers through phone, no periodic update was documented through the discussion forum:

"Documenting periodic updates helps with seeing through the numbers. But in our previous DHIS2 version, the functionality of the discussion forum was poor. A lot of people have stopped using it now. Other DHIS2 users did not receive any updates when new comments were posted, we had to manually check regularly."

A notable incident related to group 1 that applied the discussion forum was the necessity to double check the updates provided through this feature as well as incoming e-mails from program managers and co-workers:

"Checking both the discussion forum and e-mails are tedious. Sooner or later, we stop checking the one or the other and try to figure it out ourselves."

Longer time was often used to evaluate the visualizations as a result of reading through the updates from the discussion forum. However this could imply, just as reading the decision rules, that the decision-making process was performed more thoroughly.

5.2.5 Presentation Formats

Supporting different presentation formats proved to address some of the user's challenges. In almost all cases, simple column charts and line charts were the preferred formats. The charts served as a quick overview, while tabular data were applied when drilling down on the information. However, the users reported that alternating between different charts would increase the value of the dashboard's functional feature, instead of only supporting one specific chart, tabular data and geographic map.

Tabular data was more challenging to interpret when grouped with other visualizations. In the specific visualization tools, tabular data were primarily used. While in the health information dashboard, charts were more popular. Tabular data presented by the dashboard were considered an effective presentation format as long as it offered visual cues with legends through scorecards:

> *"We often export the data and drill-down through Excel. The visualization tools are a bit hard to master. Pivot tables are only useful in the dashboard when they have legends configured."*

ZW MC - Northern Region % of Reportable and Catch-Up MC Target Achieved by District

Period	October 2018					November 2018					
Organisation unit / Data	ZW MC - Total MCs (All Methods)	ZW MC TGT - Reportable MC Target	ZW MC TGT - Catch Up MC Target (USAID)	ZW MC - % of Reportable MC Target Achieved	ZW MC - % of Catch-Up MC Target Achieved	ZW MC - Total MCs (All Methods)	ZW MC TGT - Reportable MC Target	ZW MC TGT - Catch Up MC Target (USAID)	ZW MC - % of Reportable MC Target Achieved	ZW MC - % of Catch-Up MC Target Achieved	ZW MC - Total MCs (All Methods)
Harare (0202)	3 197	3 200	0	99.9		2 425	3 200	0	75.8		1 774
Kwekwe (1057)	732	1 004	0	72.9		431	1 004	0	42.9		235
Zvishavane (1060)	31	0	0			50	0	0			27
Chirumhanzu (1053)	63	220	0	28.6		54	220	0	24.5		0
Shurugwi (1059)	89	0	0			20	0	0			35
Gweru (1056)	919	1 763	0	52.1		711	1 763	0	40.3		424
Gokwe North (1054)	377	417	0	90.4		364	417	0	87.3		211
Zvimba (0631)	224	0	0			56	0	0			275
Makonde (0630)	519	800	0	64.9		890	800	0	111.3		652
Hurungwe (0627)											

Figure 5.11: Tabular data with visual cues.

Stacked column chart and stacked bar chart were both positively and negatively received as an appropriate presentation format for the health information dashboard. The user feedback confirmed the arguments stated by Few (2007, p.116) and United Nations. In that, column or bar charts were more suitable when the spread of each value was not significant:

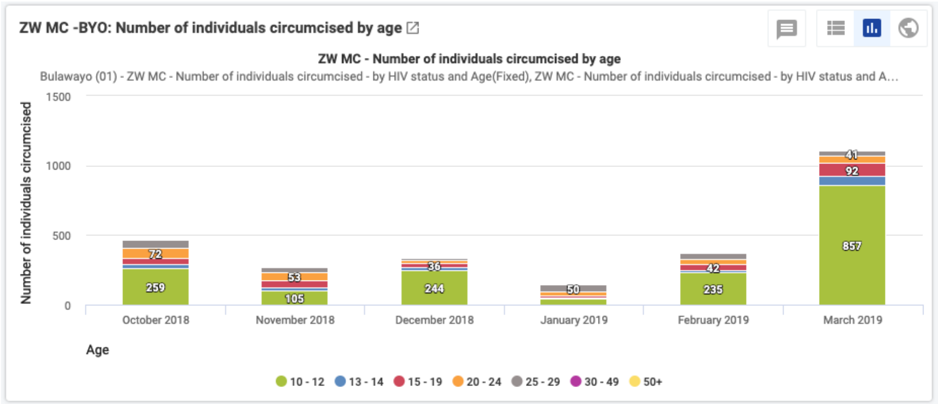


Figure 5.12: Stacked column chart with minimal spread.

As the spread of each value within one column would often vary, users emphasized the need to support alternating between different charts, instead of manually changing the format within the visualization tool. Ultimately, the countermeasure in *the use of graphs* served more useful in the dashboard, than visualizing information through tabular data.

Using consistent visualizations when conveying the same information gave both positive and negative feedback:

> *"I get that line charts is best to see values over time, but for me column charts are still easier to interpret."*

> *"I agree that line charts should be used to see values over time, as long as it is consistent with the indicators that are used in the dashboard."*

The survey for evaluating the preferred presentation formats followed WHO's four categories. In addition to the test subjects, four other DHIS2 users at the strategic level participated. To clarify the categories, WHO's presentation formats were shown to the user during the survey. DHIS2's available presentation formats were the different alternatives:

Table 5.7: Survey result for preferred presentation format

Comparison:	Distribution:	Composition:	Relationship:
• Column chart: 4 • Line chart: 4 • Bar chart: 1 • Pivot table: 1	• Column chart: 4 • Pivot table: 2 • Bar chart: 1 • Pie chart: 1	• Stacked column chart: 3 • Stacked bar chart: 2 • Pivot table: 2 • Pie chart: 1	• Column chart: 6 • Bar chart: 2

The survey was consistent with the frequency of visualization types from the quantitative results. Simple formats in line charts and column charts were primarily seen as the most appropriate visualization type.

5.2.6 Dashboard Limitations

Visualizations with dense information and multiple values as the column chart shown in Fig 5.5 on page 68 were reported to overwhelm the user. Displaying numeric values within the dashboard was preferred by some users. However, the ability to interact with the visualization to toggle the values were highly requested and seen as a limitation:

> *"Seeing so much numbers and values requires concentration. If we could toggle the values by clicking on the chart, it would be an improvement ."*

The filter functionality of the dashboard was reported to not be of much value and ultimately failed as a reactive countermeasure:

> *"The dashboard filter does often not filter out the irrelevant information. If we could filter or drill down on the visualization, it could become easier. "*

The modified dashboards initially applied visualizations with target lines instead of additional indicator dimensions. The target line applied improved data-to-ink ratio and reduced visual clutter. However, applying indicators offered improved context as the current DHIS2 version showed limitations in not being able to assign descriptive labels, or update itself dynamically:

> *"Target lines creates a more simple charts in terms of colors. But sometimes its also nice to see the specific indicator as a target to compare with."*

Lastly, the ability to switch between the most common presentation formats were highly requested and reported as a limitation for the dashboard:

> *"Supporting multiple presentation formats could improve the dashboard. Clicking on a simple button is often easier than applying the visualization tools."*

5.3 Summary

The dashboards were primarily used to monitor performance at district and province level. The quantitative and qualitative analysis showed that decision templates and discussion forums were rarely defined and used. User feedback confirmed that this was a result of inconsistent availability of decision templates. The discussion forums previously lacked functionality that could enable social collaboration and periodic updates relevant to the decision-making process. This resulted in users gradually moving back towards standard communication streams. However, some incidents showed that the discussion forum improved the decision-making process by contextualizing the visualizations' values.

The qualitative analysis and thematic findings identified design mistakes from the user as well as limitations from DHIS2's dashboard. The upper limit of maximum visualizations was reported to be 15 visualizations. Dashboards containing a higher amount resulted in users not interpreting visualizations at the lower parts of the instance. The initial impression of the dashboard design affected pre-attentive and attentive processing. Inconsistent placement of the most important visualizations displayed at the top part was reported to cause confusion. Initially displaying visualizations with crowded numeric values was reported to overwhelm the user. The ability to toggle values through interactivity could have reduced the information load. Further, the filtering mechanism was of little value and was reported as sub-optimal. This resulted in users applying specific visualization tools more often than the dashboard.

Simple presentation formats in column and line charts were the most preferred visualization types. Additional indicator dimensions were applied instead of target lines as users were unable to assign descriptive labels. This resulted in increased visual complexity but was reported to provide improved context. Repetitive chart names and chart titles, as well as aggregated organization units, cluttered the presentation formats. Adding a spacer item to group related visualization addressed this problem. Lastly, presentation formats that displayed no data due to connectivity issues resulted in users questioning visualizations within the dashboard instance. Dashboards with a portion of presentation formats displaying no data contributed with producing information overload.

Chapter 6

Discussion

This chapter offers a discussion around the case study, presented literature, and attempts to answer the research question based on the study's findings. First, I discuss the sources of information overload, and the value the decision templates and discussion forums offered as countermeasures. Then, in light of the findings, I answer the research question: *What essential features must a health information dashboard facilitate to enable evidence-based decision-making, without causing information overload?* The question is answered by providing a set of recommended design guidelines. The chapter ends with my reflections upon the study.

6.1 The Causes of Information Overload

The use of decision templates and integrated discussion forums have the potential to address some causes of information overload that can emerge from the dashboard. However, despite applying these countermeasures, empirical findings indicated that users still experienced information overload. Both as a result of a challenging design originating from the user-designed dashboards but also the application's lack of features.

Lack of interactive features and challenging design

The study revealed that dashboards monitoring performance at the province and district level were the most used instances. The national level dashboards covered broad areas with summaries from Zimbabwe or its provinces. However, these instances were rarely used compared to the lower levels. Decision-making occurred more frequently by interpreting visualizations for the province or district level, which aggregated data from multiple clinics or communities. Province and district level instances can be viewed as analytical dashboards, and according to Few (2006, p.32), should support interactivity that enables drilling down to underlying details. As DHIS2's dashboard did not facilitate these capabilities, the presented information was perceived as either overwhelming by being too static, or irrelevant as the user could not filter or investigate information further through the dashboard. Interactive features improve the interpretation process by increasing the user's information processing power (Zakkar and Sedig, 2017).

Dashboards with crowded numeric values presented by multiple visualizations could increase the information processing requirements and was reported as overwhelming. Not supporting details on demand through interactivity required users to manually reconfigure the visualization to reduce the amount of information being presented. Due to tedious reconfiguration steps, the visualizations ended up displaying everything at once. Simplicity should be emphasized as dashboards already contain a dense amount of information. Simple graphical formats have been viewed as a key factor for balancing information load and information use (Senyoni et al., 2019). Whereas details on demand through interactivity can contribute to further improved interpretation processes (Concannon et al., 2019; Al-Hajj and Pike, 2013). Ultimately, not supporting these features identified through literature rendered the dashboard as overwhelming. This required users to apply the specific visualization tools more often to filter out irrelevant information.

Task interruptions and redundancy systems

The causes of information overload originated not only from the dashboard itself. Outside of the dashboard, task interruptions were consistently observed and are one of the potential causes for experiencing information overload (Eppler and Mengis, 2002). Multiple times during the case study, DHIS2 users were required to stop their work and help others. Continuous interruptions could explain why standardized decision templates were adopted to assess the possible actions to take quickly. Providing incentives and memory cues of potential actions could also alleviate some of the required collaboration. Although, because these templates were not always available, it was rarely used. The possible actions were also considered to be known. However, the need for interrupting co-workers to assist interpretation and decision-making could suggest otherwise. Further, keeping up with all the redundancy technologies that attempted to ensure data collection quality also caused information overload.

To make up for the unstable network in Zimbabwe, a local server was used. The server was consistently applied to compare and assess the information presented by DHIS2 applications. This meant another source of information required to keep up with for the dashboard users. Overly complicated technology, poor integration of various technologies, and over-reliance on technology are all known causes of information overload (ibid.). Relying on both the redundancy and DHIS2 showed that users experienced symptoms such as *ignoring information* and *lack of critical evaluation* when inconsistencies occurred in some of the dashboard instances. This resulted in users not utilizing the dashboard to interpret unrelated visualizations. The technologies that were intended to improve data quality to facilitate well-informed decisions, ultimately impacted decision-making negatively in itself. Given that DHIS2 already have mechanisms to assess data quality, a balance must be found that ensures quality data and simultaneously enables the ability to enforce well-informed decisions.

Communicating some aspects of decision-making is appropriate through the discussion forum, while other aspects have its place through mediums such as e-mail. Managing e-mails and discussion forums without standardized communication strategies can increase the chance of experiencing information overload (Ruff, 2002). Increasing the number of ways to communicate with each other has shown to cause *communication overflow* (Ljungberg and Sorensen, 1998). The concept focuses on communication rather than information and occurs when individuals are subject to large amounts of communication that is partly desirable. Communication occurring through e-mails, phones, and discussion forum has a chance of producing communication overflow which impacts the cognitive ability to process information. E-mail is an asynchronous communication stream (Edmunds and Morris, 2000). Asynchronous communication implies that the person will not have increased information processing requirements before he or she acts on it. With this in mind, one might question the value of the discussion forum, as *introduction of more technology than is required* can increase the chance of experiencing information overload (Eppler and Mengis, 2002).

6.2 The Value of Integrated Discussion Forums

Nutley (2010) found that a barrier for data-use to facilitate evidence-based decisions is insufficient skills to analyze and interpret the collected data. The author proposed capacity building for data analysis to promote information use. Sandiford et al. (1992, pp.1084-1085) argued that because capacity building often takes place in decontextualized settings like North American and European universities, the knowledge is often difficult to take back and incorporate it into the organization's work processes. Suggesting that capacity building will only help to some degree in terms of training DHIS2 users to make sense of the data, and translate it into well-informed decisions. As these discussion forums promote the use of the health information dashboard, the increased data engagement will assist decision-makers with familiarizing themselves with the information being presented and subsequently increase the information use.

Increased Data Engagement

An important problem re-occurring in developing countries is that information with poor data quality is rarely used, and because it is not used, it remains of poor quality (Braa and Sahay, 2012b, p.39). Anomalies and errors are rapidly detected once the information is being used (Sandiford et al., 1992, p.1083). As the discussion forum encourages data engagement, the information is more likely to be assessed. In that sense, regardless of the data being acted upon, it is being used. This implies that data inconsistencies or errors are more likely to be detected and corrected through discussion within the dashboard application, which was observed during the case study. As shown in Fig 5.8 on page 73, the discussion forum served as a tool to both identify data inconsistencies and correcting the error. This particular incident could have been identified through standard communication streams such as e-mail or phone calls. However, since the information was accessible through the dashboard; knowledge on the application, the nature of the information and the behavior of the presentation formats were arguably improved which shows the value it can provide.

Interpreting visualizations and translating the information into well-informed decisions are often done through social interactions (Heer and Agrawala, 2008). Integrating embedded discussion forums could benefit visualization tools more than face-to-face collaboration, as discussions directly placed with the visualizations deepen understanding and subsequently improve decision-making. As data literacy can vary in developing countries, integrated discussion forums serve as a tool to strengthen the dashboard's ability to facilitate decision-making. Enabling collaborative efforts when performing data analysis and interpretation of visualizations that are subject to poor data quality can improve the decision-making process (Braa et al., 2012).

Adding Additional Context

Previous incidents that caused deviations on the performance of health programs were documented *with* the data. In meetings, when going through the monthly results, updates posted within the discussion forum were often referred to. A notable incident was a documented discussion of the previous month, where the generated visualization indicated a decrease in performance. In most cases of performance decrease, the root cause originated from data entry, but also administrative causes such as challenges with transport or lack of resources. This was quickly assessed by referring to the comments in the discussion forum, as shown in Fig 5.8. Exploring further clarifying information within the discussion forum improved work efficiency. Instead of investigating e-mails or performing extensive drill-down procedures, the periodic update was quickly assessed. Thus, applying the discussion forum in this fashion can increase knowledge of the health information dashboard and its ability to facilitate well-informed decisions. Contextualizing the values through periodic updates provides additional context that users can draw parallels towards and subsequently understand the nature of the information.

Increasing information load through social interaction

Surprisingly, the quantitative analysis indicated little use of the discussion forum. No additional conditions were taken into consideration when registering the use of discussion forums (e.g., exclude updates older than one year). In DHIS2, comments are permanently stored when they are posted. The findings suggested that a low amount of communication had been performed since the creation of the applied visualizations. To spark the movement of transitioning relevant updates from e-mail to the discussion forum; an internal competition had been initiated. As a result, some visualizations contained irrelevant information, and inappropriate use of the discussion forum had emerged. When investigating previous discussions related to a visualization's deviating results, some irrelevant comments were required to be processed. This increased the information load and impacted users negatively. As a dashboard already contains a dense amount of information, these comments can be considered excess clutter.

6.3 The Value of Standardized Decision Templates

Ogega (2017, p.73) identified a lack of standard guides, procedures, and processes as one of the challenges of data use through his case study on applying visualization tools in developing countries. Lippeveld et al. (2000, p.41) argued that the more formalized the decision is, the more likely the information will be used. Further, precise definitions of the actions to take and clarification that the actions make sense will promote further use. The more routine the decisions are, the more likely they will be based on the information.

In health programs that potentially cover an entire country, dashboards are applied to centralize important information from different levels of the health system's hierarchy. The composition of the various levels (e.g., national, province, district) may vary in terms of patients, health workers, hospitals, and resources. In turn, different targets and potential actions to enforce will vary with them. Reducing the complexity of the decision-making process with clearly defined goals and actions to take may improve both work efficiency and decision-quality (Eppler and Mengis, 2002). Especially when task interruptions and technical difficulties occur. However, as the empirical findings showed, following guidelines at all times are not a guarantee after they are defined. Inconsistent availability of decision templates resulted in users not supporting themselves with the guidelines. However, as previous research has emphasized the need for standard procedures (K. Stansfield et al., 2006, p.1023), as well as it being proposed solution for information overload (Eppler and Mengis, 2002), I argue that the value of decision templates improves the dashboard's ability to facilitate decision-making.

Reducing the complexity of decision-making processes

Interpreting visualizations involves applying short-term memory for pre-attentive processing, long-term for attentive processing, and cognition to arrive at a decision. These processes have their limitations that decision templates can support. Providing memory cues to aid short-term memory can reduce the complexity by guiding the user towards possible directions based on the visualization's values (Patterson et al., 2014). Standardization can also strengthen the decision-making process of future incidents as the process becomes more formalized.

As previous research has identified a lack of decision-rules and guidelines as key challenges for decision-making; findings from this study suggest that regardless of it being defined, integrating it into the decision-making process is challenging to realize.

6.4 Health Information Dashboards in Developing Countries

Previous studies have shown that one of the benefits health organizations receives when applying dashboards in developing countries, are improved data quality through timely reporting and completeness of routine health data (Etamesor et al., 2018; Concannon et al., 2019). However, to ensure improved data quality, dashboards must provide easily digestible information. Senyoni et al. (2019) investigated the adoption of dashboards for health organizations in Tanzania. From user feedback, they found that simple design without excess information was a driving factor. To address the design challenge of dashboards serving as useful for a diverse user base; a participatory approach was emphasized. The need for a simple design was identified in this study as well. The boundary between a design viewed as simple, but yet information rich are to a large extent defined by the different users that applies the dashboard. To identify this boundary, following user-centered design approaches have been proposed (Concannon et al., 2019).

Dashboard templates provided by WHO contains visualizations ranging up to 24, an amount that resulted in overwhelming the user. However, limiting the visualizations such that it is manageable for every user is often not possible in developing countries. The programs can potentially become too large in terms of available workers to divide the visualizations into small, organized dashboard instances. As WHO's recommended amount was tested in practice and overwhelmed the users suggests that new guidelines specific for dashboards in the context of HMIS are needed.

In light of the empirical findings and analysis of the dashboards that were perceived as overwhelming, we can identify causes for information overload as well as how the dashboard can address the problem. Adopting the revised definition of a dashboard offered by Yigitbasioglu and Velcu (2012), I argue that, essential features a health information dashboards must facilitate to enable evidence-based decision-making, without overwhelming the user, is a limited set of *functional* and *visual* features.

DHIS2's dashboards facilitates a generic nature such that it can serve a broad user group. The tension between designing generic systems to be applicable on a global level, while also serve useful in the local context has been identified as challenging to address in previous research but emphasized as a key development priority for DHIS2 (Nicholson et al., 2019). One factor is that generic software requires further customization to be locally adaptable. The following guidelines are targeted towards dashboard developers, such as DHIS2 core developers, to implement features that fit the generic nature of the dashboard application, while also facilitating local adaptability.

6.4.1 Essential Functional Features

A dashboard's functional features describe directly what the application can do. This section provides essential functional features that a health information dashboard should support in order to address the information overload problem. First, a description of the recommended features is given before it is summarized and presented through a table.

Discussion forum with filter

Data sets with incomplete or partial data will remain of poor quality without it being used (Braa et al., 2012). Thus, I argue that the dashboard should display visualizations with partial data. Addressing the challenge of inconsistent data collection or incompleteness can be done in multiple ways, such as contextualizing the incidents through social interactions, as mentioned in section 6.2. Integrated discussion forums are already implemented in DHIS2's dashboard, and its use and value have been identified through the case study. However, it will only help balance information load and assist with decision-making, when it is adopted specifically for adding further context to the data, or providing periodic updates on the performance situation. Designing a discussion forum that maintains appropriate use can be done by categorizing posted updates with a visual cue, such as tags or labels (e.g., request for action, or action dispatched). A filter mechanism can thereof remove irrelevant comments. However, this feature is optional and not regarded as essential in order to enable decision-making directly from the dashboard.

Description Template

Default decision templates have the potential to address the information overload problem. By defining common or specific goals, and potential actions to take; decision templates can be applied in different use-cases and reduce the complexity of decision-making processes. Upon creating a visualization, or adding one to the dashboard, a template should be available to define the objective, and possible actions to take based on the visualization's status.

Warning Message

The amount of visualizations a dashboard can contain before information overload occurs depends upon the user's information processing capabilities. During my literature review, I argued that ten visualizations should be a maximum for each dashboard instance as this was WHO's recommended amount for national HIV coverage[1]. However, even ten visualizations can result in causing information overload through the multiple dashboard instances they are divided into, causing symptoms such as *loss of control of information.* Increasing the maximum to 15 visualizations per user's requests, I observed improvement and received positive feedback. As such, I base this recommended value upon my observations and feedback from the field. If additional visualizations are added to a dashboard, a warning message should be displayed.

[1] See WHO's dashboard templates for DHIS2: `https://who.dhis2.org/demo/dhis-web-dashboard/#/q9qKbXTDgEh`

Focus, Filter and drill-down capabilities

Previous studies have mentioned that a dashboard could benefit from offering two distinct pages. The initial *view page* should display the dashboard with the arranged visualizations. The second page should enable focusing on a specific visualization, through an *analysis page* (Concannon et al., 2019; Al-Hajj et al., 2013). Focusing on specific visualizations will improve attentive processing. Especially with tabular data with high amounts of cells, which was considered sub-optimal in the dashboard. Providing a focus capability will remove irrelevant information. After a visualization is focused, additional interactive buttons should be available that enables drill-down mechanisms and toggling between presentation formats.

While observing the users; minimal use of the dashboard's filtering mechanism was registered. This was reported to be of little value as it only filtered organization units. Filtering information is a proposed solution to cope with information overload and should be facilitated (Green, 2016). I argue that this functional feature is an absolute necessity as it reduces the information load and promotes positive feedback through interactivity. An improvement for the DHIS2 dashboard's filtering mechanism could be to enable filtering on different or multiple indicators, periods, labels or presentation formats.

Further, as drill-down features are currently not supported by DHIS2's dashboard, the application's limited functional features failed to balance the information load through interaction. Enabling interactivity through drill-down features are a necessity to encourage data use and exploration (Zakkar and Sedig, 2017). A static page with dense information will often overwhelm the user. This functional feature has been proposed as a key solution for addressing information overload (Saxena and Lamest, 2018; Yigitbasioglu and Velcu, 2012). An improvement for DHIS2's dashboard is to provide this capability despite it being available in the visualization tools.

Option to hide or move header bar with logo

Renown BI software vendors recommended that dashboards should not display header bars or logos, as it takes up valuable real estate. The visualizations at the uppermost part of the dashboard are processed first and should be the most important. This study revealed that DHIS2's dashboard, in most cases, contains a scroll-bar. To increase the overall space; an interactive button can offer the ability to move or hide the header bar and logo.

Priority Placement

Creating multiple dashboard instances will help organize visualizations according to different locations or levels of the health system. Standardization of the dashboard design should be emphasized to reduce information processing requirements. This will ease the task of locating specific visualizations when alternating between dashboard instances. By assigning a priority placement value to a visualization, the dashboard can validate the arrangement such that it follows recommended placement. This feature will encourage consistent arrangement such that visualizations occupy the same row and column.

Re-arrangement, Spacing, and grouping

The dashboard should support re-arrangement capabilities for user-designed instances. Spacing and grouping capabilities provided positive user feedback. This functional feature will increase pre-attentive and attentive processing by enabling users to maximize Gestalt principles.

Multiple Presentation Formats

Lastly, the ability to switch between presentation formats served useful. However, the alternatives (i.e., tabular data and geographic map) were the least preferred presentation formats. The ability to switch between different charts promotes interactivity, which can maintain the balance between the amount of information a health information dashboard contains and the information processing capabilities of users situated in developing countries. With these functional features, the visual features of the health information dashboard can, in turn, facilitate the perceptual and cognitive aspect of decision-making.

In light of the empirical basis and findings, as contribution, I provide the following functional features as essential for a health information dashboard to support, in order to address the information overload problem:

Table 6.1: Essential functional features for a health information dashboard.

Functional Feature:	Description:
Discussion forum with filter (optional)	Users should be able to categorize and filter periodic updates based on configured categories.
Description template	When adding a visualization, the dashboard should provide an option to assign a template and specify objective and actions. It should notify users when a visualization is added without one, to encourage consistency.
Warning message	The dashboard should display a message when it contains visualizations exceeding the configured maximum value (max 15 recommended).
Focus capability	Users should be able to expand and focus on a visualization.
Filter capability	The dashboard should be able to filter visualizations based on different parameters.
Drill-down capability	After focusing on a visualization, users should be able to drill-down to specific periods or organization units.
Option to hide or move header bar with logo	The dashboard should be able to move the header bar or logo for increased space availability.
Priority placement	Users should be able to assign priority placement of visualizations, to enable consistent placement across similar dashboard instances (e.g row placement or number placement).
Re-arrangement	Users should be able to arrange the dashboard layout according to their preference.
Spacing and grouping	To assist pre-attentive processing, enable spacing and grouping capability to utilize gestalt principles.
Multiple presentation formats	The dashboard should support toggling between multiple presentation formats.

To summarize, discussion forums can improve decision-making, if it provides visual cues to quickly locate relevant information, or filter out irrelevant comments. Description templates can reduce the complexity of translating information into well-informed decisions. A dashboard should provide two pages, or *view* modes. The first page should display an overview of the dashboard with the added visualizations. The second analysis page, should provide further interactive capabilities for data exploration. The analysis page should support drill-down features, and alternating between multiple presentation formats.

6.4.2 Essential Visual Features

Similar to functional features, visual features must consist of a limited set. Too many visual cues will generate excess clutter and will consequently overwhelm the user. While too few will render the interpretation process challenging. To assist with the interpretation process; a dashboard must maximize the power of visual perception and cognition. This can be achieved by offering visual features, which refers to how efficiently information is presented to the user. In developing countries, the required information literacy to use the dashboard cannot be taken as a given. In order to convey information effectively, the dashboard designer must possess data visualization knowledge such that the appropriate presentation format is applied. However, choosing the right presentation formats is not always enough. This section provides essential visual features specifically aimed at addressing information overload.

Simple presentation formats and details on demand

Visualizations with crowded, numeric values overwhelmed the user. I argue that, in the dashboard, visualizations should initially not display numeric values but allow toggling the values through interaction. In DHIS2, hiding numeric values is a manual process through the visualization tools. An improvement could be to enable toggling through interaction, instead of requiring users to redirect themselves to the specific visualization tools and reconfigure the presentation format. Additionally, dynamic target lines will reduce the overall visual clutter instead of an additional indicator. DHIS2 can be improved by forwarding the calculated indicator value into the target line value as it applies a higher data-to-ink ratio in its simplicity.

Modifiable Color Coding

Intuitive and natural color coding should be applied when rendering visualizations while emphasizing the usage of green, yellow, or red to visualize good, medium, or poor performance (Dowding et al., 2015; Wilbanks and Langford, 2014). A notable aspect in DHIS2 is that the color green is always used, and the color red will be applied if there are three or more different items displayed. Red or green should only be rendered if it indicates relatively good or poor values. This is a limitation that originates from DHIS2's internal charts API. *HighCharts* supports the changing of color coding, an improvement for DHIS2 could be to reflect this capability to the users. Visual cues are essential to couple with the appropriate presentation format, but users should be able to interpret visualizations without the use of colors.

Tool tips, Grid-lines and High data-to-ink ratio

By following simple presentation formats, tooltips that are activated when the mouse is hovering over the specific values can balance information load and information use. Grid lines will assist in visual perception. Whereas a high data-to-ink ratio will reduce overall clutter.

Label Validation

Another aspect of unnecessary information was the chart name and chart title rendering the same string. A dashboard must convey a clear story that is easy to digest. Repetitive titles, as shown in Fig 5.3 on page 65, is redundant. Too many details produce visual clutter that will affect pre-attentive processing negatively. This is a design guideline that users should be aware of and is achievable through documentation or implementation changes. As the health information dashboard already contains a dense amount of information, excess clutter will add up and increase the chance of users experiencing information overload. If the descriptive labels are identical, one of either should be displayed.

Dynamic Labeling

Excessive information in displaying multiple organization units increases the information processing requirements. Visualizations that displays aggregated data from 3 or more sources (e.g., organization units) should instead display a number. With a tooltip, additional information can be retrieved that describes the specific dimension items that are aggregated into the visualization.

Taking these considerations into account, I recommend that the essential visual features for a health information dashboard are:

Table 6.2: Essential visual features for a health information dashboard.

Visual Feature:	Description:
Simple presentation formats	Visualizations should initially display the encoded graphical data, without specific numeric values.
Details on demand	Users should be able to interact with the visualization to toggle additional details in specific numeric values.
Modifiable color coding	Users should be able to modify a visualization's color coding.
Tool tips	Visualizations should provide tool tips when the mouse is hovering above the encoded graphical data.
Grid-lines & Maxmimize data-to-ink ratio	Visualizations should support grid-lines and maximize data-to-ink ratio.
Label validation	Users should be able to assign a title and subtitle to contextualize the visualization. Visualizations should omit identical titles and subtitles (i.e., render one of either).
Dynamic labeling	When more than 3 items (e.g. organization units) are aggregated into a visualization's filter dimension, a numeric value with the total count should be displayed. A tool tip should provide further details of specific dimension items.

6.5 Reflections upon the study

Limited use cases

Various users with varied technical knowledge apply the health information dashboard. This study focused on dashboard users that applied the application regularly, with limited knowledge of DHIS2. Different users focusing on applying the dashboard at the national level may require reduced functionalities or more. The DHIS2 dashboard fits the description of all dashboard categories stated by Few (2007) (i.e. strategic, analytic, operational). Thus, the study could have captured additional insight and understanding through observations of multiple dashboard users, focusing on all levels of the hierarchy.

Language Barrier

In the context of HMIS, decision-making processes often involve communication with co-workers or personnel from other organizations. In Zimbabwe, the native language is *shona* which I have no knowledge of. Decisions may stem from collaborative efforts that are difficult to assess when there exists a language barrier. Particular incidents could have been subject to misinterpretation. However, to address the language barrier, I regularly asked for feedback on the decision-making process.

6.5.1 Challenges with conducting field work

IS research in developing countries often proves difficult as the context of the research focus has a chance to be affected either by unforeseen obstacles or from the available resources that make up the installed base. During my case study, different challenges emerged due to the unstable situation in Zimbabwe. These challenges affected the field work in different ways and limited my ability to conduct my action case study.

Protests and Riots

Upon my arrival, the government had increased the tax on petrol by 150 percent, making Zimbabwe one of the countries with the most expensive fuel prices in the world (Reuters, 2019a). As the population already lived in severe poverty, citizens initiated demonstrations that resulted in looting and riots. As a countermeasure, the military controlled the looters and rioters with violence, which resulted in deadly consequences. To suppress potential videos of violent incidents between civilians and the military circulating social media, the government blocked incoming and outgoing internet traffic throughout the entire country (Reuters, 2019b). This resulted in downtime for daily businesses, which also affected PSI's daily work routines and ultimately halted my research.

The first week of my stay, business was shut down on a national scale due to the demonstrations and the loss of network connectivity. The following week, network traffic was re-established. However, since the data warehouse had not been receiving any new data, the dashboards were not updated. At this stage, PSI was also performing an upgrade on their DHIS2 instance to the latest version. Due to loss of connectivity; smartphones, tablets, and computers required extensive troubleshooting to re-connect with the newly upgraded DHIS2 version. In addition to the gas price being raised, the fuel stations had limited or no petrol available. This, in turn, impaired public transport used by the field workers for data collection and patients wanting to visit clinics and hospitals. As a result, the available data from the various reporting schemes were reduced.

Unstable Network Connection

In the wake of the civil unrest, business went back to usual. However, the general network quality for offices in Zimbabwe is poor. The country has fiber optic cables inter-connected with nine other countries. Despite this, packet loss is substantial, and the overall uptime is unstable. Averaging two days a week; the network was down for most of the day which disconnected PSI's users with the back-end server located in the United States of America.

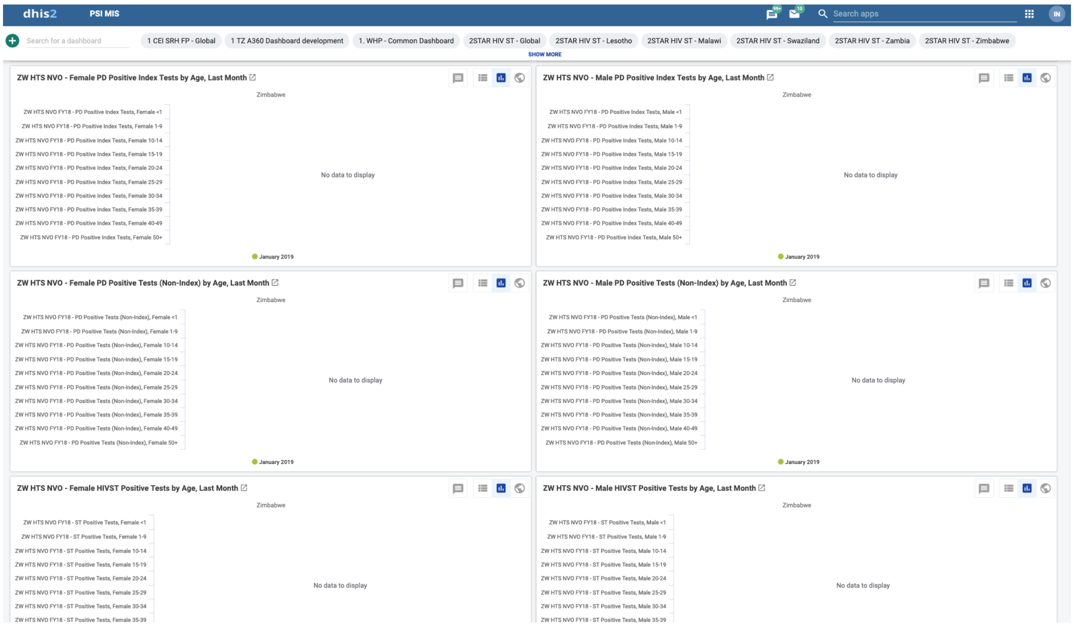


Figure 6.1: Several dashboards had no data to display during the case study.

The health organization had previously installed solutions for these incidents involving a local server that communicated with the back-end server through regular updates. The automation that facilitated these updates were incomplete and exhibited limitations. In several occurrences, data inconsistencies or visualizations with no data at all were present within the health information dashboard. In total, network connectivity was down in two out of four weeks. The downtime was instead used to gather feedback and performing surveys from the users' experience of their existing dashboard instances and usage of the application.

Research Approach

The research method used during the fieldwork was of an interpretive nature with minimal interventions. Due to the unforeseen events, a large portion of the field work's time frame was effectively removed. After re-establishing connectivity, I had to intervene with modifying decision templates, design layout, as well as asking continuous feedback related to translations. These measures could be considered as interventions that fall outside the minimal scope. In addition to this, the cyclical nature of information overload implies that continuous refinement is needed. Based on this, Adopting an *action research* methodology could have been an appropriate method. There are several frameworks of action research that does not explicitly involve prototyping or implementation. The cycle could have been used to create desired change of how users interacted with the dashboard, as well as desired changes to the design layout itself. However, to answer the research question, I believe an interpretive approach that emphasized gaining understanding through participant observation, such as the action case was sufficient. Triangulating findings from observations, as well as feedback, made this possible. With deliberate changes within such a limited time frame, I argue that the feedback would have been affected, such that users eventually provided positive answers.

Chapter 7

Conclusion and Future work

This thesis conducted an interpretive qualitative action case study to gain insight and understanding towards the use of health information dashboards for users situated in developing countries. The goal of the study was to explore how a dashboard can facilitate evidence-based decision-making without causing information overload. Before I started my investigation, a health organization argued that assigning decision templates to visualizations and applying integrated discussion forums was a potential solution. By defining clear goals and guidelines of potential actions to take based on the presented data, complexity of the decision-making process was arguably reduced. Utilizing an integrated discussion forum to contextualize quantitative data and further assist with decision-making through social interactions showed both positive and negative results. Applying decision-rules have been proposed to reduce the chance of experiencing information overload (Eppler and Mengis, 2002; Edmunds and Morris, 2000; Ruff, 2002). While enabling social interactions when interpreting visualized information have been stated to improve decision-making (Braa et al., 2012; Heer and Agrawala, 2008; Al-Hajj and Pike, 2013). In addition to applying these solutions, different presentation formats, dashboard design and interactive capabilities were evaluated to answer the following research question: *What essential features must a health information dashboard facilitate to enable evidence-based decision-making, without causing information overload?*

Health information dashboards can be evaluated in terms of how users interact with the application. The users are interacting with the application through its functional and visual features. In order to facilitate evidence-based decision-making, these features must consist of limited capabilities. To balance the information load, the visual features must provide visual cues in addition to the functional features offering interactive capabilities to encourage data exploration. However, too many visual features will produce excess clutter. While too many interactive features will cause excessive feedback and ultimately render the dashboard as overwhelming for the user.

In order for a health information dashboard to reduce the chance of producing information overload, guidelines provided in section 6.4 should be followed. However, the point at which information overload occurs varies depending on the user. This means that, in order to address this problem, continuous refinement and adjustments of the dashboard design is required. I cannot claim that I have solved users problem of experiencing information overload. Rather, I have illuminated how it can happen. In light of the findings, I would argue that following the recommended design guidelines when implementing, and designing a dashboard - the chance of experiencing information overload can be reduced. However, this involve dashboard implementers to not develop too many features as well as dashboard designers applying them sufficiently.

7.1 Future work

Extant literature views dashboards as a potential solution to information overload (Al-Hajj and Pike, 2013; Saxena and Lamest, 2018; Yigitbasioglu and Velcu, 2012), but identifies information overload as one of the key challenges of effective dashboards (Wilbanks and Langford, 2014). Research on the use and effect of dashboards as well as how they can be evaluated is hard to come by. Thus, further improvement on DHIS2's dashboard coupled with in-context research can provide fruitful results. Both related to dashboard design, information overload and conceptual frameworks to evaluate dashboards.

Further development of DHIS2 dashboard

The DHIS2 dashboard application is under further development and have room for additional improvement. As of now, DHIS2's dashboard enables filtering only on organization units. Additional filtering capabilities related to periods or indicators as well as drill-down features within the dashboard is a potential solution to reduce information load and improve its ability to facilitate evidence-based decision-making.

Standardized decision templates are primarily used by the health organization PSI which I studied. However, its underlying functionality and intended goal is applied by all other health organizations that utilize DHIS2. When monitoring the performance of a health program through visualizations, health organizations do so to reach a specific goal by acting on the data. Having a clear set of guidelines integrated with each visualization will enable users to reduce complexity of the tasks related to evidence-based decision-making, without spending excessive time on analyzing the presented data.

Implementing built-in drill-down capabilities for each presentation formats, with increased filtering mechanisms, along with standardized decision templates have the potential of improving the DHIS2 dashboard. Enabling an *analysis page* with additional interactive capabilities, coupled with in-context research of its usage, can provide basis for further research on how dashboards should be designed and used.

Integrated communication in DHIS2

Enabling communication with field workers, clinics and hospitals at the operational level and connecting them with the managers and decision-makers at strategic level can offer improved communication and work efficiency. Applying a communication strategy that is in an incomplete state, as the integrated discussion forum is now, will result in users exploring other alternatives or traditional methods. Supporting integrated communication within DHIS2 when working with big data provides opportunities to both contextualize the results, document the collaborative effort, while also enable communication between involved parties. As e-mails and intranets increase the number of information items and acts as a known source of information overload, removing those streams completely have potential to influence both the dashboard and other sources in the organizational setting that can cause information overload.

The current functionality in DHIS2 is integrated with capabilities of notifying other users that are involved with collecting data or monitoring specific visualizations. Additionally, by tagging other users, an e-mail will be sent with a notification through DHIS2's messaging application. However, this functionality did not work and field workers or managers never received a notification. This resulted in the DHIS2 dashboard users and program managers regularly checking up on a visualization to see if any new comments have been posted. The field workers that had smart phones or tablets would also not receive any updates if they were involved or being tagged. As a result, the discussion forum had lost its value and users had started to use regular e-mails and text messages, as the feature now effectively worked only as a documentation tool and not as a communication tool.

Facilitating two-way communication such that data collectors with smart phones and a DHIS2 application, or mobile phones able to receive SMS, all relevant parties of the health system could communicate through DHIS2. Enabling this possibility, such that it becomes a complete push to pull technology, would improve the value of the discussion forum and ultimately reduce the chance of experiencing information overload by removing additional sources of information streams. Additionally, categorizing the updates such that only relevant information is presented by the visualization can further improve its value.

Bibliography

AbouZahr, C. and Boerma, T. (2005). Health information systems: the foundations of public health. *Bulletin of the World Health Organization*, 83:578–583.

Al-Hajj, S. and Pike, I. (2013). Interactive Dashboards : Using Visual Analytics for knowledge Transfer and Decision Support.

Al-Hajj, S., Pike, I., Riecke, B., and Fisher, B. (2013). Visual Analytics for Public Health: Supporting Knowledge Construction and Decision-Making. In *2013 46th Hawaii International Conference on System Sciences*, pages 2416–2423.

Braa, J., Heywood, A., and Sahay, S. (2012). Improving quality and use of data through data-use workshops: Zanzibar, United Republic of Tanzania. *Bulletin of the World Health Organization*, 90:379–384.

Braa, J. and Sahay, S. (2012a). Health Information Systems Programme. In *Routledge International Handbook of Participatory Design*. Routledge.

Braa, J. and Sahay, S. (2012b). *Integrated Health Information Architecture: Power to the Users.*

Braa, J. and Sahay, S. (2017). The DHIS2 Open Source Software Platform: Evolution Over Time and Space.

Braa, K. and Vidgen, R. (1999). Interpretation, intervention, and reduction in the organizational laboratory: a framework for in-context information system research. *Accounting, Management and Information Technologies*, 9(1):25–47.

Braun, V. and Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative research in psychology*, 3:77–101.

Card, S. K., Mackinlay, J., and Shneiderman, B. (1999). *Readings in Information Visualization: Using Vision to Think*. Morgan Kaufmann. Google-Books-ID: wdh2gqWfQmgC.

Chrysantina, A. and Sæbø, J. I. (2019). Assessing User-Designed Dashboards: A Case for Developing Data Visualization Competency. In Nielsen, P. and Kimaro, H. C., editors, *Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D*, IFIP Advances in Information and Communication Technology, pages 448–459. Springer International Publishing.

Concannon, D., Herbst, K., and Manley, E. (2019). Developing a Data Dashboard Framework for Population Health Surveillance: Widening Access to Clinical Trial Findings. *JMIR formative research*, 3(2):e11342.

Crang, M. and Cook, I. (2007). *Doing Ethnographies.*

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* SAGE. Google-Books-ID: 4uB76IC_pOQC.

Denzin, N. K. and Lincoln, Y. S. (2000). *Handbook of qualitative research.* Sage Publications, Thousand Oaks, Calif. OCLC: 43384732.

DHIS2 (2019a). 23.5 Manage indicators. *https://docs.dhis2.org/master/en/user/html/manage_indicator.html#about_indicator.*

DHIS2 (2019b). 35.2 Data elements: the what dimension. *https://docs.dhis2.org/master/en/user/html/data-elements-the-what-dimension.html#.*

DHIS2 (2019c). DHIS2 Documentation 1.42 Analytics. *https://docs.dhis2.org/master/en/developer/html/webapi_analytics.html#.*

Diamond, L. and Lerch, F. J. (1992). Fading Frames: Data Presentation and Framing Effects*. *Decision Sciences*, 23(5):1050–1071.

DiCicco-Bloom, B. and Crabtree, B. F. (2006). The qualitative research interview. *Medical Education*, 40(4):314–321.

Dowding, D., Randell, R., Gardner, P., Fitzpatrick, G., Dykes, P., Favela, J., Hamer, S., Whitewood-Moores, Z., Hardiker, N., Borycki, E., and Currie, L. (2015). Dashboards for improving patient care: Review of the literature. *International Journal of Medical Informatics*, 84(2):87–100.

Edmunds, A. and Morris, A. (2000). The problem of information overload in business organisations: a review of the literature. *International Journal of Information Management*, 20(1):17–28.

Eppler, M. J. and Mengis, J. (2002). The Concept of Information Overload: A Review of Literature from Organization Science, Accounting, Marketing, MIS, and Related Disciplines. *The Information Society*, 20(5):325–344.

Etamesor, S., Ottih, C., Salihu, I. N., and Okpani, A. I. (2018). Data for decision making: using a dashboard to strengthen routine immunisation in Nigeria. *BMJ Global Health*, 3(5):e000807.

Few, S. (2006). *Information Dashboard Design: The Effective Visual Communication of Data.* O'Reilly Media, Inc.

Few, S. (2007). Why Most Dashboards Fail. page 2.

Forsgren, M. (2015). *Designing a Risk Manager Dashboard.*

Gizaw, A. A., Bygstad, B., and Nielsen, P. (2017). Open generification. *Information Systems Journal*, 27(5):619–642.

Green, A. (2016). Information overload in healthcare management: How the READ Portal is helping healthcare managers. *Journal of the Canadian Health Libraries Association / Journal de l'Association des bibliothèques de la santé du Canada*, 32:173.

Greenwood, D. J. and Levin, M. (1998). *Introduction to Action Research: Social Research for Social Change*. SAGE Publications. Google-Books-ID: nipHAAAAMAAJ.

Hall, A. and Walton, G. (2004). Information overload within the health care system: a literature review. *Health Information & Libraries Journal*, 21(2):102–108.

Heer, J. and Agrawala, M. (2008). Design Considerations for Collaborative Visual Analytics. *Information Visualization*, 7(1):49–62.

Huerta, E. and Jensen, S. (2017). An Accounting Information Systems Perspective on Data Analytics and Big Data. *Journal of Information Systems*, 31(3):101–114.

Hwang, M. I. and Lin, J. W. (1999). Information dimension, information overload and decision quality. *Journal of Information Science*, 25(3):213–218.

Inbar, O., Tractinsky, N., and Meyer, J. (2007). Minimalism in Information Visualization: Attitudes Towards Maximizing the Data-ink Ratio. In *Proceedings of the 14th European Conference on Cognitive Ergonomics: Invent! Explore!*, ECCE '07, pages 185–188, New York, NY, USA. ACM.

K. Stansfield, S., Walsh, J., Prata, N., and Evans, T. (2006). Information to Improve Decision Making for Health. In *Datenbank Rundbrief - GIDR*.

Klerings, I., Weinhandl, A. S., and Thaler, K. J. (2015). Information overload in healthcare: too much of a good thing? *Zeitschrift für Evidenz, Fortbildung und Qualität im Gesundheitswesen*, 109(4):285–290.

Lippeveld, T., Sauerborn, R., Bodart, C., and Organization, W. H. (2000). *Design and implementation of health information systems*. World Health Organization.

Ljungberg, F. and Sorensen, C. (1998). Are you "pulling the plug" or "pushing up the daisies"? [communication patterns]. In *Proceedings of the Thirty-First Hawaii International Conference on System Sciences*, volume 1, pages 370–379 vol.1.

Masse, M. (2011). *REST API Design Rulebook: Designing Consistent RESTful Web Service Interfaces*. "O'Reilly Media, Inc.". Google-Books-ID: eABpzyTcJNIC.

Microsoft (2018). Best design practices for reports and visuals (whitepaper) - Power BI. *https://docs.microsoft.com/en-us/power-bi/visuals/power-bi-visualization-best-practices*.

Negash, S. and Gray, P. (2008). Business Intelligence. In Burstein, F. and W. Holsapple, C., editors, *Handbook on Decision Support Systems 2: Variations*, International Handbooks Information System, pages 175–193. Springer Berlin Heidelberg, Berlin, Heidelberg.

Nicholson, B., Nielsen, P., Sæbø, J., and Sahay, S. (2019). Exploring Tensions of Global Public Good Platforms for Development: The Case of DHIS2. pages 207–217.

Nielsen, P. (2017). Digital Innovation: A Research Agenda for Information Systems Research in Developing Countries. In Choudrie, J., Islam, M. S., Wahid, F., Bass, J. M., and Priyatma, J. E., editors, *Information and Communication Technologies for Development*, IFIP Advances in Information and Communication Technology, pages 269–279. Springer International Publishing.

Noyes, J. M. and Thomas, P. J. (1995). INFORMATION OVERLOAD: AN OVERVIEW. In *IEE Colloquium on Information Overload*, pages 0_6–.

Nutley, H. T. (2010). A Review of Constraints to Using Data for Decision Making: Recommendations to Inform the Design of Interventions — MEASURE Evaluation. Publication.

O'Donnell, E. and David, J. S. (2000). How information systems influence user decisions: a research framework and literature review. *International Journal of Accounting Information Systems*, 1(3):178–203.

Ogega, P. M. (2017). Data use challenges and the potential of live visualization tools data - A case study of health data-use workshops in Zambia.

Patterson, R. E., Blaha, L. M., Grinstein, G. G., Liggett, K. K., Kaveney, D. E., Sheldon, K. C., Havig, P. R., and Moore, J. A. (2014). A human cognition framework for information visualization - PDF Free Download.

Pauwels, K., Ambler, T., Clark, B., LaPointe, P., Reibstein, D., Skiera, B., Wierenga, B., and Wiesel, T. (2009). Dashboards as a Service : Why, What, How, and What Research Is Needed? *Journal of Service Research*, 12:175–189.

PSI (2016). DHIS2 for Data Use at PSI. *https://mis.psi.org/dhis2-for-data-use-at-psi/?lang=en.*

Qlikview (2011). Qlikview Best practices. *https://community.qlik.com/t5/New-to-QlikView/Qlikview-Best-practices/m-p/255654#M39731.*

Reuters (2019a). Fuel price protests in Zimbabwe turn deadly. *https://www.reuters.com/article/us-zimbabwe-economy-strike-idUSKCN1P80RH.*

Reuters (2019b). Internet blacked out in Zimbabwe as U.N. urges end to crackdown. *https://af.reuters.com/article/topNews/idAFKCN1PC0KQ-OZATP.*

Roland, L. K., Sanner, T. A., and Monteiro, E. (2017). Architectures of large-scale participatory design. page 33.

Ruff, J. (2002). Information Overload: Causes, Symptoms and Solutions. page 13.

Sandiford, P., Annett, H., and Cibulskis, R. (1992). What can information systems do for primary health care? An international perspective. *Social Science & Medicine*, 34(10):1077–1087.

Saxena, D. and Lamest, M. (2018). Information overload and coping strategies in the big data context: Evidence from the hospitality sector. *Journal of Information Science*, 44(3):287–297.

Senyoni, W. and Braa, J. (2017). Boundary Object in HIS: Designing and implementation of a regional scorecard. In *2017 IST-Africa Week Conference (IST-Africa)*, pages 1–8.

Senyoni, W., Kimaro, H., Braa, J., and Kumalija, C. (2019). An Institutional Perspective on the Adoption of Open Dashboard for Health Information Systems in Tanzania. pages 272–283.

Sisense (2018). Dashboard Design Best Practices - 4 Key Principles. *https://www.sisense.com/blog/4-design-principles-creating-better-dashboards/.*

Spence, R. (2001). *Information Visualization.* Addison-Wesley. Google-Books-ID: gYQoAQAAMAAJ.

Tableau (2019). Best Practices for Effective Dashboards. *https://onlinehelp.tableau.com/current/pro/desktop/en-us/dashboards_best_practices.htm.*

Tufte, E. R. (1983). *The visual display of quantitative information.* Graphics Press, Cheshire, Conn. (Box 430, Cheshire 06410). OCLC: 9480885.

Tufte, E. R. (2006). *Beautiful Evidence.* Graphics Press. Google-Books-ID: v302PAAACAAJ.

Umanath, N. S. and Vessey, I. (1994). Multiattribute Data Presentation and Human Judgment: A Cognitive Fit Perspective*. *Decision Sciences*, 25(5-6):795–824.

UN (2018). | Human Development Reports. *http://www.hdr.undp.org/en/2018-update.*

Walsham, G. (2006). Doing interpretive research. *European Journal of Information Systems*, 15(3):320–330.

Ward, M. O., Grinstein, G., and Keim, D. (2015). *Interactive Data Visualization - Foundations, Techniques, and Applications.* Second edition edition.

Wilbanks, B. A. and Langford, P. A. (2014). A Review of Dashboards for Data Analytics in Nursing:. *CIN: Computers, Informatics, Nursing*, 32(11):545–549.

Wilson, T. D. (2001). Information overload: implications for healthcare services. *Health Informatics Journal*, 7(2):112–117.

Yigitbasioglu, O. M. and Velcu, O. (2012). A review of dashboards in performance management: Implications for design and research. *International Journal of Accounting Information Systems*, 13(1):41–59.

Yin, R. K. (1994). *Case study research: design and methods*. Sage Publications. Google-Books-ID: AvYOAQAAMAAJ.

Zakkar, M. and Sedig, K. (2017). Interactive visualization of public health indicators to support policymaking: An exploratory study. *Online Journal of Public Health Informatics*, 9(2).

Øverland, L. H. (2006). Global Software Development and Local Capacity Building : A means for improving Sustainability in Information Systems Implementations.