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MSc. ICT in Business and Public Sector

A FAIR Data Based BI Framework within the Healthcare Domain in Africa

Name: Yi Lin

Student number: s2603411

1st Supervisor: Prof. Dr. Mirjam van Reisen

2nd Supervisor: Dr. Katy Wolstencroft

MASTER'S THESIS

Leiden Institute of Advanced Computer Science (LIACS)

Leiden University
Niels Bohrweg 1

2333 CA Leiden
The Netherlands

Abstract

Deficiencies of current Health Management Information Systems (HMIS) are spotted leading to the discussion of a feasible alternative to tackle the damage caused by COVID-19 pandemic especially in developing geographies such as the African continent. It results in a poor data ownership which is reflected at facility level by how difficult it is for local facilities to access their own data from the central HMIS. The open data feature of these systems makes data availability for other users having access to data entries and the ability to change them become concerns. As a result, data quality is undermined, and data are not secured. Another problem is the insufficient interoperability caused by incompatibilities in abstraction and granularity as disease categories are often defined by the local government differing from other systems. Not only does using these systems challenge data ownership in Africa, but it also burdens local clinics with heavy workloads as the use of such systems at point of care is lack, and paper-based manual data collection is still common at the facility level.

FAIR data, on the other hand, increases manageability and governance of massive data by adding FAIR Data Points (FDP) to decentralized data rather than warehousing data, in order to align with machine-readability, data ethics, and historicity. In this way, specific data are only findable and accessible to a specific use-case in the matching temporal and spatial context in a readable format for both humans and algorithms. FAIR data has been widely implemented globally in diverse domains as tackling shared data via FAIR Principles does not violate data sensitivity yet enhance data governance, compared to other approaches based on open data. VODAN is a joint association created by the Committee on Data of the International Science Council (CODATA), Research Data Alliance (RDA), World Data System (WDS), and Global Open FAIR (GO FAIR), aiming for the creation of a new platform to FAIRify patient data so that the data are findable, accessible, interoperable and reusable by both humans and machines, not only during this epidemic of COVID-19, but also as a solution to potential future infectious disease outbreaks. Along with the growth of VODAN, it stepped onto a global stage. The establishment of VODAN Africa and Asia pioneers the use of a localization architecture enabling health data to be FAIR and offering a real-time Business intelligence (BI) solution. Once FAIR data are implemented at local hospitals and clinics across Africa and Asia, health professionals can access data needed for research and clinical observation. The data ownership is guaranteed, while important data can be accessed by anyone under the data regulatory laws of the country where it was generated. The real-time BI solution will also bring a digital revolution to local clinics in developing geographies to help health staff handle COVID-19 clinical and research data.

This research aims to explore the possibility of introducing a FAIR data based BI framework to local healthcare facilities in Africa.

Key words: FAIR Principles, FAIR data, healthcare, VODAN, BI, CEDAR

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1. Introduction

In this chapter, introduction regarding the research problem and research gap is delivered. Research questions as well as objectives are explained respectively. Other topics such as study relevance, ethical concerns and research schedule are also elaborated in this chapter.

1.1 Problem Statement

Deficiencies of current healthcare information systems are spotted leading to the discussion of a feasible alternative to tackle the damage caused by COVID-19 pandemic especially in developing geographies such as the African continent. An example is the loss of the data on Ebola collected from Liberia being unavailable in its MoH. It results in a poor data ownership which is also reflected at facility level by how difficult it is for local facilities to access their own data from the central HMIS. The open data feature of these systems grants other users the accessibility to data entries and the ability to change them become concerns. As a result, data quality is undermined, and data are not secured. Another problem is the insufficient interoperability. Not only does using these systems challenge data ownership in Africa, but it also burdens local clinics with heavy workloads as the use of such systems at point of care is lack, and paper-based manual data collection is still common at the facility level. In order to further identify the problems in detail, it is necessary to target mainly used HMISs in Africa and choose one to study. This research thus has studied the District Health Information Software 2 (DHIS2) as it is currently one of the biggest systems in Africa.

DHIS2 began in post-Apartheid South Africa and is now adopted in more than 73 countries worldwide in line with WHO resolution calling on Ministries of Health (MoH) of member countries to strengthen district health by collecting and analyzing health data. It is coordinated by the Health Information Systems Programme (HISP) at the University of Oslo (UiO). There are several issues of this system that caught attention. For example, the data availability for other users having access to data entries and the ability to change them become concerns as the availability and quality of data affect the installation and usefulness of DHIS2 [1]. Thus, extra requirements are created regarding data input and security issues. But there is a lack of skilled IT staff to handle the high volume of work associated with implementation in Africa [2]. Another problem is the insufficient interoperability caused by incompatibilities in abstraction and granularity using DHIS as disease categories are often defined by the local government differing from other systems [3].

FAIR data, on the other hand, increases manageability and governance of massive data by adding FAIR Data Points (FDP) to decentralized data rather than warehousing data, in order to align with machine-readability, data ethics, and historicity [4]. In this way, specific data are only findable and accessible to a specific use-case in the matching temporal and spatial context in a readable format for both humans and algorithms. FAIR data has been widely implemented globally in diverse domains as tackling shared data via FAIR Principles does not violate data sensitivity yet enhance data governance, compared to other approaches based on open data. For example, VODAN is a joint association created by the Committee on Data of the International Science Council (CODATA), Research Data Alliance (RDA), World Data System (WDS), and Global Open FAIR (GO FAIR), aiming for the creation of a new platform to FAIRify patient data so that the data are findable, accessible, interoperable and reusable by both humans and machines, not

only during this epidemic of COVID-19, but also as a solution to potential future infectious disease outbreaks. Along with the growth of VODAN, it stepped onto a global stage. The establishment of VODAN Africa and Asia pioneers the use of a localization architecture enabling health data to be FAIR and offering a real-time Business intelligence (BI) solution. Once FAIR data are implemented at local hospitals and clinics across Africa and Asia, health professionals are able to access data needed for research and clinical observation. The data ownership is guaranteed, while important data can be accessed by anyone under the data regulatory laws of the country where it was generated. The real-time BI solution will also bring a digital revolution to local clinics in developing geographies in order to help health staff handle COVID-19 clinical and research data.

BI is an umbrella term coined and promoted by Howard Dresner of the Gartner Group in 1989 describing a set of concepts and methods to improve business decision making by using fact-based support systems [5]. Besides the natural role of BI in the business world, BI has also stirred much interest in the public sectors such as museum activities, public administration, geomatics and education [6]. Especially in the public healthcare domain, BI is leveraged as an emerging solution of Healthcare Information Systems (HIS) to bring a number of benefits including easier access to massive data, improved decision making [7], and increased financial performance [8]. In particular, BI not only includes the strategies, processes, applications, data, products, technologies and technical architectures used to support the collection, analysis, presentation and dissemination of business information, it also includes the reporting layer providing data presentation and visualization through the use of BI reports, dashboard or queries [9]. BI has a competitive advantage in formulating strategic decision-making and improving analysis of operational data. BI users from local clinics can have a better insight of health data in hand by performing basic data analysis through the dashboard instead of relying on physical records. Therefore, a FAIR data based BI solution has the potential to innovate the data analytics in African healthcare domain, while the data ownership is promised.

1.2 Research Gap

Two main research gaps are identified in this research. The first one is the understanding of the circumstances about implementing FAIR Principles at a global level remains incomplete, especially outside Europe. Although there is a certain level of expansion in acceptance and implementation of FAIR Principles worldwide, the implementation is mainly limited to the western hemisphere and to bio- and natural sciences based on 95% of articles reviewed by the previous study [10]. In detail, the investigation reveals that FAIR Principles have been implemented largely in European geographies (67%) and with a smaller proportion in American geographies (14%), together accounting for 81% of implementation efforts. The Southern and Eastern hemispheres are largely excluded from implementation efforts at this point. It leads to an academic concern whether FAIR data are also under discussion in those geographies, and how is the local political situation of adopting FAIR data. Especially in countries like China and Japan, local languages are also intensively used in the publication besides English. As a result, it is not explicit if the policy window of FAIR adoption is possible to open in another geography other than Europe which will hinder the development of healthcare solutions based on FAIR guiding principles. Thus, it is necessary to answer these questions by exploring non-English publications since no research has been found regarding this topic so far.

The second one is that no research had been carried out into setting up a BI environment based on FAIR Principles up to the time, as far as could be established. BI has appeared as a leading-edge technological approach to optimizing decision-making as well as to delivering deep business insights as outputs by tackling open massive data as inputs [7]. However, dealing with open data could result in violating privacy, possible misuse and misinterpretation of data [11]. It potentially undermines the decision-making process. Therefore, it is unknown whether such drawbacks of a data management system caused by using big data could be solved through a different data distribution strategy, which inspires a part of this research to dive into the potential solution based on FAIR Principles in order to fill the gap of relying on conventional methods relevant to big data.

1.3 Research Questions

Developing a FAIR-data-supported BI framework is important for local healthcare organizations, and an avant-garde data distribution strategy needs to be introduced to mitigate the deficiencies of DHIS2. The overarching research question as well as sub-questions addressed are therefore as follows:

How are FAIR Principles regarded as a key component of constructing the proposed BI framework to improve the data stewardship and data governance within the healthcare domain in Africa?

i. What is the current situation of FAIR implementation in non-Western geographies, especially in Africa?
ii. What is the health data management system like regarding internal criteria such as data integration in each of the African member countries of VODAN Africa?
iii. What is the capacity gap between the current system and the proposed system under the VODAN localization architecture?
iv. What are the perceptions of local clinics of African member countries in terms of processing and managing patient data in practice?
v. What are local healthcare professional's expected functionalities of dashboards as the BI solution and their own criteria for the data management and control within and across clinics?
vi. What is the design of the dashboard from an originally centralized architecture to a localized one in relation to the CEDAR infrastructure?

1.4 Objectives

The leading objective of this study is to fill the research gap by proposing a BI framework based on FAIR Principles with the purpose to serve local healthcare organizations using the VODAN localization architecture. Furthermore, the objective of each sub-question is

Table 1 Research questions and respective objectives

	Question	Objective
1	What is the current situation of FAIR implementation in non-Western geographies, especially in Africa?	To understand a comprehensive condition of global FAIR adoption and the readiness of

		introducing FAIR based BI framework to African clinics.
2	What is the health data management system like regarding internal criteria such as data integration in each of the African member countries of VODAN Africa?	To understand how internal criteria of DHIS2 in each African member country were determined and developed, and then how FAIR data could contribute to additional criteria.
3	What is the capacity gap between the current system and the proposed system under the VODAN localization architecture?	To understand the capability difference of DHIS2 and the proposed system based on the VODAN architecture and the potential of FAIR data.
4	What are the perceptions of local clinics of each African member country in terms of processing and managing patient data in practice?	To understand the roles and tasks of data controllers and processors in detail from local African clinics.
5	What are local healthcare professional's expected functionalities of dashboards as the BI solution and their own criteria for the data management and control within and across clinics?	To understand the needs of local healthcare staff for the dashboard solution on top of the routine of data management and data analysis within and across clinics.
6	What is the design of the dashboard from an originally centralized architecture to a localized one in relation to the CEDAR infrastructure?	To understand concrete steps taken towards the construction of designing the dashboard UI and prototype supported by the CEDAR platform.

1.5 Study Relevance

The implementation of FAIR Principles at a worldwide level enhances the ability of data to be found and used automatically by machines, as well as reused by humans. It is approved not only by academia, but also by many stakeholders, such as academic publishers and funding agencies [12]. By implementing FAIR Principles, changes are being made about a different mindset on data usage, and the relationship between data providers and users globally. However, studies show that around 80% of the implementation of FAIR guiding principles occurred in geographies where English is mainly used to carry out academic research and discussion. The adoption of FAIR in other regions and areas where English is not mainstream remains unknown. Therefore, it is important to understand the worldwide influence of FAIR implementation by researching selected non-Western geographies.

On the other hand, VODAN is dedicated to making healthcare data in a FAIR manner, i.e., Findable, Accessible, Interoperable and Reusable. To deal with the growing impact of COVID-19, VODAN also spreads the influence on a global scale by launching VODAN Africa and Asia projects to help local hospitals and clinics improve data governance and analytics capacity. However, local health data are currently obligatory to output to the DHIS2 in line with the request of WHO resulting in concerns in terms of data ownership and local regulations. An example is that the local government has lost the Ebola data collected from Liberia. Moreover, local African communities are seeking to establish their own digital health platform being able to deal with healthcare and patient data. For example, the African Open Science Platform (AOSP) has been launched to help African scientists understand and accept data-intensive science in order to solve data related challenges such as low data quality and improper data governance. FAIR data

are not only the key to solving those problems, but also is the catalyst to accelerate the digital transformation of local clinics and hospitals in Africa.

Therefore, the relevance of this study is pointed out through the delivery of a systematic literature analysis regarding the implementation of FAIR Principles in non-English geographies by conducting a systematic literature. The analysis examines whether FAIR Principles or FAIR equivalence have been introduced and discussed by various parties such as local governments, academic associations and so forth among selected geographies. The proposal of the novel FAIR data based BI solution under the VODAN localization architecture is also with high relevance since it aims to help local healthcare stakeholders with the digital transformation, while issues of data ownership are to be solved.

1.6 Research Approach

The methodology adopted in this research is composed of a systematic literature review, a qualitative method and a design method. The systematic literature review is conducted to create a global insight of how FAIR is implemented in non-Western geographies. The qualitative method leads to a series of data collection approaches such as questionnaires and interviews among local clinics located in Africa. The data will be used to validate the effectiveness of the VODAN localization architecture and to construct a list of features for the BI solution. The features should not only assist medical staff with the digital transformation of local clinics, but also assure them of data ownership. The interviews will not be recorded, yet answers collected by coordinators will be processed in order to extract useful data. As to the design method, a technical plan will be drafted about the BI dashboards. The dashboards will play an important role in the VODAN localization architecture as it enables healthcare professionals or researchers from anywhere perform analysis on FAIR secured health data without violating the data ownership. Table 2 further elaborates the details of the research approach.

Table 2 Research approach

	Question	Data	Collection Method	Chapter
1	What is the current situation of FAIR implementation in non-Western geographies, especially in Africa?	Literature data	Systematic literature review	4
2	What is the health data management system like regarding internal criteria such as data integration in each of the African member countries of VODAN Africa?	Interview transcript, literature data	Interview, literature review, document review such as photos and screenshots	5, 6
3	What is the capacity gap between the current system and the proposed system under the VODAN localization architecture?	Interview transcript, research paper, grey literature, processed data from Q2	Interview, literature review	5, 6
4	What are the perceptions of local clinics of each African member	Interview transcript	Interview	6

	country in terms of processing and managing patient data in practice?			
5	What are local healthcare professional's expected functionalities of dashboards as the BI solution and their own criteria for the data management and control within and across clinics?	Interview transcript	Interview	5, 6
6	What is the design of the dashboard from an originally centralized architecture to a localized one in relation to the CEDAR infrastructure?	Processed data from Q1-Q5, VODAN architecture, new data would be the design of dashboard	Qualitative data analysis such as coding and labeling	7

1.7 Ethical Considerations and Data Management

In this research, ethical considerations and rules regarding data management and processing are strictly followed. The collected qualitative data might involve sensitivity of local healthcare data and other information, therefore awareness of the ethical and legal issues surrounding data gathered and used in the research is built. The management of possible sensitive data are fully conducted through the cooperation with local and global stakeholders such as defining and protecting ethical rules, to maintain high ethical standards and to minimize the risk to participants, researchers and third parties including the university. All the signed agreements with stakeholders are attached in appendix A.

1.8 Timeline

Table 3 Research timeline

To deliver	**Deadline**
Final research proposal	4.8
Perform literature review	4.22
Write the chapter "Introduction"	4.23
Write the chapter "Theoretical Framework"	4.30
Define questions of needs from data processors for the dashboard	5.5
Define questions regarding relied on DHIS2 functions from data processors	5.7
Define questions regarding functions and data governance for DHIS2	5.12
Prepare interviews	5.16
Launch interviews and collect data	5.28

Write the chapter “Methodology”	5.28
Process and code data	6.6
Write the chapter “FAIR Principles and Implementation”	6.10
Design a prototype of the BI framework	6.13
Add features based on coding results	6.20
Write the chapter “BI Dashboard”	6.21
Get feedback from data processors and improve designing	6.30
Write the chapter “Interview Analysis and Results”	7.15
Repeat until finishing the prototype	8.6
Write chapters “Discussion” and “Conclusion”	8.13

1.9 Thesis Outline

The research outline is composed of ten chapters. Chapter 1 is the introduction which introduces the research background and research problem followed by drawing research questions as well as research objectives. Other topics such study relevance, ethical concerns and research schedule are also elaborated in this chapter. Chapter 2 is the theoretical framework which explains the theories and concepts used as a guidance in this research. Chapter 3 is the methodology which dives deeper into the details of methods adopted in this research to embody the theoretical framework. Research design provides an overview of the methodological structure of the study. The systematic literature review identifies the global policy agenda of FAIR data Principles, whereas semi-structured interview helps collect required data for the preparation of designing and creating a BI plan as the output of this research. The dashboard design method provides a guideline of the prototype development and future work. Chapter 4 is the literature analysis of global FAIR implementation and the identification of FAIR readiness in Africa. Chapter 5 is the literature review of BI in healthcare and further investigation of currently used HMIS in African countries. Chapter 6 explains the procedure of semi-structed interviews, the analysis and results. Chapter 7 introduces the FAIR based BI framework, data pipelines. Chapter 8 explains the UI design and mock data creation, and delivers the built prototype. Finally, chapter 9 is the conclusion and chapter 10 is the discussion which leads to the end of the research.

2. Theoretical Framework

In this chapter, theoretical frameworks which explains the theories and concepts used as a guidance in this research are discussed. Two theoretical frameworks are included which are the Kingdon theory and BI process flow. Both theoretical frameworks are dynamic models, which are suitable for analysis of decision-making during social processes.

2.1 Kingdon Theory

The Multiple Streams Framework (MSF) of John Kingdon is used in the systematic literature review to assess the public agenda in terms of implementing FAIR data in selected geographies. The multiple streams consist of three streams which are the problem stream, the policy stream and the politics stream [13]. Furthermore, two types of agenda are defined according to the Kingdon theory which are the governmental and the decision agenda. The governmental agenda is a list of issues that government officials as well as individuals outside the public sectors are paying serious attention to at any given time. The decision agenda, on the other hand, is a subset of the governmental agenda dealing with issues that are going to become public policy or are ready for policy decision makers to confirm. But according to Kingdon, "we should also distinguish between the governmental agenda, the list of subjects that are getting attention, and the decision agenda, the list of subjects within governmental agenda that are up for an active decision" [14, p. 4]. The reason for having such differentiation is that both agendas are affected by different decision-making processes.

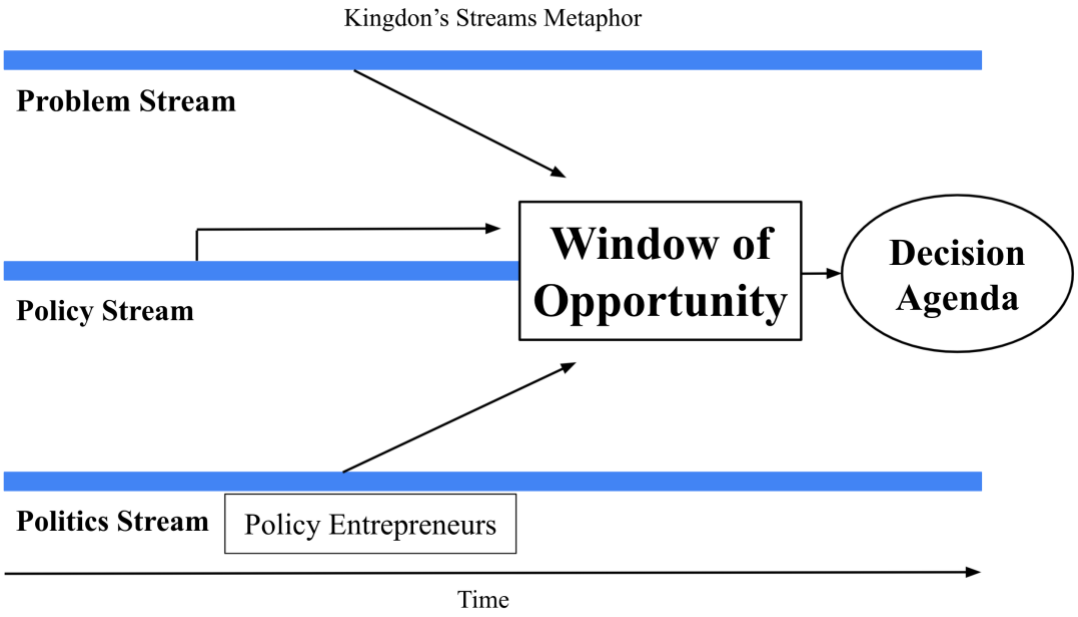

Figure 1 The metaphor of Kingdon's MSF, source: created by the author, Yi Lin

In certain circumstances, a convergence of these three streams can be identified leading to a possibility for change on the agenda. When this policy window opens, a solution needs to be crafted to deal with a recognized problem and political conditions allow such change to happen. During this window of time, not

only is the integration of the three streams completed and the agenda is created, but it is also when political entrepreneurs come to play an important role of investing in an idea and of synchronizing the three streams by recognizing the political opportunity and by facilitating access of the issue to the agenda. They can be part of the government, but it is not mandatory. The metaphor of Kingdon's MSF is illustrated by Figure 1.

There are also limitations of Kingdon's MSF. Even if the policy window is open by identifying the convergence of three streams, the formation of the policy agenda may differ from the reality. For example, the policy making processes are different by countries, and Kingdon's MSF may not be suitable in some countries where policy making is extremely centralized [15].

Problem stream

The problem stream indicates the way a problem is perceived. Problems do not exist but must be created by someone. Otherwise, the existence of such an entity is considered as a condition. The difference between a condition and a problem is that the latter is regarded as something that we ought to seek a solution to [16]. Under the problem stream, the transition of an issue from a private problem to a public one that the government should be involved in fixing is marked, especially when the current condition of the issue does not match the values and perception of their ideal state [13]. For example, a situation is regarded as a "problem" based on its variance with people's understanding of some desired situation. Analyzing the problem stream helps decision-makers identify public problems that public officials ought to act on by monitoring of indicators or current legislation, interest groups, the media or real events.

Policy stream

The policy stream shows the set of available alternatives to adopt. It is composed of suggestions or alternative solutions to the problems defined in the problem stream by discussing a series of ideas among expert groups such as researchers, scholars and technical professionals that have expertise and responsibilities in certain fields. Collected divergent ideas are delivered to the next step to be combined, softened up, recombined and defended until a converged proposal is agreed. Then the policy entrepreneurs are introduced to the step of providing a suitable climate where the public and policy community are able to ease the acceptance process of the proposal, whereas the decision makers take the proposal into serious consideration [14]. The proposal may be created from original ideas or it may be reformed of existing ones [17]. For example, the proposal in this study to level up current data management systems in Africa is a combination of existing solutions, i.e., FAIR data Principles and BI, leading to the possibility of constructing a new framework of healthcare data management and analytics.

Politics stream

The politics stream identifies changes in political dynamics and public opinion. The evaluation of the politics stream provides researchers with the capacity to gain a broader understanding of the themes brought up by stakeholders in policy on the issue by obtaining qualitative data and employing textual analysis techniques [13]. Compared to the policy stream officials that focus on the content of ideas, the politics stream values the concepts of pressure, influence and national mood that affect what ideas will be acted upon in the politics stream. It is noted that the alteration of the national mood has the power to promote the

proposal on the governmental agenda and to strengthen the impact of the politics stream in the opening of the policy window as the perception generated from the change of national mood influences certain issues to be promoted in the agenda while the other agendas are detained [18]. In this research, the analysis of local political conditions under the MSF can identify the potential adoption of FAIR data in a specific country or region from the point of view of the agenda-setting. The confluence of the three streams is especially analyzed to ensure the opening of the policy window.

Policy Entrepreneurs

As aforementioned, policy entrepreneurs are the key role to accelerate the generation of policy window by making the three streams come across. Based on Kingdon's theory, they "are responsible not only for prompting important people to pay attention, but also for coupling solutions to problems and for coupling both problems and solutions to politics" [14, p. 20]. Kingdon further described the characteristics of policy entrepreneurs, "they could be in or out of government, in elected or appointed positions, in interest groups or research organizations. But their defining characteristic, much as in the case of a business entrepreneur, is their willingness to invest their resources-time, energy, reputation, and sometimes money-in the hope of a future return" [14, p. 122]. As to the literature review in this research, multiple policy entrepreneurs were identified due to various implementation cases of FAIR data.

2.2 BI

BI is an umbrella term that includes concepts, architectures, tools, databases, applications and methodologies with the goal of analyzing data in order to support the decisions of business managers, or to improve business decision-making processes by using fact-based support systems [5], [19]. Although BI is often seen as an emerging concept or technology, there is a long history in terms of its philosophical roots despite the more recent systematic use in the business environment of BI. For example, Pirttimaki stated that the philosophy of BI originates from ancient Chinese military planning and thinker, Sun Tzu [20], whereas the genesis of BI is considered to be more recent in the context of commerce and business [21].

In the 1980s, BI was identified as an analytical process by which raw data are converted into relevant, usable and strategic knowledge and intelligence with the emphasis of the continuous monitoring of customers, competitors, market, technologies, products and environment [22]. Similarly, BI is seen as "both a process and a product." The process is composed of methodologies enabling organizations to develop useful information and to gain insights that help them survive and thrive in the global economy. The product is an informative output or tool that will allow organizations to be competitive with their "competitors, suppliers, customers, technologies, acquisitions, markets, products and services, and the general business environment" with a degree of certainty by generating prediction of business behaviors [23]. However, Shollo and Kautz [24] emphasized the importance of distinguishing BI from Competitive Intelligence (CI) since the scope of CI covers the entire competitive environment by collecting internal and external data to identify business opportunities and threats [25], yet BI initially utilized internally produced data such as all the transactional data accumulated within the organization [26]. Due to the rapid growth of openly accessible data on the internet and the limited focus of CI on the marketing context, the expanded potential of BI has significantly changed the situation, i.e., competitive intelligence is now considered as a subset of BI or a "specialized branch of BI" [27]. On top of the acquisition of business insights through BI, it is also

regarded as a performance management framework as BI is an ongoing cycle tightly connected to the setup of a company's strategic vision via the repeating process to set goals, analyze development, gain insight, take action, and measure success [28]. Extra organizational contribution besides improving decision quality of using BI is also pointed out [29]. For instance, BI adoption can enhance team productivity by facilitating team coordination that streamlines the collection and analysis of project documents, while productivity of organizations can be positively affected by the comprehensiveness, flexibility, support, communication, BI strategy orientation, business/BI partnership and project collaboration of BI adoption strategy [30], [31].

The concept of BI is multidimensional, as a result, the content of BI is writer-specific depending on the emphases of the author. But the core of BI has not changed much since the 1980s which is to provide an intelligence process that includes a series of systematic activities, being supported by a diverse range of technological tools and being driven by the specific information needs of decision makers and the objective of achieving competitive and managerial purposes. BI tools include decision support systems (DSS), executive information systems (EIS), extract transform and load (ETL), data warehouse, online analytical processing (OLAP), data mining systems, knowledge management (KM), geographic information systems (GIS) and dashboard etc. [32]. BI tools play a key role in the IT industry because there is a lack of efficient data mining tools to support unstructured datasets, and BI works very well with both structured and unstructured datasets. [7] Similarly, Ashrafi at el. stated that "whether data collection, transformation, and analysis of data triggered by the processes or routinely deployed to support decision making process, BI capabilities improve and fosters organizational capabilities by empowering the users, facilitate the IT structure, and enhance the use of structured and unstructured data" [33, p. 122]. Nevertheless, because of the high demand for digitalized and innovative data management approaches in society, BI is no longer exclusive in the business world but rather becoming essential in public sectors as well. BI tools are often used in public health fields "for financial and administrative purposes. Now BI is also helping public health organizations with diagnosing and treating patients with long term conditions and evaluating alternative treatments based on outcomes analyses" [32, p. 97]. The general BI process flow is illustrated in Figure 2.

As BI systems are featured in aspects with connection to both process and product, the success measurement needs to be evaluated from both sides as well. Organizational and process-related factors, as non-technical factors, can affect the adoption of BI solutions more than technological and data-related factors, and the implementation of BI systems is different from other systems in terms of the contextual issues of the critical success factors [34]. However, Bonney emphasized the impact of technological and data-related factors on implementing BI systems in digital healthcare, especially in relation to data roles, data governance and data architecture such as data integrity, data semantics and data security [7], [8], [35]. The data integration capability is considered as one of the most essential features of BI systems implemented in healthcare organizations according to Ashrafi et al., "It links structured and unstructured data from a variety of sources, such as internal databases and knowledge repositories. BI integration capability significantly reduces the time it would take a human to catalogue these data and it is intended to solve cost and quality problem in healthcare" [33, p. 123].

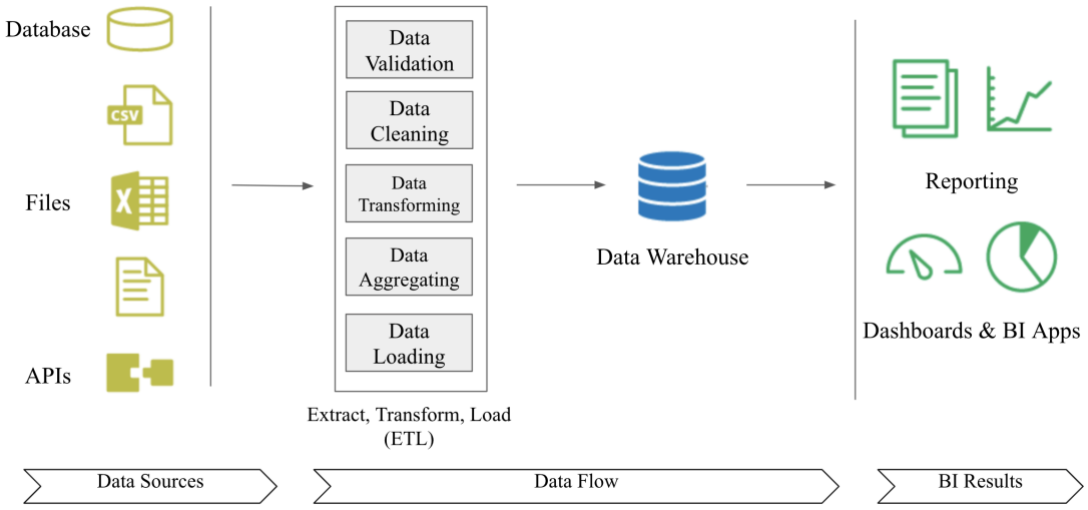

Figure 2 The general BI process flow, source: created by the author, Yi Lin

The limitation of common BI models is that data are usually stored in a centralized data warehouse. This structure makes the phase of data storage and management the weakness of the whole model and amplifies the drawbacks of data warehouse. For example, data warehousing often has the concern of a low data ownership as nowadays data management is facing a trend of cloud migration which is not suitable for some use case such as local African health facilities due to the data sensitivity. As a result, although normal BI frameworks can deliver insights to decision making, data ownership in this case is further undermined.

3. Methodology

In this chapter, methodologies used to conduct the research are explained. Several methods are adopted to embody the theoretical framework. Research design provides an overview of the methodological structure of the study. The literature review identifies the context regarding the global FAIR adoption, BI in healthcare, and HMIS situation in Africa. Semi-structured interview helps collect required data for the preparation of designing and creating a BI plan as the output of this research. The dashboard design method provides a guideline of the prototype development and future work.

3.1 Research Design

Qualitative data analysis was performed under the MSF of John Kingdon. The analysis used open, axial and selective coding as a grounded theory method. The reason for choosing this method is that the concepts emerge from the raw data and later grouped into conceptual categories in the process of open coding, with the goal to build a descriptive, multi-dimensional preliminary framework for later analysis. By doing so, the process itself ensures the validity of the work as its build directly comes from the raw data [36]. Then axial coding was conducted to relate codes (categories and concepts) to each other through a combination of inductive and deductive thinking. As the final step, the selective coding was used to gather a complete picture of the information obtained during the data collection process [37]. The results of selective coding based on each chosen non-Western geography were further classified into three streams of the MSF, namely the problem stream, the policy stream and the politics stream. Under the MSF, it is possible to identify the policy window for the potential adoption of FAIR data in the local context. The same approached was also used in the interview analysis to identify the acceptance of proposed system by local data processors. Moreover, a design study method of dashboard development was adopted to create a prototype of the proposed BI solution.

3.2 Literature Review

In order to identify to what extent FAIR data are able to support the BI framework in healthcare under the VODAN Africa localization architecture as well as to globalize the VODAN project, it is necessary to perform a literature review with regard to the current implementation of FAIR data at an international level. As aforementioned, because around 80% of the implementation of FAIR has been found in Europe and North America, researching selected non-Western geographies will be the focus of the literature review as it is important to understand the worldwide influence of FAIR implementation. It is noted that the systematic literature review of global FAIR adoption is going to be published and included in a journal called Data Intelligence and therefore the first version of the draft is used in this thesis to present relevant findings. The role of BI in the healthcare domain in general will be investigated to understand its capacity in such a specific area, followed by literature analysis of health information systems in Africa.

Appropriate search strategies and selection processes were formulated and performed according to the specific topic being researched. Regarding global FAIR implementation, selected non-English geographies were determined depending on the language skills of the team members. Yi Lin was in charge of searching and selecting literature written in Mandarin and Japanese since his mother tongue is Mandarin and he speaks advanced Japanese. Putu Hadi Purnama Jati from Indonesia investigated literature in the local languages,

while Aliya Aktau investigated Russian-speaking regions as well as Kazakhstan since she speaks both languages fluently. Mariem Ghardallou took charge of searching literature based in the Arab world since she is an Arabic native speaker. Lastly, according to Sara Nodehi, all the literature found regarding the FAIR adoption in African countries are all in English.

Local databases and search engines were chosen to provide data written in local languages. As to Japanese literature, the most leveraged literature databases in Japan were used, which are CiNii, J-Global and researchmap.jp, and the most popular search engine, yahoo.co.jp, was used. The specific search strategy regarding key words connected with Boolean operators were defined (see Table 4). Keywords include but are not limited to "FAIR", "data" as well as the translation of the word "data" in respective languages. The time frame was set between 2014 and 2021 because FAIR data Principles have started getting attention since the year of 2014. Google scholar was also utilized as a supplement to find resources. Finally, baidu.com was used to search Chinese literature as it is the biggest search engine in Chinese-speaking geographies, while yandex.ru, as the most used search engine in regions influenced by the Russian language, was used to find corresponding data.

Table 4 Search strategy of literature about global FAIR implementation

Search strategy (CiNii, J-Global, researchmap.jp, google scholar, yahoo.co.jp, baidu.com, yandex.ru)
(((findable OR findability) AND (accessible OR accessibility) AND (interoperable OR interoperability) AND (reusable OR reusability)) OR (FAIR AND (Asia OR Africa OR Arab OR China OR Indonesia OR Japan OR Kazakhstan OR Russia)) OR FAIR) AND (data OR 数据 OR データ OR البيانات OR деректер OR данные) **Search range by year: 2014–2021**

The selection criteria for the literature were defined. Articles written in languages other than English that contain keywords and discuss the introduction or the adoption of FAIR data Principles in specific regions or countries were selected, whereas articles written in English yet particularly focusing on applying FAIR data in geographies located in the Southern and Eastern hemispheres were also chosen because English is the dominant language in scientific publication. The results were further processed using inclusion and exclusion criteria. Literature was included if FAIR data Principles were implemented to make a novel and concrete academic proposal in the study, and gray literature was included if cutting-edge policies in terms of FAIR were mentioned. On the other hand, literature was excluded if duplication was spotted and if contents were considered as irrelevant by screening abstracts and titles or assessed as non-eligibility. In this way, identified data was narrowed down for further analysis in the next step. Among selected literature data, three master theses from Putu Hadi Purnama Jati, Aliya Aktau and Mingyue Huo were chosen as the data reflect the latest local development of adopting FAIR data in Indonesia, Kazakhstan and China. The selection process is also illustrated in the following workflow. (Figure 3) The search strategy regarding repositories, websites, key words in different languages and time frame are showed in Table 4.

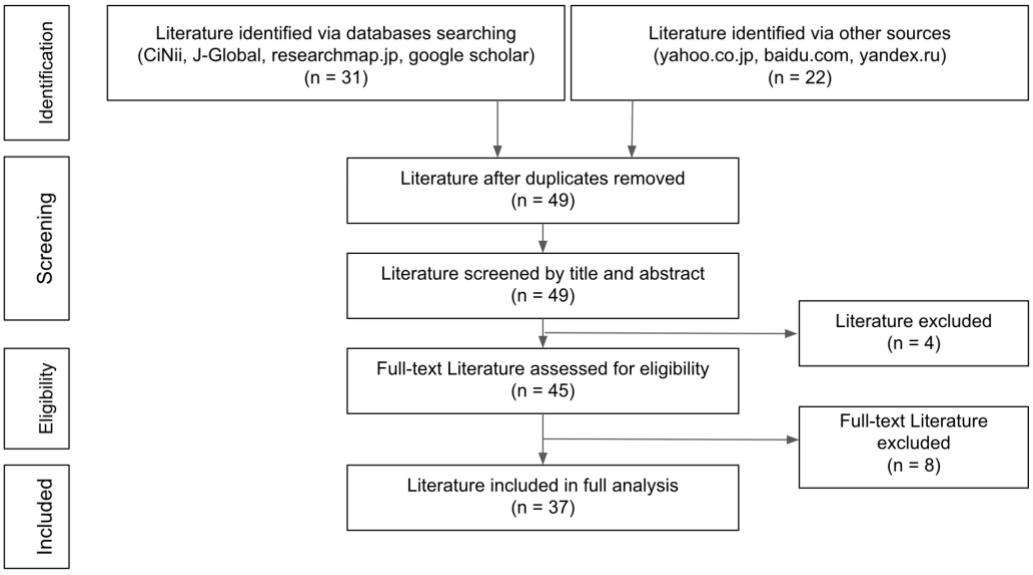

Figure 3 The workflow of the identification of qualified literature, source: created by the author, Yi Lin

The collected literatures were studied using coding labeling method explained in the last section. Critical labels were made by scanning the literature data, and then labels were categorized into three groups in accordance with three streams of Kingdon's theory. Under each stream group, sub-groups were further identified depending on the label contents. In terms of the concept list of global FAIR implementation, nighty one critical labels were determined whereas eight sub-groups were found (see Appendix B).

Moreover, the demand for leveraging BI as a solution to helping optimize decision making processes in the domain of healthcare needs to be clarified. There appears to be research available on this clarification, by considering the availability of review papers on the topic [38]. The snowballing method is then used on top of the study of L. Loewen and A. Roudsari to extend the data scope. As the purpose is to depict a general background of BI in the healthcare domain, 18 articles have been selected to perform the literature review. The selection criterion is that literatures are included if information in terms of the history as well as competition and challenges of BI are contained.

Table 5 Search strategy of literature about HMIS in Africa

Search strategy (google scholar, google.com)
(HMIS OR health information system) AND (Africa OR Uganda OR Ethiopia OR Liberia OR Nigeria OR Kenya OR Somalia OR Tanzania OR Zimbabwe OR Tunisia) **Search range by year: 2005–2021**

Literature review about HMIS in Africa was performed. The search was done mainly on google scholar and google.com. The search strategy is showed in Table 5. The keywords used are "HMIS", "health information system", "Africa" and VODAN Africa member countries. The time frame was set from 2005 to now as the development of HMIS is fast. Some systems may not be used anymore if the time range is too long. Due to the lack of resources in articles, the snowballing method was also used to search for more literature that can provide useful information. In addition, websites and other documents such as reports and government papers have also been included to find needed information. As the purpose is to identify capabilities of current systems and to conduct a comparison between them and the proposed system, the selection criterion is that resources were included if needed information is contained. As a result, 35 literatures have been selected and studied.

3.3 Semi-structured Interviews

A semi-structured interview allows researchers to collect information from interviewees in a relatively open and flexible way with a loosely structured question preparation while interviewees are still able to extend the answer freely by fully giving their opinions through open questions. The semi-structured interview was used in this research because it is the most commonly used data collection method in qualitative research in a healthcare context [39], and it is important to understand the perspective and needs of local clinics in Africa as much as possible through interviews with healthcare staff led by open questions.

In order to answer research question two, three, four and five, semi-structured interviews were designed and conducted among local hospitals and clinics in Africa. As this research is a part of VODAN Africa research team, the interview design and conduct are collaborated with African country coordinators from the research team. Due to the concern of data sensitivity and better cooperation, country coordinators played an important role in the whole interview process. For example, opinions of country coordinators about interview questions were considered as improper questions that might offend interviewees due to cultural difference and related reasons need to be excluded. Country coordinators also directly took charge of carrying out interviews and collecting data as a practical solution because of trust concerns.

Depending on the participation of local facilities and responsibility of country coordinators, 31 interviewees have been determined in this research. All the respondents are data clerks as they are familiar with all the detail about the data management processes in all the local health facilities. Respondents were contacted by email. All the communication as well as interviews were delivered in English as it is the official language to converse.

The results were collected in a google sheet and the analysis was performed using Kingdon's MSF as the guidance to identify whether the policy window is open to introduce an alternative system in local facilities. As to the analysis method, same coding labeling method was used to find important labels which were then categorized by three streams (i.e., problem stream, policy stream, politics stream). After that, sub-groups were defined under each stream group. The concept list of interview analysis was also created by determining 67 important labels and 11 sub-groups (see Appendix C).

The interview was introduced with the following opening statement:

"Thank you very much for your participation as the respondent for our project. My name is [name], and I am working on a project of Improving Quality of Healthcare Through Data Ownership and Localization.

The general objective of this project is to achieve realization of healthcare quality by improving the data ownership in the facilities. The final report of the project can be sent to you if you would like to know the results.

A few questions are prepared, and please feel free to share your opinions regarding any other information that you think might be relevant to this project. In case you are not comfortable with some questions, you do not need to feel obliged to answer. In this interview, there are no right or wrong answers. Furthermore, it is ensured that all discussions are kept anonymous to protect your confidentiality."

Interview questions are categorized into three groups along with the three-around interviews from basic questions to deeper ones. The three categories are "Health Facilities General Information", "Role Identification", and "Current Data Management System". Questions examples used in the semi-structured interviews are as follows:

Health Facilities General Information
Role Identification
Current Data Management System

Table 6 Interview questions in three categories

No.	Questions
1	Background information on the interviewee - Current roles/responsibilities - Years of experience (first join the office) - Description of roles/responsibilities
2	How would you describe your experience with the patient data management in this facility?
3	Type of Facility - a health center or a health post - who operates the facilities (Government, Private, Military, etc)
4	The number of Outpatient Data (OPD) registers
5	Use HMIS? What?
6	Does this clinic have functioning computers, and how many?
7	Does this clinic have an internet connection?
8	How many data clerks in this facility?
9	Would you tell me more about facilities patients? - Major economic activities of the people living in the region

	- How many patients are seen daily? - What type of patients are seen daily? (preventive/sick)
10	Would you tell me more about patient data collection? - Who is responsible for recording the patient data? - Would you mind sharing the contact of this person? - Tell me about the purpose of patient data collection - Who decides this purpose? (Data controller) - Any policies and regulations that govern patient data in the hospital/clinic? - If yes, what are the policies/regulation procedure?
11	Access to the patient data - Who has access to the patient data? (Doctor? Data steward? MoH? Patient? etc) - How did you access the patient data? (or that person access the data) - How did the Ministries of Health access the patient data? - Who decides this access? (It's all decided by the MoH or health facilities?)
12	Data Analyses - What do you know about the patient data analyses? (if any analyses) - What is the analysis purpose? (if any analyses) - Who decides the purpose? (Data Controller) - Who does the analysis? (Data Processor) - Who has access to the analyses? - Would you mind sharing the contact of a data analysis person?
13	How was the patient data collected? - Is this OPD recorded on paper or using computers? - What happened next with the data? (data and information flow) - Where is the data storage? (Physical storage in the archive room or in the pc?) - How long does this process take place? (from collection to store the data/report to HMIS) - If the health facilities use HMIS, how frequent the data input to HMIS? - Any problems you find with the data collection? - Any problems you find with the data storage?
14	How did the facilities transfer patient data from/to other facilities?
15	If the clinic was provided with a generic dashboard for the public with data analytics, what kind of data would the facility want to show? Who would have access to the generic dashboard?
16	If the clinic was provided with an internal and customized dashboard with the purpose of data analytics, what kind of data would the facility want to show? Who would have access to the internal dashboard?

17	Anything else that the interviewee feels has been missed and anything that they didn't get a chance to discuss fully?
18	Anyone else that would be useful to speak to?

3.4 Dashboards

Among BI tools, a dashboard is one of the most vital and essential ones for monitoring the daily health of organizations. From the user interface, decision makers have access to KPIs as an actionable information that can be used to effectively guide and track operational performance in both private and public sectors. A successful implementation of dashboards could help organizations gain critical insights from different needed aspects. In this research, the development plan of a dashboard is considered as an important step of accomplishing the VODAN architecture, not only because BI dashboards are becoming the must-have key elements of modern HMIS, but also due to the novelty of realizing real-time data analysis without interfering with the data ownership by following FAIR Principles.

According to Orts, it is necessary to rely on a methodology to create a dashboard as the successful implementation of a dashboard is complex and requires a step-by-step process that takes all aspects of building a dashboard into account as a project lift cycle. The process includes plan, design, build, deploy and maintain a dashboard, where the tasks and their order will be similar, regardless of the technology used [40]. Figure 4 illustrates the complete development life cycle of a dashboard project, yet steps from plan to design will be used in this research as the rest steps from build and validate to maintain will be considered as the future work.

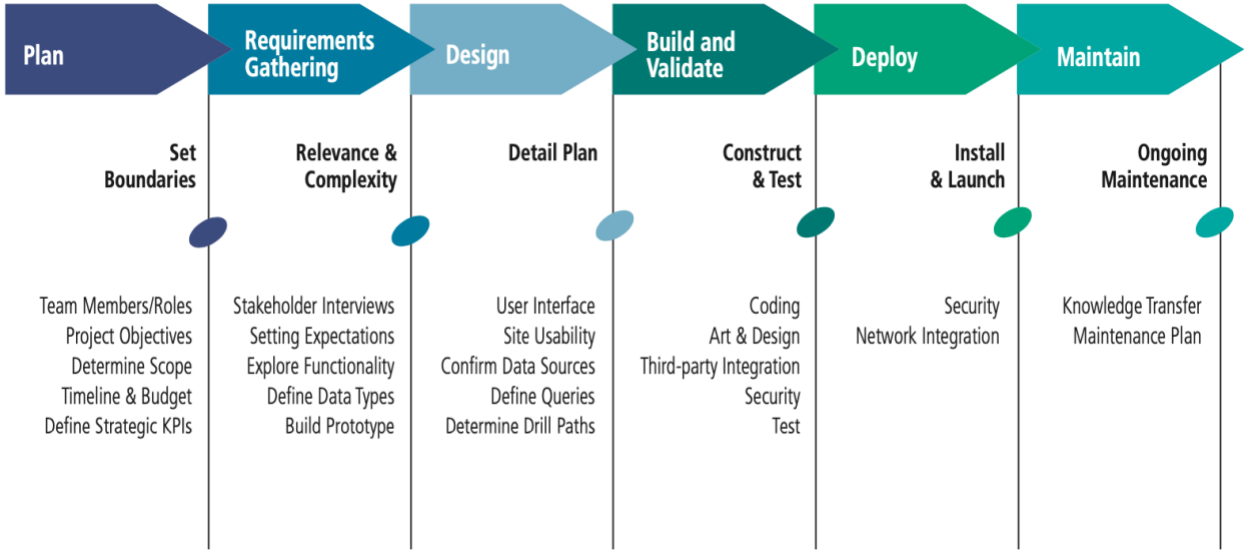

Figure 4 Dashboard Development and Deployment Methodology, source: D. Orts and Noetix Corporation [40, p. 1]

At the plan stage, basic boundaries will be defined by setting up a few essential elements. For example, a technical team will be formed by selecting members and the roles will be defined. Then the objectives will be determined during a series of team discussion, during which the concrete timeline will also be drafted.

Strategic KPIs will be decided by conducting interviews with data stewards from the local health facilities as their expertise and first-hand experience can help define which KPIs will be mostly essential to fit the needs of local African facilities. Therefore, defining strategic KPIs will be conducted using the analysis outputs of the expert interviews.

At the stage of requirements gathering, more interviews will be made with relevant stakeholders to clarify available capabilities of existing systems in different countries in Africa. It is an important step of recognizing the capacity gap as any duplicate functionalities need to be avoided while constructing the proposed VODAN architecture so that the benefits for both stakeholders can be maximized. During the following up interviews, perspectives and expectations of data stewards as well as local authorities will also be acquired which can help better understand their needs of data management and attitudes towards the acceptance of the new architecture. In terms of design of data types, information from two sources is considered, i.e., expert interviews and technical discussions. Data fields will be formed first in accordance with paper based OPDs from local facilities and then will be approved by discussing with local data stewards regarding the usability. Other data fields in relation to information of facilities, patient, disease and diagnosis etc., will be determined later in further discussions.

At the design stage, two main tasks are to be tackled, i.e., the design of User Interface (UI) and the design of data queries. The UI would be consulted by interviews first to have an overview of local facility's preferences, and then will be refined after their assessment, which may repeat for several rounds. The data queries will be realized through the CEDAR API, which is scheduled as a future task as relevant deployment and test are still ongoing, and mock data will be enough to use in the phase of creating the prototype. Lastly, the remaining three stages (i.e., build and validate, deploy, and maintain) will be included in the future work as these tasks are out of the scope of this research and more participation of other team members are required to handle the workload as well as task complexity.

4. FAIR Principles and Implementation

In this chapter, FAIR Principles are explained in detail. A systematic literature review of global FAIR implementation and the identification of FAIR readiness in Africa is performed with the guidance of the Kingdon theory. The conformation of FAIR readiness in Africa helps answer the research question one.

4.1 FAIR Principles

The FAIR Principles were constructed to guide the creation of data that fulfill the requirements of Findability, Accessibility, Interoperability, and Reusability. The initiative stem from a study published in 2016 with the intent to build a guideline with diverse stakeholders (i.e., academia, industry, funding agencies, and scholarly publishers) in order to enhance the ability of machines to automatically find and use the data besides its reuse by individuals [4]. The details of FAIR Principles are showed as the following according to the guidance from GOFAIR:

Findable

"The first step in (re)using data is to find them. Metadata and data should be easy to find for both humans and computers. Machine-readable metadata are essential for automatic discovery of datasets and services, so this is an essential component of the FAIRification process."

F1. (Meta)data are assigned a globally unique and persistent identifier

F2. Data are described with rich metadata (defined by R1 below)

F3. Metadata clearly and explicitly include the identifier of the data they describe

F4. (Meta)data are registered or indexed in a searchable resource [41]

Accessible

"Once the user finds the required data, they need to know how they can be accessed, possibly including authentication and authorization."

A1. (Meta)data are retrievable by their identifier using a standardized communications protocol

A1.1 The protocol is open, free, and universally implementable

A1.2 The protocol allows for an authentication and authorization procedure, where necessary

A2. Metadata are accessible, even when the data are no longer available [41]

Interoperable

"The data usually need to be integrated with other data. In addition, the data need to interoperate with applications or workflows for analysis, storage, and processing."

I1. (Meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.

I2. (Meta)data use vocabularies that follow FAIR principles

I3. (Meta)data include qualified references to other (meta)data [41]

Reusable

"The ultimate goal of FAIR is to optimize the reuse of data. To achieve this, metadata and data should be well-described so that they can be replicated and/or combined in different settings."

R1. Meta(data) are richly described with a plurality of accurate and relevant attributes

R1.1. (Meta)data are released with a clear and accessible data usage license

R1.2. (Meta)data are associated with detailed provenance

R1.3. (Meta)data meet domain-relevant community standards

The principles refer to three types of entities: data (or any digital object), metadata (information about that digital object), and infrastructure. For instance, principle F4 defines that both metadata and data are registered or indexed in a searchable resource (the infrastructure component) [41]. In the next section, the global FAIR implementation will be further discussed.

4.2 Global FAIR Implementation

4.1.1 China

Problem stream

Submitting data as independent information objects and storing them in open access repositories to provide public access has become the dominant approach to data management, not only globally, but also in China. In order to identify the problem in China, this analysis looked at data in the humanities and social sciences, as well as in the healthcare sector. FAIR is one method of meeting the demand for data reuse and supporting academic research in the humanities and social sciences, based on large-scale data integration. But most studies in China, as well as the application of FAIR Data Principles, focus on the natural sciences instead of humanities and the social sciences [42].

Regarding healthcare data management in China, conventional data stewardship hinders the potential for data reusability, limiting the efficiency of the reuse of health data in digital health. Although FAIR data has

already been successfully applied in the healthcare sector [43], the fact that the major implementation of FAIR has been in European and the American geographies affects its effectiveness as a general principle. Hence, it is necessary to explore the attitudes and acceptance intentions of applying FAIR Principles in China's digital health arena [44].

Policy stream

In order to clear the barriers to sharing and reusing data in the field of humanities and social sciences in China, a multi-level system architecture is needed, based on a qualitative comparison of three international data platforms: the Data Archiving and Networked Service (DANS) based in the Netherlands, the TGIR Huma-Num based in France, and Dataverse based in China. The three platforms were chosen according to a survey of the Go FAIR initiative's founding countries and international data projects by considering factors such as maturity, representativeness and data domain [42]. The FAIRification of data for publishing on this platform needs to be conducted on at least five layers. The knowledge infrastructure layer consists of the classification mechanisms, raw data and cyberinfrastructure, and provides data sources, expertise and relevant technical support. The metadata layer is the basis for interoperability, based on FAIR data. It can be an important data source and provides a basis for reusability in research in the humanities and social sciences after data publication, due to the feature of unstructured and semi-structured data. The tool layer includes knowledge representation tools, retrieval tools and analysis tools. Although FAIR Principles do not request specific technologies or tools as guidelines, RDF Mapping Language (RML), Triple Pattern Fragments (TPF) and W3C standards are the usable basic structure, which is machine-readable and satisfies FAIR Principles. The data layer focuses on data structures and reusability. The interoperability of data is enhanced by unstructured and semi-structured data, based on structured metadata descriptions, providing a variety of machine-readable data reference formats. And, lastly, the resource layer is the implementation level of FAIR data used to improve the FAIRness of the data [42].

In terms of identifying the acceptance of FAIR data in digital healthcare in China, a recent case study interviewed 30 respondents (15 medical staff and 15 patients) in a hospital in Miyun District, Beijing. The extent to which FAIR data are accepted and adopted in Chinese digital healthcare was researched from three aspects: (i) attitude – whether medical staff and patients consider FAIR data as an effective mechanism for data reuse in digital health, (ii) social norms – from the perspective of the patient's family members and peers and the experts in healthcare, indicating what the social perception on health data sharing and reuse is, and (iv) perceived behavioural control – identifying what factors encourage and impede the adoption and acceptance of the FAIR Principles, in today's policy environment and hospital atmosphere [44].

Through the interpretation of the political environment and cultural context for the implementation of FAIR in China, the results reveal that the adoption and acceptance of FAIR differs between medical staff and patients. Young medical staff have a positive attitude towards the adoption of FAIR, whereas older medical staff and patients have neutral or even negative attitudes [44]. Similarly, several other published papers suggest that FAIR data has already caught the attention of Chinese scholars who have carried out literature reviews on the introduction of FAIR data and experiences with the implementation of FAIR in Europe [45] [46].

Politics stream

In the field of humanities and social science research, digitalised scholarship has accelerated data-driven research tooling, methodologies, and critical thinking. The amount of data being generated and the demand for data are growing, leading to the concern about data reusability. The FAIR Data Principles provide guidance for the workflow of data publishing and assessment of reusability. Thus, the challenges of data publishing in humanities and social sciences, such as the diversity of data formats and the prevalence of unstructured and semi-structured data, can be solved. Researchers and scholars in the field of humanities and social science research can, thus, benefit from FAIR-based data publishing platforms.

On the other hand, the political willingness to accept FAIR comes from the government, medical staff and the patients as all the three stakeholders have influence on the policy creation. Not only do the FAIR Data Principles coincide with the Internet Plus Health Care policy of the Chinese government, but there is also a strong demand for the shareability and reusability of health. In addition, the State Council, the chief administrative authority of the People's Republic of China, has declared that big data on medical and health is an essential strategic resource. However, FAIR implementation in healthcare may not be completely wide open on a national scale, but could be possible with some restrictions, influenced by national policy, as health data are not only owned by an individual in China, but seen as an important national strategic resource [44].

4.1.2 Indonesia

Problem stream

In Indonesia, there have been problems with data gaps among government ministries and institutions. In government agencies, land data, agricultural production, and unemployment can be controversial and are heavily discussed. In 2016, in a meeting to coordinate the economic census, the President of Indonesia expressed his dissatisfaction with the lack of sharing of data and the data inconsistencies between government agencies [47]. As a result of the weak collaboration between government agencies, the government has been unable to optimise its data management [48] to effectively use the data it currently has.

Policy stream

In order to solve its data management problem, the Government of Indonesia wants to increase integration, synergy and the coherence of data generation [49]. Towards this, various meetings and in-depth discussions have been held by ministers and heads of departments [49]. As a result, the Indonesian government has come up with a two-pronged strategy for data management which are being implemented under Satu Data Indonesian.

The first part of the strategy is enhanced collaboration by developing an organisation for data production within the government. Under this arrangement it is believed that the sectoral ego can be eliminated and collaboration facilitated, as the project forces all relevant ministries and agencies to communicate before the publication of information [48]. The second component is the data principle. The Indonesian government believes that rules for data production are needed, in addition to coordination. Therefore, four data principles have been initiated: data must conform to data standards, metadata has to be available, data

must be interoperable, and a reference code for data must be used. Although the Indonesian government's data principle does not mention FAIR, Satu Data Indonesia has some similarities with FAIR.

Satu Data Indonesia follows the FAIR Principles in the following ways: [48]

- The data standards and code reference principle of Satu Data Indonesia follows the third sub-principle of FAIR – 'Reusability' (R.1.3[1]) – to meet domain-relevant community standards.
- Satu Data Indonesia's interoperability principle follows the principle of 'Interoperability' from FAIR, which requires its data to be interoperable.
- Satu Data Indonesia's metadata principle follows all the facets of the FAIR Principles for 'Findability' (F1, F2, F3, F4) and the first facet for 'Reusability' (R1) in relation to the metadata requirement.

Three out of four of the principles of Satu Data Indonesia are identical to FAIR: data should conform to data standards, metadata should be accessible, and data should be interoperable.

Even though FAIR is not mentioned in Satu Data Indonesian, awareness of FAIR still exists among Indonesian academia. FAIR data, as a strategy for data management, is not simply an administrative movement, but plays an important role in guiding scientists in the proper collection, storage and sharing of research data in a sustainable way [50]. Moreover, FAIR data was mentioned as one of the main criteria for complying with Open Science Framework (OSF) dynamic repository and static institutional repository. In 2020, Indonesia's science repository clearly stated in its guidance that FAIR Principles be implemented to support open science [51].

Politics stream

As mentioned above, Indonesia is implementing strategies to improve data management by streamlining the data from various government agencies [48]. Satu Data Indonesia was published in 2019 to guide the coordination and implementation of data management principles among Indonesian ministries and agencies to improve the quality of data produced by the Indonesian government. The Ministry of National Development is the driving force behind Satu Data Indonesia and has consistently suggested that the President of Indonesia regulate Satu Data Indonesia. In addition, researchers in Indonesia have increased their awareness of data management by implementing FAIR Principles to support open science. Therefore, it appears that there is potential to implement the FAIR Principles in Indonesia by extending the model for the management of government data as well as data in research repositories.

4.1.3 Japan

Problem stream

Regarding the adoption of FAIR in Japan, most of the scenarios are about the improvement of research data distribution, although the specific context varies. For example, due to the explosion of digitised data in the field of agricultural research, it is necessary to establish an approach to collecting and managing such data

[1] The refers to the facets of FAIR of which there are 15: F1, F2, F3, F4, A1, A1.1, A1.2, A2, I1, I2, I3, R1, R1.1, R1.2, R1.3

efficiently in order to improve the research environment, as well as to provide mechanisms to facilitate the application of statistical analysis and machine learning. On the other hand, a new approach under the frame of a central data management system is considered necessary to increase the legitimacy of research data and avoid data breaches. Therefore, the Government of Japan has launched a new data management strategy to support universities and research institutes in terms of data archiving, management and queries [52].

At the same time, some FAIR equivalencies are being discussed by academics in Japan, and some were even adopted by Japanese research institutes [16]. For example, Dataverse (https://dataverse.org), developed by Harvard University, is one of the adopted systems by Japanese institutes. Dataverse is also used by the French public research institute dedicated to agricultural science (INRA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). It is featured to increase accessibility and reusability of data. In 2020, the National Institute of Informatics in Japan decided to adopt GakuNin research data management (RDM) (https://rdm.nii.ac.jp), which is a localised open-source software based on Open Science Framework (OSF, https://cos.io/our-products/osf) stemming from the Center for Open Sciencelink in the United States. GakuNin is a platform for accessing research data in a sharable manner, like J-STAGE Data, which is another FAIR equivalent platform. However, the aforementioned systems and services all have a problem in terms of accessibility, to various extents, due to the fact that the design purpose is to protect research data. For example, problems with accessibility occur when shared folders are used in the built-in database. In particular, automatic modification triggered by adding unique IDs and changing organisations results in the automatic inheritance of access rights from the parent directory. The authority of accessibility is also automatically identified by checking whether data fields, e.g., fund and licence, confidentiality types, and personal information, are existing. Moreover, specialised functionalities are required in the field of agriculture in relation to setting up metadata freely, use of agricultural terminology, and data query [52].

In term of FAIR equivalence, the data management plan (DMP) templates in Japan are in line with FAIR Principles. A DMP is a plan for how to manage, handle, maintain, store and publish data collected and created for research, and can maximise the value of investments in research results by enabling the reuse of data and ensuring that data are managed efficiently and appropriately [53]. If DMP templates can be created and implemented flawlessly, the data are able to be reused over time. OpenAIRE and the European Commission's (EC) FAIR data experts conducted a survey[2] on templates among DMP creators and support staff in 2017 [54]. Approximately 60% of respondents perceived the process of creating and supporting DMP templates positively, and 16 perceived it negatively. However, there is concern that researchers might have to spend too much time making DMP templates, the purpose of which is to save them time. Therefore, the need to develop a DMP tool is increasing. Based on the output of DMP, the author has further applied the discussion and discoveries to the RDM tool [55].

In relation to the adoption of FAIR in public research (e.g., by national universities) in Japan, there has been an emphasis on increasing data reusability and preventing academic dishonesty. For example, institutional research organisations like national universities have allocated significant financial and human resources to research activities, since institutional research (IR) was introduced in Japan in early 1990s, but there are still problems with regards to the lack of professionals and technological skills. The reason is that

[2] To which they received 289 responses.

universities do not have sufficient funds to investment in conducting institutional research, in addition to retaining skilled personnel, as institutional research requires many skill sets including management, data processing and statistical analysis. As a result, staff with backgrounds in pedagogy and statistics are assigned to handle tasks related to institutional research, instead of those specialising in social science. On the other hand, tasks that require IT solutions are usually outsourced, which generates concerns about data security [56].

Last, but not the least, FAIR data has also been implemented in citizen science interlinked with community-based participatory research for solving socio-environmental issues [12]. In a recent study by Kondo et al. in 2019, a theoretical framework called 'open team science', featured in a data visualisation method based on the FAIR Data Principles, has been created and will be tested using case studies. In this study, the issue of waterweed composting in the Lake Biwa catchment in Shiga Prefecture was perceived different by different stakeholders. For the prefectural office, which is responsible for preserving the lake and removing overgrown waterweeds, it was an environmental maintenance issue, while to the public it was a social issue because of the bad odour and waste released when the waterweed drifted ashore. Therefore, there are significant inter-actor boundaries between different actors preventing the shareability of information. Besides these differences in the process of data sharing, projects were also disrupted by socio-psychological boundaries during the initial phase of team building, according to coordinators. Such issues are often generated by asymmetric information, knowledge and power among actors [57].

Policy stream

Various strategies are needed to deal with the issues outlined above. First of all, a data scheme for the new system, called the National Institute of Agriculture, Forestry and Fisheries (NARO) Linked Database (narolin DB), is proposed by NARO in Japan. This scheme is guided by the Japanese government in terms of building the research data repository and is based on FAIR Data Principles. The main purpose is to improve the reusability, interoperability and shareability of research data by implementing metadata. Besides typical metadata such as title, author name, date, keywords and location, customised NARO Commons metadata keywords have been created. For example, there are numerous data classification to indicate research categories (10 big groups, 60 middle groups, and 106 small groups), more than 21 thousand translatable keywords, and terminology about more than 14 thousand species. All metadata are stored in Excel and uploaded together with original data to the system [52].

Secondly, based on the findings about the DMP tool, it is considered necessary to decrease the burden on researchers to making templates and improve the reusability of research data. Hence, next-generation DMPs are needed that encompass FAIR Data Principles, as well as the standardisation of DMPs and development of active DMPs. In response, a RDM rubric has been developed to support researchers and libraries in Japan. These RDM evaluation tools, which have developed to suit the situation in Japan, are useful for researchers and research institutions to visualise inadequacies and examine priorities. In addition, these evaluation tools were used among researchers in Japan, and the results provided a good clue for understanding the needs in constructing the RDM service [55].

Thirdly, checklists based on the FAIR Principles can be applied to institutional research data in national universities in Japan. These checklists can be used when the system is updated or modified. Such checklists

would also help university staff to understand the task better in terms of the requirements for IR interoperability in certain systems. In particular, FAIR Principles allow users to add a unique ID so that metadata holds explanatory information. This ID could be used by digital media and the network, while also making it possible to authorise accessibility. The shareability of metadata are important during the reconstruction phase after data are collected, by using analysis methods via data warehouse. A system with the following four elements is proposed with regards to the definition of analysis methods via data warehouse and databases based on institutional research data, related to the maintenance and realisation of metadata: (i) metadata, (ii) entity-relationship diagram, (iii) star scheme, (iv) online analytical processing (OLAP) [56]

Lastly, the framework 'open team science' was developed in the Biwa Lake case study to achieve boundary spanning with the transcend method and the goals were discovered and shared, allowing actors with different interests to cooperate. The results of the questionnaire survey were disclosed as FAIR data. Experience and lessons learnt can inform subsequent stages or new projects as input resources. In the authors' opinion, it is thus possible to bridge these boundaries by sharing information, knowledge and wisdom through appropriate visualisations and dialogue based on FAIR data [12].

Politics stream

A new integrated innovation strategy was approved by the Ministry of Health, Labour and Welfare of Japan in 2018. The purpose of this strategy is to promote the formulation of data policies not only at the national research institutes under its jurisdiction, but also at national experimental research institutes and independent administrative agencies. The government white paper claims that, as one of the requirements for data management, the FAIR Data Principles should be followed to enable research data to be found, accessed, shared, and machine-readable in order to increase the efficiency of data-use in the research context [58]. In line with this new data policy, the implementation of FAIR data in Japan has been stepped up among diverse political actors. For example, NARO is responsible for constructing the new system to improve the quality of research data management in the field of agriculture. The Japan Science and Technology Agency (JST) has claimed that it was necessary to develop DMP since 2017, whereas in 2018 the New Energy and Industrial Technology Development Organization (NEDO) and the Japan Agency for Medical Research and Development (AMED) have both expressed the same manifesto [53].

The shareability of research data in open science is also being addressed and it is necessary to find a solution to enable researchers, research institutions, libraries, and other stakeholders to use research data in open science. With regards to community-based participatory research, researchers and societal stakeholders (such as governmental agencies, industries, non-profit organisations and civil society) share leadership roles to reach decisions. They work collaboratively to design research agendas, to find solutions, produce knowledge, and disseminate the results [59]. Collaborative learning and the integration of information through mutual understanding between different actors is particularly important during this process [60] [61].

4.1.4 Kazakhstan

Problem stream

Since 2013, Kazakhstan's main focus in the field of digital healthcare has been on establishing an integrated information environment as the basis for personalised and preventive healthcare services [62]. The country has allocated resources for integrated data infrastructure to improve people-centred health systems. (To this end, 22 health information systems provide statistics and analytics in Kazakhstan for better decision-making. Although the implementation of the Interoperability Platform has been finished, data remains fragmented at the level of healthcare organisations, as the platform has not gone live yet and, therefore, the data cannot interact with each other [63].) To address data fragmentation issues, an Interoperability platform was presented, the launch of which was expected in 2020 [33]. Although the implementation of the Interoperability Platform should be finalized, there are no updates in the sources. Consequently, the data remains fragmented at the level of healthcare organizations, since the platform is not launched, and, therefore, health data cannot interact with each other [28].

According to the World Health Organization (WHO) in Kazakhstan [64], one of the top three challenges in the country is to develop capacity for handling data. The volume of data has grown rapidly in recent years, making it necessary to not only improve the quality of data for interested parties and medical personnel to easily access, but also to allow data to interact to facilitate the provision of healthcare services as well as medical research. In accordance with the Ministry of Health reforms, efforts to introduce the Interoperability Platform have been unsuccessful [65]. As a result, data are still not findable, accessible, interoperable and, therefore, cannot be reused by healthcare organisations. The FAIRification of data can address these issues and allow the discovering meaningful patterns, contribute to better decision-making, as well as saving billions of euros [66].

Policy stream

Most health-related issues in Kazakhstan are identified by the Ministry of Health, which is pursuing reforms and policies to align with the national strategies [67]. To address the issue of data fragmentation, the Ministry of Health has launched a number of programmes since 2013, which use international standards and vocabularies and show a willingness to participate in global science. This may prompt the development of an FDP for digital healthcare in Kazakhstan, contributing to the development of medical science in Kazakhstan and Open Science globally.

In order to implement FAIR data in Kazakhstan, awareness about FAIR needs to be raised more broadly. If stakeholders understand the benefits that FAIR could bring to the country their interest in FAIR may increase. However, as the people of Kazakhstan are used to a top-down approach, the government needs to reach out through people who understand the value of FAIR data and promote it from bottom to top. Combining both bottom-up and top-down approaches might bring results in terms of the acceptance of FAIR in Kazakhstan, leading to its adoption.

Politics stream

In order to achieve sustainable development for the adoption and implementation of FAIR, a favourable environment, including an institutional framework and standards, data and funding for use-cases must be provided, rather than investment in any particular technology [68]. In this regard, the Government of Kazakhstan is willing to develop a healthcare data infrastructure to serve as the foundation for the provision

of healthcare and medical research. A strong political resolution to improve health outcomes is evident in a number of the recent reforms, including the digital health concept 2013–2020 [63], Densaulyk 2016–2019 [64] and State Health Development Program for 2020–2025 years [63]. All of these policies and programs endorse the interoperability of data and its efficient (re)use.

4.1.5 Russia

Problem stream

In Russia, from a technological point of view, there is a problem with the logical integration, harmonisation, and unification of heterogeneous data from different sources, specifically, interdepartmental government information systems (electronic services) [69]. In addition, a single form of scientific data representation and data management is lacking within the scientific community in Russia [35–37]. The key problem is not about collecting, publishing and storing information, but about ensuring the findability, accessibility and reusability of data, including on other platforms. FAIR data can not only share scientific results in a form that is understandable to investors, government agencies and the public, but can also ensure control over a large amount of scientific data [70].

Policy stream

In December 2018, Russia introduced the National Data Management System (NDMS) as a part of its national programme 'Digital Public Administration', to overcome the lack of logical integration, harmonisation and unification of heterogeneous data generated from various sources. The NDMS has been crafted with the purpose of repairing the fragmented information systems across the various ministries and departments (electronic services), as well as enabling their interaction (interoperability). As this is a large-scale and complex project, the solution was first tested in the Arctic macro-region [69], after which it will be rolled out across the rest of Russia.

The main goal of the NDMS is to increase the efficiency of the creation, collection and (re)use of state data for the provision of state and municipal functions, and to meet the needs of individuals and legal entities in terms of access to information. Implementing FAIR data are seen as one of the most succinct frameworks that can overcome the challenge of data fragmentation. The adoption of FAIR is considered to be the next step in the management of data in Russia [69].

Work is also underway in Russia to ensure access to information and data processing in the scientific field and appropriate regulatory mechanisms are being developed. The Connecting Russian and European Measures for Large-scale Research Infrastructures-plus (CREMLINplus) project is being developed by Russia and the European Union to expand ties in the field of scientific and technical cooperation. This project is based on providing access to the Russian research infrastructure for international use, as well as for the exchange of knowledge. FAIR Data Principles are included in CREMLINplus in terms of the accessibility of data from European research groups by Russian scientific infrastructure [70]. Based on FAIR Principles, it is practical to better integrate Russian research infrastructure with European ones, as well as provide a basis for developing similar data management rules.

Political stream

The NDMS concept considers FAIR data as the foundation of the main international conceptual requirement for data, and the FAIR Principles are already including in CREMLINplus. Both policies confirm the compatibility of data in different organisations and their effective use, which is important for analytics and decision-making processes led by political stakeholders from the central government. In addition, discussion with regards to the introduction and possible implementation of FAIR data was found in several articles funded by the Russian Academy of Sciences [38–40], and adopting FAIR in the management of research data in order to effectively manage data life cycle in scientific was the concerned of the Russian academia. Although the findings indicate that there is potential for the adoption of FAIR in Russia, locally owned data management practices are still preferred, which means that a policy window is not entirely open and more awareness raising of the benefits of FAIR need to be conducted before it is put firmly on the policy agenda.

4.1.6 Middle East

Problem stream

In Middle East, there are many challenges with the management and sharing of research data. A recent study found that more than half of Arabic researchers in Egypt, Jordan and Saudi Arabia had no DMP and 42% were unfamiliar with such plans [76]. Hence, it appears that this step in the research life cycle is a new concept for the participants in that. In this study, researchers were concerned more about issues of confidentiality in relation to providing access to their research data [41]. In the same vein, a study by Malone, which looked at the data sharing practices and perspectives of scientists in the Middle East (in the Gulf Cooperation Council countries[3]), also indicated that the majority of researchers (72%) are not required to have a DMP as part of their research projects or do not know if one is required [77]. This common practice may explain the almost complete absence of articles documenting the use or implementation of FAIR Principles in the Middle East.

Policy stream

Governmental bodies, especially higher education institutions, are at the cutting edge of scientific research in the Middle East. However, this scientific research faces many challenges, such as a lack of focus with respect to research priorities and strategies, and insufficient funding to reach research goals. Despite the fact that sharing research data has been recognised as a strong scientific need, several major research efforts in the region – such as the Arab Strategy for Scientific and Technical Research and Innovation; the National Policy and Strategy for Science, Technology and Innovation 2013–2017 in Jordan; the Science, Technology & Innovation Policy in the United Arab Emirates; and the National Strategy for Science, Technology and Innovation 2015–2030 in Egypt – have restricted their motivation of sharing research data, which impacts not only on how they profit from research outputs and published articles, but also how researchers in the

[3] Gulf Cooperation Council countries are Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman.

Middle East can exchange published research outputs. Furthermore, no focus is given to unpublished data sets or raw data [77].

Despite this, there are some initiatives in this field that deserve to be mentioned. First, there is the Research Output Management through Open Access Institutional Repositories in Palestinian Higher Education (ROMOR), launched in 2016 under the auspices of the European Union's Erasmus Plus programme. Over the course of three years, this project aims to build capacity for research output management in four Palestinian universities by establishing Open Access Institutional Repositories (OAIRs) based on FAIR Principles in order to increase the accessibility, interoperability and reusability of research data [78]. Secondly, we can also point to the experience of using a digital data management system called 'Lesionia', which is an open-source web application for the collection, management and analysis of clinical and epidemiological data related to patients suspected of having cutaneous leishmaniasis. It was initially conceived and developed in the frame of the PEER518 project, funded by the USAID-NAS. This system is meant to enable researchers within the project consortium to enter and access data using the FAIR criteria. The project consortium included nine institutions based in five countries: Tunisia, Morocco, Lebanon, Mali and the USA [79].

Politics stream

Although a policy window for the implementation of FAIR is not quite open, countries in the Middle East are in the early phase of data sharing and have identified the problem (lack of data sharing and management policies and formal mechanisms for openly sharing data) and are working towards a solution. This process can be pushed forward through partnerships with transnational universities – and the mood seems to be receptive of this now, as evidenced by the various projects discussed above. These international collaborations with experienced researchers can promote a culture of research and pave the way for the implementation of FAIR.

4.1.7 African countries

Problem stream

In Africa, digital health initiatives suffer from a lack of capacity to share health data among stakeholders in the healthcare sector. For instance, the multiple health data systems in Africa were not connected during the Ebola outbreak that occurred in West Africa. As a consequence, major challenges were faced in containing the disease [80]. Since early 2020, the COVID-19 outbreak has resulted in significant loss of life as well as economic loss, in Africa and the world. Although suboptimal data management and data reuse have been leveraged during this epidemic, as with the Ebola epidemic, access to valuable data about past epidemics, and the current one, has not been provided equally for different populations in different places on the African continent [81]. These experiences have sparked the African community to consider a digital solution for current and future outbreaks, namely, a digital platform to increase the accessibility of health data.

Policy stream

Continental level

On a continental level, initiatives have been taken to examine data aresues occurring in Africa. One example is the African Open Science Platform (AOSP), which has been launched to bring African scientist to the cutting edge of modern technology, so that data-intensive science can be used to solve the challenges faced. In addition to AOSP, there are several sister initiatives, such as the IN-AFRICA GO FAIR implementation network and CODATA. The aim is to cover FAIR and open science infrastructure in Africa to enable smoother access to data and provide enhanced computing capacity [82].

During the COVID-19 pandemic, besides the community healthcare providers holding the first line of defence against coronavirus, experts from other domains have also contributed to the fight, including computer and data scientists. These people are dedicated to providing understandable artificial intelligence (AI)-ready data, for machines to conduct analytics to discover patterns in epidemic outbreaks so that impacts of the virus can be mitigated. In order to provide machine actionable data, the Virus Outbreak Data Network (VODAN) Implementation Network (IN) was created by CODATA, together with Research Data Alliance (RDA), International Science Council (ISC) World Data System (WDS) and GO FAIR. According to VODAN, machine readable data are created using FAIR Principles, together with technical ability and commitment from experts in the affected countries [81]. FAIR based data and metadata ensure the discoverability of data on the Internet. To implement this approach, FDPs are established, and FAIR (meta)data are opened up by publishing data on FDPs, enabling algorithms to find patterns by searching these (meta)data [83].

Regional level

Plans on the regional level have also been drafted, especially in East Africa. These plans consist of an assessment of regional visions and goals and the actions required to achieve these goals – which has led to the creation of the Digital REACH Initiative plan. This plan brings all the stakeholders from the East African Community (EAC) together with the specific aim of improving health outcomes across the EAC through the use of digital health. It is believed that coordination in digital health will result in economic efficiencies, including the sharing of digital health resources across the region; improvements in health systems through enhanced data sharing, policies and standards; and improved decision making through the use of data and disease surveillance, etc. [84].

One of the main potential health programmes discussed in this plan is the East Africa Open Science Cloud for Health (EAOSCH). This programme aims to create a supporting structure for the seamless sharing of health data across EAC partner states. Through this health programme, a real-time regional data warehouse was established to capture, store, retrieve, analyse and manage national and regional health in East Africa. But in order to enable cross-border healthcare across the EAC region, harmonisation is required including interoperable workstream sets and shared standards for digital health [84]. As FAIR Principles articulate the attributes of data needed to enhance the reusability of data for both humans and machines [4], FAIR Principles have been used as a tool to enhance the reusability of data. The establishment of this real-time data warehouse enhances the ability of health data to be shared across the East Africa community.

Egypt and Tunisia

In North Africa, two data repositories were listed on re3data.org: the first being a government data repository in Egypt, namely, Egypt's Information Portal [85], and the second being Open Data for Africa, which includes Tunisia [86]. Although these two research data repositories provide open access to its data, and the terms of use and licences for the data are provided, they do not use a persistent identifier (PID) system.

More recently, in order to address the challenges caused by the COVID-19 pandemic on the African continent, Tunisia also participated in the VODAN Implementation Network carried out by GO FAIR, in collaboration with other institutions, such as the Leiden University Medical Center. This work aims to implement FAIR Data Principles in relation to non-patient COVID data. It is also related to the impact of the COVID-19 crisis on migrants, refugees and asylum seekers from Sub-Saharan African countries. The pre-FAIRification phase has been completed and the FAIRification phase is in progress. For the moment, data on migrants are available for consumption through a FDP deployed and hosted on the website of the University of Sousse in Tunisia (https://fdp.uc.rnu.tn) [87]. The initiative VODAN Africa is based on FAIR Principles and involves, especially in the case of Tunisia, the University of Sousse as a partner. The main goal of this collaboration is to develop expertise on FAIRification through capacity building workshops, exchanges experiences and so forth.

Kenya

In Kenya, digital innovation is taking place in data management in healthcare, which has intensified during the pandemic. VODAN has created its own solution with the aim of providing accessible COVID-19 data by establishing an overarching network implementing FAIR Principles. Kenya is one of the leading participants in this initiative. Not only does FAIR data play an important role in healthcare in Kenya, it has the potential to improve the data ecosystem in other sectors. One example is the International Livestock Research Institute (ILRI), which has used FAIR Principles to FAIRify its livestock data. Although FAIR Principles look straightforward, some challenges have occurred during the implementation of this project. For instance, the lack of resources has created problems in terms of data findability, whereas accessibility was not able to be provided due to unclear roles and responsibilities of data stewards. Tools were well prepared to implement interoperability, but a lot of plans were required to make SQL databases open access. And reusability was questionable, in terms of how useful it is to make raw data available [88].

Zimbabwe and Uganda

Zimbabwe and Uganda are also two of the main partners in VODAN. Together with VODAN's other partners, these two African countries plan to make research data findable, accessible and reusable. The first machine readable FDP was installed on 22 July 2020 at Kampala International University, Uganda. This will be followed by other installations in partner universities and hospitals [89]. The successful implementation of FAIR requires three pillars [90]: firstly cultural adaptation (GO CHANGE) is required, which is defined as making FAIR Principles a working standard; next, technical infrastructure is needed (GO BUILD); and, lastly, training is required as the idea is novel and there is a the lack of skilled people (GO TRAIN) [91].

Another initiative that should be mentioned here is a collaboration between a local health provider, SolidarMed, which is a non-profit association, and the Great Zimbabwe University in the Masvingo province, Zimbabwe. This initiative aims to solve the needs of local hospitals and communities, and is using FAIR Principles to assess the FAIRness of systems [92].

South Africa

FAIR Principles are also being implemented in South Africa. The CODATA of the ISC works on improving the availability and usability of data for research. CODATA believes that data should be open or FAIRified in an intelligent way in order to advance data usability and interoperability [93]. Different partners are collaborating with CODATA. In South Africa, the CODATA member organisation is the National Research Foundation, which aims to improve the quality of life of all South Africans by supporting and promoting the development of new technologies and knowledge [94].

One of the projects being implemented in South Africa is AOSP, which is funded by the South African Government's Department of Science and Technology, with the collaboration of National Research Foundation, the ISC and CODATA. This platform aims to determine the current state of data science initiatives in Africa and promote open science by increasing the number of participants using FAIR data in the global ecosystem. Policy frameworks, training and technical infrastructure are also needed for the successful operation of ASOP [95].

Politics stream

In different countries in Africa, diverse actors are involved in the implementation of FAIR across a number of different projects. The local African community plays a big role in terms of the politics stream, as there is a lack of acceptance of concepts or technologies such as FAIR data, when they are first introduced. Due to colonial history and more recent practices of Europeans in Africa, the African community regards Westerners as people who extract things from and exploit Africa. In addition, African people tend to think that the data gathered in health research is supported by actors from the Western world, from their perspective and in line with their world view, and, therefore, meeting only their own needs and objectives. As a result, the trust by African communities of European innovation is limited [92].

The COVID-19 pandemic has been a catalyst for the implementation of FAIR, which has been carried forward by VODAN Africa. VODAN Africa has unified a number of stakeholders, including ministries of health, universities and hospitals in Uganda, Ethiopia, Nigeria, Kenya, Tunisia and Zimbabwe [96]. For example, the Great Zimbabwe University identified the VODAN project as a new generation of data and services [90], whereas the first FDP was installed at Kampala International University [89].

Complex modern challenges could be solved by the integration of diverse data resources, but the engagement of more societal actors is necessary, and priorities of each stakeholder should be considered. With regard to FAIR implementation, Africa should adapt FAIR in its own way as a leader with its own societally engaged priorities. AOSP allows Africa to seize this opportunity. This is the first time that African regions have come together to solve a shared issue. Although countries from the EAC are at different stages

regarding their digital health strategies, the whole continent will become stronger with interoperable digital health systems, due to the routine travel of African citizens across borders [80].

4.3 Results

The results of coding labeling show that 91 labels were found, and 8 sub-groups were defined (see Appendix B). The analysis of coding results further explains that China, Kazakhstan and Russia remain in a preliminary phase of FAIR adoption compared to Japan and Indonesia. In China and Russia, the focus at the moment is to introduce the FAIR concept to researchers and stakeholders in scientific data publishing, whereas China shares the same research direction as Kazakhstan in terms of introducing FAIR data for the local digital healthcare system. Moreover, Indonesia has developed its own FAIR data equivalent system called Satu Data Indonesia, led by the government. Japan is ahead in terms of the adoption of FAIR, compared to its counterparts in Asia, Kazakhstan and Russia, as it has implemented FAIR in various fields such as agriculture, institutional research and citizen science.

As to FAIR implementation in Africa and the Middle East, the analysis indicates that there is also a convergence of three streams. Specifically, there is a demand for a research data management system to be built for data sharing among Arab researchers, and FAIR principles are considered a solution to fill the gap created by the lack of a DMP as an important step in the research life cycle for scientists in the Middle East. FAIR data is actively and widely suggested as a feasible solution to issues concerning healthcare data management and environmental challenges on the African continent. There are three main projects, namely: AOSP, CODATA and VODAN, all based on FAIR data, although carried out through different channels on a regional or country level with different stakeholders. As to specific African countries, the main participants of the VODAN project consist of Uganda, Ethiopia, Kenya, Nigeria, Tunisia and Zimbabwe. In particular, FDPs have been deployed at University of Sousse in Tunisia and Kampala International University in Uganda, whereas in Kenya, FAIR data is proposed to improve data management in the field of healthcare and agriculture. In South Africa and Zimbabwe, GO FAIR training has been launched to accomplish a cultural adaptation for the FAIR adoption. South Africa also plays an important role in bridging AOSP and CODATA. Like in Japan and Indonesia, the implementation of FAIR equivalent systems is also found in Egypt and Tunisia. Research data repositories are included on re3data.org, namely: Egypt's Information Portal and the African Development Bank Group (AfDB) statistical data portal Open Data for Africa. The purpose of both repositories is to increase the shareability of data in a real-time manner and to promote local open science.

4.4 Conclusion

In conclusion, the first research question is answered by confirming that the policy windows of implementing FAIR Data Principles are open in Asia, Africa and the Middle East confirming the feasibility of FAIR Principles, however, more awareness needs to be raised in China, Russia and Kazakhstan about the benefits of FAIR to get it firmly on the policy agenda. Particularly in Africa, the political environment of adopting FAIR is mature whereas some implementation has been facilitated. However, the literature data found and used in this chapter have barely touched the role of BI which indicates the interaction between FAIR in non-Western geographies and BI solutions needs more investigation. On the other hand, the contribution of Kingdon's MSF has been proved regarding identifying the open condition of policy window

in different political context yet challenges still remain in some countries where the policy making process is centralized, which weakens the analysis of the convergence of three streams.

5. BI and Healthcare Information Systems

In this chapter, the literature review of BI in healthcare is performed in order to identify the competition as well as challenges of applying BI in this domain. A further investigation of currently used HMIS in African countries and their capabilities is conducted to answer the research question two.

5.1 BI in Healthcare

The development of the knowledge system has evolved during the last two decades in the healthcare domain from predicting epidemics [97] to a broad spectrum of data mining applications [98]. BI, as an emerging technological solution, has played an essential role in healthcare organizations, and the BI adoption is "mainly for providing information to aid the decision-making process at a strategic level, with certain implications at the operational level. The BI technology uses historical and current data in order to visualize them through reports, graphs, and Key Performance Indicators (KPIs), using analytical processing tools" [99, p. 4]. Gaardboe stated that two main tasks, "view" and "analyze", are fulfilled by using BI systems so that employees can follow up on KPIs, forecast the load on hospitals' resources, data extraction for research and other types of analysis [100]. Mettler and Vimarlund argued that the need of healthcare organizations to develop expertise and technology for BI is increasing, with the purpose of tackling new legal requirements to gather systematic performance information such as supply of healthcare information to national and local authorities. This will also strengthen the competition of healthcare organizations in terms of the dissemination of a wide array of information such as the provider's experience in treating particular diseases, the availability of beds, the pricing of health services [101].

According to Jinpon et al. [32], BI solutions have been applied to a number of public health fields, i.e., radiology, environmental health, traditional Chinese medicine, healthcare, public health management and disease control, and health promotion, with diverse objectives. For example, BI tools are used in radiology to improve the healthcare quality, safety, efficiency and financial performance, whereas the goals of BI adoption in environmental health are to reduce health risks caused by an environmental source, to access statistics and other information, and to discover new knowledge. Particularly in the healthcare domain, BI systems play an important role not only in supporting communication between caregivers, Health-care planning and decision making of local and regional health-care authorities, but also in performing hospital population surveillance, enabling clinical quality initiatives, remoting diagnosis and treatment, monitoring patient's body conditions, and in improving quality of patient receiving care, etc.

The contribution of BI systems in Healthcare Information Systems (HIS) is also revealed. Gaardboe concluded that it is relevant to apply BI solutions to HIS as the healthcare sector has historically generated a significant amount of data due to the demand for record keeping, compliance, regulatory requirements and patient care. Gaardboe further illustrated that BI systems have been widely used in Denmark to align with local HIS, although the complexity in the public healthcare sector is much higher than in the private sector [100]. For example, "the public hospitals in Denmark use BI with HIS as a data source in combination with other data sources, such as the accounting and payroll system. Most professions have access to the BI system, including secretaries, doctors, care staff, management and administrative staff. Sometimes they have access to data both in the source system and in the BI system; other times the data come only from BI" [100, p. 484]. It is noted that healthcare organizations with Information Systems (IS) have higher total

margins and operating margins than those without using IS [102]. Implementing BI systems with HIS will be the standard in healthcare organizations. In addition, BI has the potential to operationalize the repository content of Electronic Health Records (EHR) in order to support evidence-based practice and to improve the quality of healthcare delivery because the EHR contains massive clinical datasets about patients, and BI therefore can maximize the logic and inference rules created from the Electronic Health Records [7]. In the same research, the author further stated that "with an increasing need to deploy Electronic Health Records (EHR) and Electronic Medical Record (EMR), there is also a corresponding need to apply data mining technologies to extract quality data and inference rules from the information stored in those electronic records to provide real-time decision supports to clinicians and healthcare providers. Most clinical datasets are not structured and applying BI technologies ensure quality data extractions and analysis" [7, p. 259]. "The integration of the BI technology with the EHR will also offer many advantages to caregivers in clinical practice" [7, p. 260]. For instance, BI systems allow internal actors that represent the personnel of the healthcare organization such as doctors and controllers to access personalized services and the most recently updated information [101]. Moreover, BI tools increase autonomy and flexibility of users by helping them create reports, quick and simple analyses, improved decision support and operational efficiency, and a range of new analytical functions [103]. This is pointed out by Kudyba and Rader [104] as well, that BI is able to generate required structured information in order to target the hidden issues such as what patients need to be targeted for specific evaluations while admitted to a facility given particular symptoms.

Using BI tools and analytics to help improve efficiency in healthcare has high potential, while there are many challenges because of the complexity of healthcare and how quickly reimbursement methodology, regulating agency policies, and technology are changing within healthcare [105]. Loewen and Roudsari concluded that challenges and tasks still remain in the implementation of BI solutions from four perspectives, i.e., organizational, technical, data and end user perspective [38]. From the organizational perspective, there is a lack of skilled analytics resources; leverage drivers such as external compliance or reporting mandates; strong organizational vision; address organizational silos; and address underlying care coordination factors [105]–[109]. From the technical perspective, the concerns include the integration across multiple platforms, and the need for a strong underlying technology platform [105], [106], [109]. Bonney also argued that it is challenging to implement the BI technology in EHR because of the difficult integration of BI systems into the EHR caused by contextual issues related to the EHR since the contextual issues of the critical success factors of BI systems are different from the implementation of other systems [7]. From the data perspective, it is important to ensure underlying data quality and semantic interoperability [105], [106], [110]. Especially in a healthcare organization, Glaser and Stone emphasized that data governance is connected to the establishment of organizational structures, policies and processes that are needed to define, control and ensure the quality of the data, and clear data governance and roles of data stewards are essential as it affects healthcare providers' decision-making to determine the types of analyses, to define their data stewards and responsibilities they hold [8]. Finally, from the perspective of end user adoption, there are considerations including strong perceived usefulness and ease of use, changeable and controllable presentation of data by end users; and ability to address fear of measurement and transparent reporting [107], [108], [111]. Gaardboe stated that BI systems should be user friendly as "higher information quality does not automatically lead to greater use of BI, … if the BI system is easy to use and easy to learn, employees will use it more. Regarding the System Quality, the item 'The information in BI is easy to understand' was rated highest by the users. The users found that the system was easy to use, and in last place, it was easy to learn [100, p. 488].

5.2 Health Information Systems in Africa

The electronic Patient Management System (ePMS) has been adopted in Namibia since 2007, and the use is mainly in HIV programs with the focus on capturing Tuberculosis (TB)-related information such as screening for TB, dates of treatment, Isoniazid Preventive Therapy (IPT) and cotrimoxazole, while capturing information of Tuberculosis Infection Control (TBIC) is not included yet. The data source for the system is from local patient care booklet, meaning that data are entered into ePMS at district level before reports for the district are made, and data are aggregated in periodic reports for the regional level [112].

A customized version of ePMS is the current leading HMIS in Zimbabwe at a national level, in partnership with the Zimbabwe Ministry of Health and Child Care (MoHCC), United Nations Development Programme (UNDP), the Global Fund etc. ePMS was developed by the University of Dar es Salaam in Tanzania, and the data holder is MoHCC. The system for piloting started in 2012, while the first phase of full implementation of ePMS kicked off in 2013 with "being installed in 85 sites, including central, provincial, district hospitals and city clinics. An estimated 61% of patients on ART nationwide were covered by ePMS at these sites by the end of 2013" [113, p. 7]. As of 2014, the same document pointed out that an additional 161 health facilities were added including rural health centers, mission hospitals and some larger clinics in 2014, whereas the remaining 184 facilities would be added in 2015 and 2016, resulting in a total number of 534 health facilities and meaning that 97% of patients would be covered by the ePMS. By leveraging ePMS, several positive outcomes have been made [113]. For instance, the more efficient and effective management of HIV and TB patients was ensured, the lack of follow-up with patients on treatment was minimized, and the quality of healthcare data was improved in terms of accurate forecasting and evaluations of interventions.

On the other hand, the system of Impilo, proposed by MoHCC in Zimbabwe, is being implemented nationwide for broadband connectivity in the country's top 350 health facilities, and aims to replace ePMS in the future. According to the Information, Publicity and Broadcasting Services Minister Monica Mutsvangwa at a post Cabinet briefing, Impilo is applied to "patient registration, patient management and evaluation, patient tracking, stock usage and tracking, and data aggregation, validation and analysis. Impilo will be deployed at five Central Hospitals, seven Provincial Hospitals, 30 District Hospitals, and 384 Clinics across the country" [114].

Since 2004 in Zambia, the SmartCare EHR system, used for management of client health records, generation of reports and in auxiliary services such as pharmacy, labs, logistics and user and provider management, has been developed by the Zambia Ministry of Health (MoH) in collaboration with the Centers for Disease Control and Prevention (CDC) and partners. The system is a fully integrated EHR system to provide continuity of care and a clinical management information system at the facility and district level. It is also simplified to be more hospital friendly starting with the OPD module, supported by CDC through BroadReach HealthCare Corporation. SmartCare consists of 3 subsystems, i.e., the trained and certified users, the software system and computers and other physical infrastructure that supports use of the system [115], [116].

SmartCare is also playing an important role in Ethiopia. In 2009, the MoH together with the support of the Tulane University Technical Assistance Project in Ethiopia (TUTAPE) started the development and

implementation of a localized SmartCare system [117]. In the beginning, the SmartCare system was deployed in 5 hospitals in the capital city, Addis Ababa, and other hospitals at regional level, while the MoH adapted the system as a national EHR for all hospitals, and planned to scale it up to further hospitals and regions in 2013 [118], [119].

The SmartCare system used in Ethiopia has different components according to Tilahun and Fritz, such as "registration, outpatient department, inpatient (to admit, follow, and discharge patients in wards), tuberculosis, pediatrics, HIV/AIDS (to manage patients in antiretroviral therapy clinics), antenatal care, postpartum, pharmacy, drug stock control, laboratory (to store and send laboratory results to the requesting clinic), eHMIS (to generate monthly, quarterly, and annual reports), and finance" [117, p. 3].

The Open Medical Record System (OpenMRS) is another flexible, modular, multi-layered system adopted in several African countries as the main HMIS. However, the system is not directly used by the local healthcare facilities. Instead, each country developed their own customized version of OpenMRS using the OpenMRS platform, and the tailored system is called a OpenMRS distribution. Using the OpenMRS distribution allows each African country to remain a certain level of autonomy by developing and levering OpenMRS modules and applications that are necessary for the local needs. In this way, healthcare facilities with limited resources and development environment can afford owning a HMIS and avoid creating one from scratch, while the openness and variety of system construction is generated. In Mozambique, the eSaude distribution was developed and maintained by the regional eSaude community in order to echo the requirements of the Mozambique MISAU (Ministry of Health) for HIV Care & Treatment and Maternal and Child Health [120]. However, the project seems terminated as no more information is available on the official website, nor does the demo function anymore. In Kenya, a customized distribution of OpenMRS called KenyaEMR is used under the guideline of the Kenya Ministry of Health. This system was originally developed by the International Training and Education Center for Health (I-TECH), a center in the University of Washington's Department of Global Health, and is currently supported by Palladium Group through the Kenya Health Management Information System project (KeHMIS), and has been deployed to over 800 health facilities in 44 out of 47 counties in Kenya, and supported by 38 service delivery partners (SDPs) [121]. Figure 5 shows the distribution of sites in Kenya where KenyaEMR has been deployed.

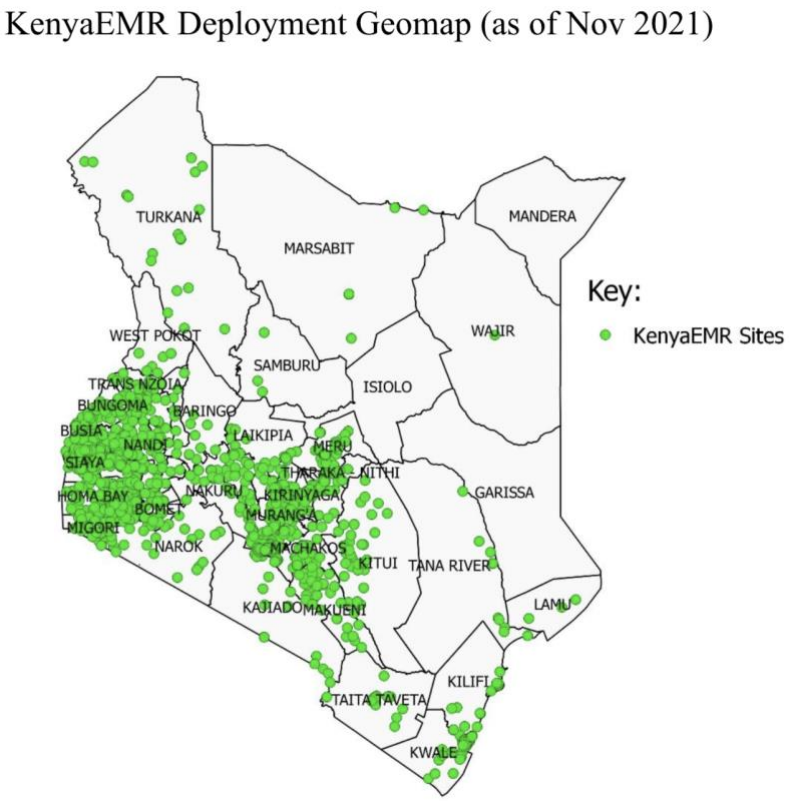

Figure 5 KenyaEMR Deployment Geomap (as of Nov 2021), source: National Integrated Data Warehouse

It is noted that KenyaEMR has a high flexibility of integrating with other systems and supports seamless data exchange through an interoperability layer. For example, the interoperability layer application allows KenyaEMR to support direct reporting of the MoH indicators from local facility to national reporting repository, i.e., DHIS2, and Platform for Partner Progress Monitoring (3PM) aggregate reporting [121]. Figure 6 illustrates the UI of KenyaEMR including the login page, the home page, the dashboard, the patient chart and the reporting page etc.

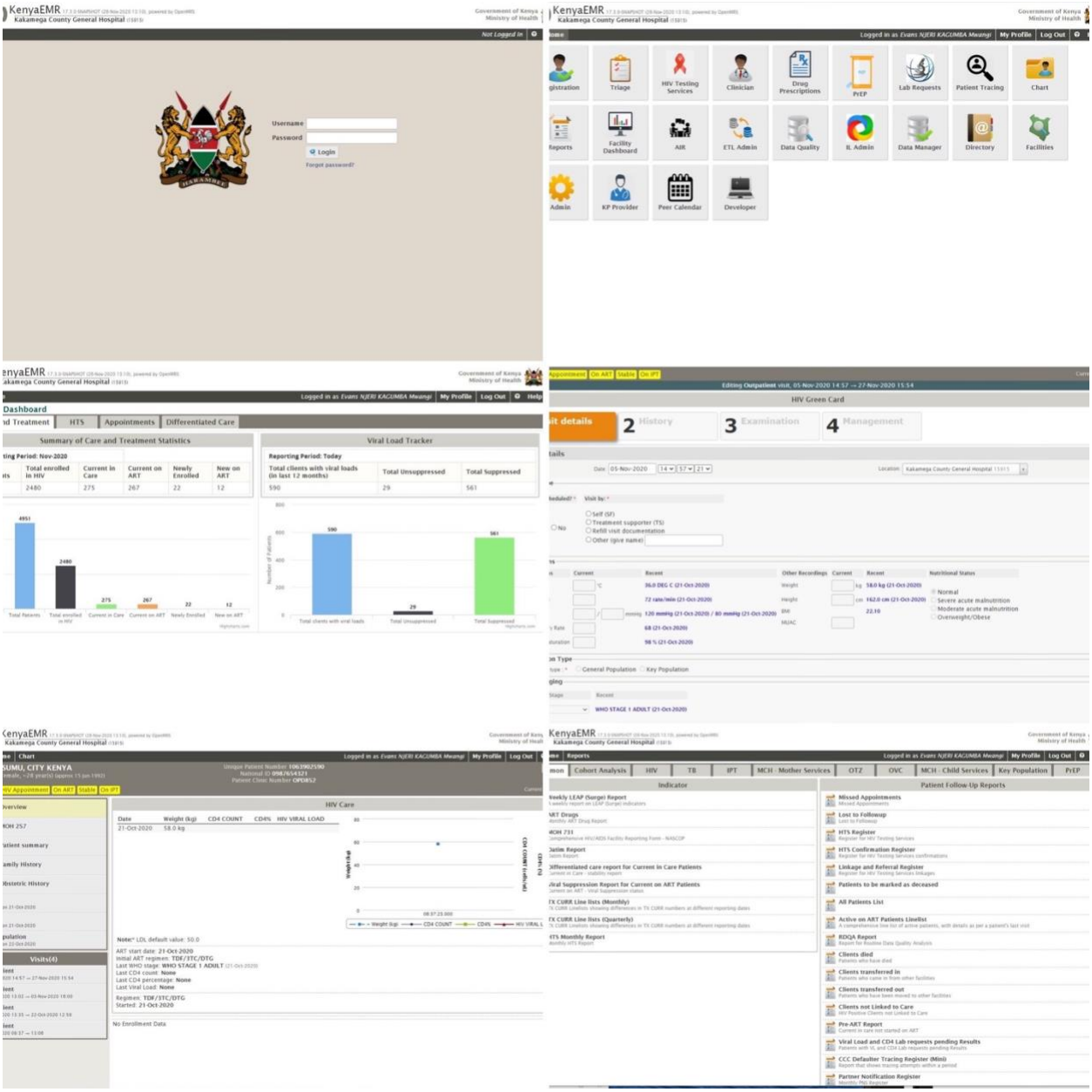

Figure 6 Sample interface screenshots of KenyaEMR, source: OpenMRS Wiki

In Nigeria, the tailored distribution named OpenMRS Nigeria has been used not only in healthcare facilities, but also in large national institutes. OpenMRS is currently deployed to over 119 health care facilities by phase implementation, with more than 475 users trained across supported states in Nigeria, while various organizations in Nigeria are also on the implementation list including Institute of Human Virology Nigeria (IHVN), Management Sciences for Health (MSH) and eHealth for Everyone (eH4E) [122]. UgandaEMR is another custom implementation of OpenMRS in Uganda, which is mandated by the MoH, and includes HIV testing and treatment for adults and children as of 2016. It also provides mandated ministry reports for facility management. If the healthcare facilities in Uganda intend to follow Ministry guidelines to receive

funding from the government, introducing and implementing UgandaEMR is needed, whereas private clinics can use it if it meets their specific needs [123].

Figure 7 Sample interface screenshots of OpenClinic GA, source: sourceforge.net

OpenClinic is an integrated open-source HMIS covering management of administrative, financial, clinical, lab, x-ray, pharmacy and other data, and it also has Extensive statistical and reporting capabilities. It has been implemented in 4 facilities in Burundi, 1 facilities in Mali, 5 facilities in DRC and 15 facilities in Rwanda, especially the Kigali University Teaching Hospital (CHUK), a national referral hospital in Rwanda, was the first facility to use OpenClinic from early 2007 [124]. OpenClinic was developed by the project ICT4Development of Vrije Universiteit Brussel (VUB) and Medical eXchange Solutions (MXS),

both based in Belgium [125]. Furthermore, "it was specifically designed to meet the needs of countries with restricted resources and with a patient-centric model in mind. It was developed on an open-source platform which enables the wide spread of the application (currently over 500 installations). Apart from the electronic medical dossier, it also covers all hospital management needs, eliminates fraud, and increases hospital productivity" [126]. Figure 7 illustrates some Uis of OpenClinic such as the record summary, the encounter management and the health insurance management.

In Tanzania, there are two HMISs being used simultaneously. One is called Electronic Health Management System (eHMS) developed by a local private company, Tanzanians ICT organization, whereas the other is called Tanzania National Health Portal, owned by the government of Tanzania. The features of eHMS include high localization as it is fully developed and maintained by a Tanzanian company compared to HMISs adopted in other African countries, as well as patient reception and admission, doctor consultations, orders to exit or discharge, a e-payment system, interoperability and a telemedicine technology called G-TELE. The interoperability feature enables eHMS to get integrated into other systems such as the investigation devices in laboratory (Hematology, Biochemistry, Hormones etc.), and radiology devices (X-Rays, CT Scans or MRI etc.). The e-payment system is a highlighted feature of eHMS which functions both through banks and mobile networks. In particular, eHMS is the only system in Tanzania that is integrated to National Hospital Insurance Fund (NHIF) electronic billing (E-Billing) and e-payment whereby hospitals using eHMS no longer need to use paper claim forms from NHIF. eHMS accelerates the transformation into cashless business environment and increases cash revenue collections robustly. Last but not the least, G-TELE is the remote diagnosing and treatment of patients by leveraging telecommunications and computer technology, which allows health care professionals to evaluate, diagnose and treat patients at a distance. For example, care givers from one hospital are able to help a patient in another health facility or hospital [127]. On the other hand, the government owned system lacks the key feature of e-payment, while other functionalities are also covered such as data management and data visualization. However, the statistical dashboard seems only accessible through local IP address. According to a healthcare stuff from the Kilimanjaro Christian Medical Centre (KCMC), eHMS has been deploied in less than half healthcare facilities in Tanzania, although it is the dominant system nationwide. The Tanzania National Health Portal led by MoH collects some healthcare data and shares with eHMS at a certain level.

As mentioned in the first chapter, DHIS2 is recommended as the dominant HMIS in more than seventy low and middle-income countries by WHO. DHIS2 covers more than 2.4 billion users and is the world's largest HMIS platform [128]. DHIS2 is the continuation of the District Health Information System Software (DHIS) that is a free and open-source database and application for collecting, processing, and analyzing health information. DHIS is also the earliest version developed and implemented in South Africa back in 1998, but the successful adoption of such system in South Africa has spread and convinced partners in many parts of Africa and Asia. DHIS allows healthcare professionals to use data to analyze and predict service needs, and assess performance in meeting health service targets as the leading feature of DHIS is to decentralize healthcare decision-making and health service management [129], [130]. The DHIS2 version brough several improvements such as extending the use of the data, enabling reports based on data visualization that could help enhance health services at all levels, and facilitating healthcare decision-making made at health centers, as well as local, provincial and national health departments [131]. In order to solve the connectivity issues happened often in African countries, DHIS2 is not only equipped with a Web-based platform and database, but also supports an offline mode, in order to handle tasks in terms of data

management and act as a "data warehouse." Furthermore, DHIS2 is based on Free and Open Source Software (FOSS) providing different countries with an opportunity to get the software free of charge and to customize it according to local needs by local IT experts. The customization includes mimicking manual health data collection tools to look similar on the software data entry forms, accommodating most routine data elements, and in some cases translating the software into the local language [132].

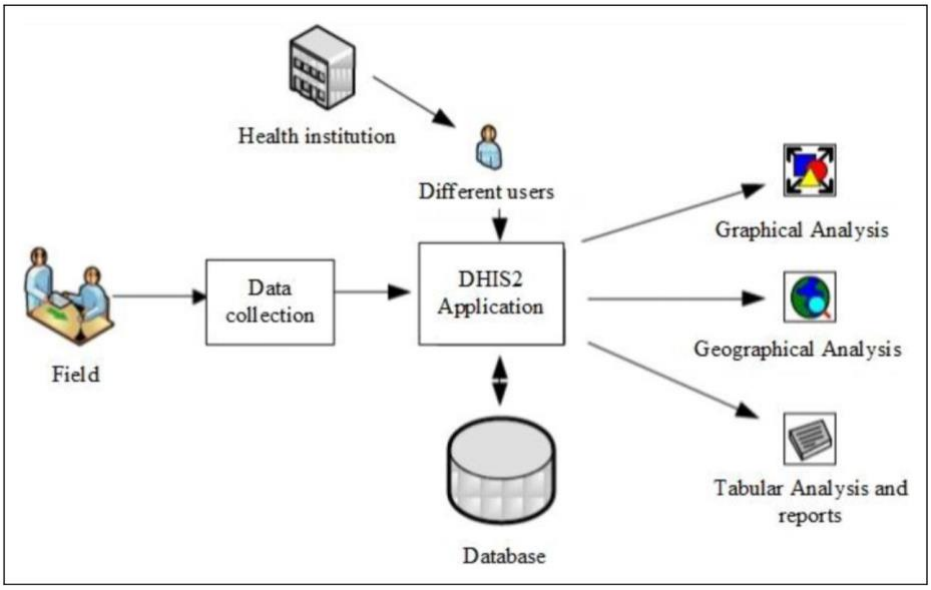

Figure 8 Overview of the DHIS2 architecture, source: Manoj et al., [133, p. 5].

There are other characteristics, and "these features include, customized data entry, indicator defining, data visualizing through various types of graphs, web based pivot tabling, integrated GIS module, meta-data importing and exporting, custom data quality checks, user access control, integrating the messaging system and DHIS2 mobile solution" [133, p. 2]. Dehnavieh et al. also pointed out that the highlighted features of DHIS2 are data management, data visualization, modularized components, communication function, compatibility with Microsoft tools such as Access and Excel, localization from the perspective of developing needed functionalities in different countries, and economic benefits such as the elimination of the cost of transporting paper reports by using DHIS2 [134]. However, implementing DHIS2 also requires adequate and stable funding that weakens the economic benefits. Although DHIS2 provides an offline mode as connection challenges are always a main concern in African countries, restrictions on connecting to the Internet can develop problems for the installation of the software. Other challenges include requirements of adequate data for reporting and high-quality data for deployment; education and training as there is a shortage of adequately trained personnel and a lack of adequate motivation in personnel to use the new systems; management and leadership difficulties, such as "local laws that do not support the implementation process, managers with negative perceptions and attitudes towards the implementation of new technology and administrative structures that are unsupportive of change can all affect the successful implementation of new software" [134, p. 69]. These challenges are also echoed by Braa and Sahay, "while the analytic and visualizing functionalities of the DHIS2 are constantly improving, experience indicates that country MoH users are not exploring these new features adequately enough. Their focus is still predominantly on data

reporting, with less attention given to dissemination and data analysis. To change the behavior of thousands of health workers and managers is of course a complex task not solvable by technology alone" [135, p. 9].

Another major concern of using DHIS2 is the lack of data security, and it further undermines the foundation of data governance due to local regulatory requirements. The development of DHIS2 was based on the premise of open data, and this design grants to all health systems as well as external stakeholders and other interested individuals. As a result, data input by healthcare staff at the district level may be modified or even deleted by other users at different locations [1]. As showed in the Figure 8, this architecture may cause health data loss and weaken the data ownership of local authorities. It may further bring damage to trust and acceptance of other technologies in the future. The open data feature of DHIS2 has already created concerns with regard data security in some African countries. Thus, data security is a key issue in adopting DHIS2, and another solution needs to be considered.

However, due to the other useful features as well as DHIS2's relative success in South Africa and the fact that the application is highly adjustable in order to fit the local country's needs have led to the export of DHIS2 adoption and transfer from paper-based systems to modern health data management to other African countries, e.g., Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, Ethiopia, Gambia, Guinée, Guinée-Bissau, Liberia, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Ghana, Sénégal, Sierra Leone, Somalia, Tanzania, Togo and Uganda [131], [136]. Based on the analysis of found literature, we discovered that the adoption and implementation of DHIS2 in diverse African countries differ largely due to the timeframe of the adoption decision made by the authority and the version of DHIS available at that time. The following implementation of DHIS2 at which level also varies a lot from country to country due to the using experience. For example, Malawi, South Africa and Zanzibar had successful experience of using DHIS since they have launched the project to perform the digital transformation, which convinced these countries to continue the adoption by migrating from DHIS to DHIS2 [131], [137]. Some countries like Mozambique and Tanzania had negative experience of using DHIS caused by different reasons, such as misaligned expectations between the DHIS implementers and the country's health policy makers [138], technical challenges including limited capacity for scalability, lack of personnel with extensive technical support [131], poor usability and content, failure of DHIS data to be used as initially envisaged include computer illiteracy, and the inflexibility of the DHIS version in Tanzania etc., [139]. But they still have decided to use DHIS2 according to the new healthcare policy.

Ethiopia has initiated a collaborative project, called HISP-Ethiopia, between departments of Information Science, Addis Ababa University and the University of Oslo, Informatics department in 2003. The objective was to upgrade the existing routine paper-based systems with a digital one using DHIS [140]. Yet in 2017, Ethiopia has announced to roll out the eagerly awaited comprehensive health data management platform, i.e., DHIS2, and the Federal Ministry of Health (FMOH) has organized the Master Training of Trainers (TOT) in Adama in the same year After months of customizing and testing the software. DHIS2 has been positively accepted at a national level. According to Dr. Desalegn Tegabu, the director of the Policy and Planning Directorate at the FMOH, "DHIS2 is not only a data collection software but also an engagement forum where data from other platforms converge; allowing data analysis, and use" [141].

Kenya, on the other hand, has started the implementation of DHIS2 relatively late in 2010. As "Kenyan health facilities suffer from the usual infrastructural problems experienced in other developing countries

such as inadequate access to computers, internet connectivity, telephone and electricity services" [131, p. 54], a paper-computer hybrid system has been adopted meaning that most of the Kenyan health facilities still generate paper-based monthly reports that would then be sent to respective districts for inputting to the web-based DHIS2. Particularly, a central server solution for the DHIS2 implementation was chosen instead of deploying offline standalone instances in districts around the country as the majority of the district, county and referral hospitals have access to computers and internet via mobile provider-based modems that produced positive using experience during the piloting phase. However, an external server supported by the "cloud computing" infrastructure came to take the role as the MoH server was not ready for the installation [142], which yet raises some questions with regard to the data localization.

In Uganda, the influence of DHIS2 is becoming larger along with the support from MoH, yet not all the regions of Uganda are able to receive the benefits due to many reasons such as insufficient basic infrastructures in rural areas. Therefore, the project, called Regional Health Integration to Enhance Services (RHITES) activity, has established a series of goals to deliver healthcare services to people living in rural areas of Uganda. For example, RHITES-East aims to reach about 5.7 million people in Eastern Uganda and Karamoja with services for major healthcare concerns such as HIV, malaria, tuberculosis, maternal, newborn and child health, whereas RHITES-N focuses on increasing the access and utilization of quality health services in the Acholi region of northern Uganda, including eight districts (Amuru, Nwoya, Gulu, Pader, Lamwo, Kitgum, Omoro, and Agago, by strengthening the supported districts' health systems and encourage healthy behavior [143], [144]. The northern region of Uganda has particularly difficult challenges such as high burdens of HIV and malaria, high rate of institutional maternal mortality, low levels of antenatal care visits among pregnant women, recent civil conflict and ongoing security challenges, and refugee population from South Sudan. Nevertheless, the RHITES project has achieved a few milestones during the course of five-year deployment. For example, malaria case management has been improved at 97% across supported districts, and continuous data management has been accomplished through tracking malaria cases using malaria data channels to set up timely interventions in response to upsurges and to keep mortality below 1% [144]. Similarly, RHITES-SW zooms in on 16 districts in the Southwest of Uganda in terms of increasing the availability, accessibility and quality of integrated health services including HIV prevention, care, and treatment, TB, maternal, neonatal and child health (MNCH), family planning, and other primary care services [145]. However, the lifespan of this project is only five years meaning it is coming towards the end by the year 2022. Consequently, the capability of DHIS2 to cover the rural areas in Uganda after the curtain call of RHITES project remains questionable.

In conclusion, DHIS2 is used in eight out of nine member countries of VODAN Africa, and there are no records found with regard to the HMIS in Tunisia. The data management strategy of DHIS2 is mainly based on a central server supported by a data warehouse to enhance the data quality in Africa. The second dominant HMIS adopted in African member countries is OpenMRS, yet with the local customized version system, in countries like Kenya, Nigeria and Uganda, while SmartCare was chosen in Ethiopia and eHMS was developed in Tanzania together with the Tanzania National Health Portal led by the government. Last but not the least, Impilo is taking over the role of ePMS in Zimbabwe as the main HMIS.

5.3 Results

In the section 5.2, all the main HMIS adopted in each member country of VODAN Africa as well as their capacities have been summarized. As the dominant system, the DHIS2 architecture has been illustrated (see Figure 9). Data captured from paper forms at the facility level are gathered by data clerks from local facilities, and then are input into the DHIS2 system at the district level by MoH appointed data clerks. Although diverse functionalities are currently available within DHIS2, such as dashboards, instant visualization tools, GIS, and pivot tables, that lower the complexity of data analysis, data processors of country MoH still mainly focus on data reporting rather than new features. This data reporting routine echoes the hybrid system existing in the VODAN member countries, i.e., paper-based data management approach is still common at the facility level, while the workflow is digitalized from the district layer using DHIS2. The data reporting procedure is based on a monthly frequency.

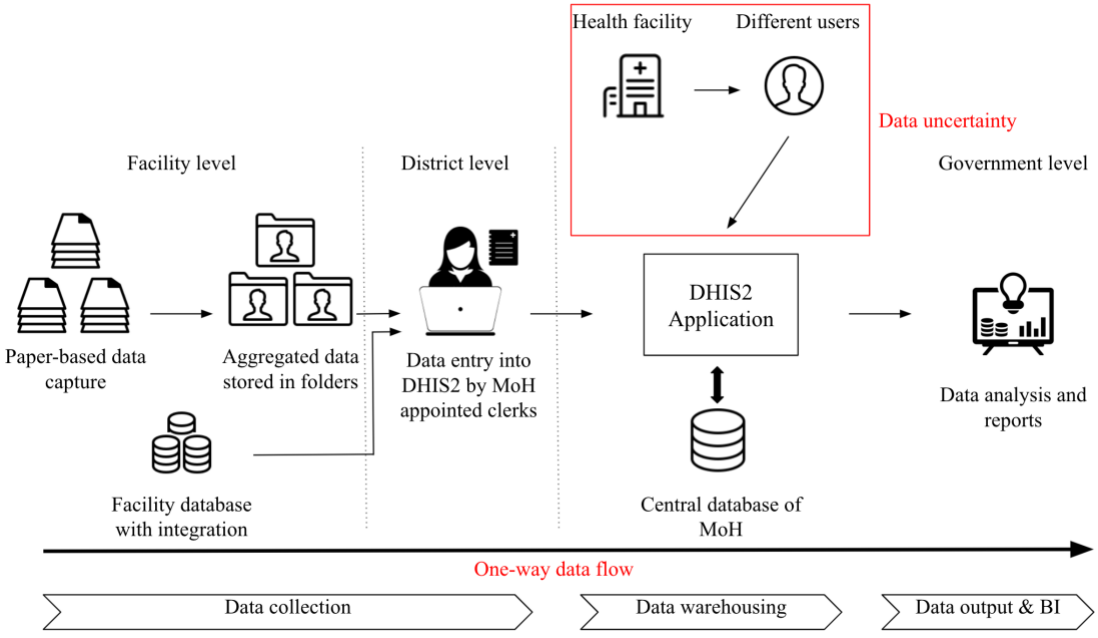

Figure 9 DHIS2 Architecture, source: created by the author, Yi Lin

The capacity overview of the mainstream HMIS implemented in member countries of VODAN Africa and proposed VODAN architecture are showed in detail in Table 7. Most of the current HMIS share the same capabilities including patient profile management, health data management, data analysis, data visualization, data prediction, integration with other systems. Only a few HMIS support e-payment or finance such as SmartCare and eHMIS. Customization based on local needs is another important feature which is supported by systems like OpenMRS Nigeria, DHIS2. DHIS2 offers the most diverse customization options from UI, data entry forms to languages. Another key point of benefiting from DHIS2 is no charge of use, compared to other systems, while the development and maintenance of tailed local version needs independent funding.

On the other hand, the VODAN architecture provides a platform that guarantees the data ownership while data are still able to be visited. The data access is further controlled actively by the data owner meaning the health facilities even at the community level have the power to fully manage the accessibility of their patient

and medical data. Moreover, data analysis and visualization through dashboards are also available according to the architecture, whereas the unique feature is that the data accessibility is also controlled by the data owner in a real-time manner.

Table 7 Capacity comparison between major HMIS and the VODAN architecture

Country	HMIS	Capacity
Ethiopia	SmartCare	Registration, outpatient department, inpatient (to admit, follow, and discharge patients in wards), tuberculosis, pediatrics, HIV/AIDS (to manage patients in antiretroviral therapy clinics), antenatal care, postpartum, pharmacy, drug stock control, laboratory (to store and send laboratory results to the requesting clinic), eHMIS (to generate monthly, quarterly, and annual reports), and finance
Kenya	KenyaEMR	Integration with other systems; seamless data exchange through an interoperability layer
Nigeria	OpenMRS Nigeria	Custom designed tools of HIV/AIDS and MDR-TB programs as well as certified data collection tools (DCTs)
Tanzania	eHMS	Fully developed and maintained by a Tanzanian company; patient reception and admission, doctor consultations, orders to exit or discharge; e-payment system integrated to National Hospital Insurance Fund (NHIF) electronic billing (E-Billing) and e-payment; interoperability to get integrated into other systems such as the investigation devices in laboratory (Hematology, Biochemistry, Hormones etc.), and radiology devices (X-Rays, CT Scans or MRI etc.); a telemedicine technology called G-TELE
	Tanzania National Health Portal	Data management; data visualization
Uganda	UgandaEMR	HIV testing and treatment for adults and children; provides mandated ministry reports for facility management; allows the healthcare facilities to receive funding from the government
	RHITES	Integrated health services including HIV prevention, care, and treatment, TB, maternal, neonatal and child health (MNCH), family planning, and other primary care services
Zimbabwe	ePMS	Management of HIV and TB patients; accurate forecasting and evaluations of interventions

	Impilo	Patient registration; patient management and evaluation; patient tracking; stock usage and tracking; data aggregation, validation and analysis
Ethiopia, Uganda, Nigeria, Kenya, Somalia, Tanzania, Liberia, Zimbabwe	DHIS2	Data analysis and service needs prediction; performance assessment in meeting health service targets; reports based on data visualization; independent Web-based platform and database; an offline mode; act as a "data warehouse."; Free and Open Source Software (FOSS) meaning free of charge; customization including mimicking manual health data collection tools to look similar on the software data entry forms, accommodating most routine data elements, and translating the software into the local language; web based pivot tabling; integrated GIS module; meta-data importing and exporting; custom data quality checks; user access control; integrating the messaging system; mobile solution; compatibility with Microsoft tools such as Access and Excel;
Ethiopia, Uganda, Nigeria, Kenya, Somalia, Tanzania, Tunisia, Liberia, Zimbabwe	VODAN Architecture	Data held under regulatory framework that applies in the country where data are produced; compliance with the key notions of EU GDPR such as that data belongs to the data-subject and data are collected for well-defined purposes; data are curated as Human and Machine-readable and Findable; accessibility is as open as possible and as protected as necessary through permission rules for access; data are held under control of where it is produced; data-visiting of federated data replaces data warehousing; rich metadata and data provenance contributes to situational understanding of data; real-time dashboard-based data analysis

5.4 Conclusion

In conclusion, the second research is answered by confirming that a hybrid data management system combining with paper-based manual data collection and centralized DHIS2 data warehousing is the current solution in all the VODAN member countries. However, the data flow of such approach is a one-way process meaning that data collected by facilities only moves to the centralized "data warehouse" without any feedbacks or analytic results returned to each health facility. The open-data-based system design of DHIS2 also has data uncertainty issue as other health systems as well as external stakeholders and other interested individuals can modify or even delete data. This finding not only reflects the drawback of the conventional BI process flow model (see Figure 2), but also indicates the lack of FAIR adoption. It further shows a gap between stakeholders that want to implement FAIR data and the current HMIS owners that centralize data.

This leads to answering the third research question about the capacity gap between current HMIS and the VODAN architecture. Based on the analysis result, the difference is mainly identified as the protection of data ownership that also aligns with all the relevant regulations such as EU GDPR and local ones. As current HMIS has a much longer implementation and development history than the VODAN architecture, there are

more basic functions from the user perspectives such as user registration and profile management etc. However, one of the main purposes of the proposed architecture is to improve data quality by upgrading data accessibility and control without interfering with currently existing capacities. Therefore, there is no conflict identified between proposed system and existing ones. The data security issue caused by the traditional BI model can be potentially fixed through the replacement of date warehouse with FDP. Nevertheless, in order to configure the FAIR-based BI framework, it is necessary to clarify the perceptions of data clerks of local facilities regarding processing and managing patient data in practice, which are investigated in the next chapter.

6. Interview Analysis and Results

In this chapter, data collected from interviews are analyzed using Kingdon theory to identify whether the policy window of introducing a new system in local facilities is open. The results are further used to answer research questions four and five.

6.1 Interviews

The findings of interview analysis are showed in this section. Kingdon theory was used to perform the analysis and therefore questions (see Table 8, Table 9 and Table 11) as well as outputs of respondents are analyzed and categorized into three streams (i.e., problem, policy and politics stream) in accordance with the relevance to each stream. The result of analysis shows the convergence of three streams and the possibility of opening the policy window. On top of that, the role of VODAN as the policy entrepreneur is also discussed.

	Health Facilities General Information
	Role Identification
	Current Data Management System

Problem stream

Table 8 Problem related questions

Question
Does this clinic have a functioning computer, if yes how many computers?
Does this clinic have an internet connection?
How would you describe your experience with the patient data management in this facility?
Would you tell me more about patient data collection?
How was the patient data collected?
Is this OPD recorded on paper or using computers?
What happened next with the data?
Where is the data storage?
How long does this process take place?
If the health facilities use HMIS, how frequent the data input to HMIS?
Any problems you find with the data collection?
Any problems you find with the data storage?
How did the facilities transfer patient data from/to other facilities?
Anything else that the interviewee feels has been missed and anything that they didn't get a chance to discuss fully?

The analysis result of interview answers shows that local health facilities have different level of IT infrastructures. Some facilities (e.g., Case Clinic in Uganda) have equipped with well-connected internet and functioning computers, while others face big challenges (e.g., Shabelle Health center in Somalia). Among all the interviewed health facilities that provided answers so far, the percentage of having

functioning computers is 62%. This finding echoes the previous discussion in terms of the infostructure challenges in African healthcare domain and confirms the reason of using a hybrid system to collect data. All the facilities are using a certain type of HMIS. Some facilities use an internal system (e.g., Case Clinic and KIU both in Uganda), whereas all the facilities leverage a government led system.

Based on the report of data clerks, it is noted that one of their main job tasks is to collect data and then to enter the data into different systems, and this routine is on a daily basis. Another main task is to collaborate with data stewards at district level for the data report using DHIS2 monthly. This finding reflects the hybrid system that most facilities are relying on now. In detail, most facilities collect data during patient registrations and consultations using paper-based approach and then store the data in a folder. All the folders are then stored in the archive room physically. There is some exception due to the relatively advanced IT infrastructure in some facilities in Uganda. For example, patient data are stored on the central server in Case Clinic, whereas KIU stores data both in a paper form and in the internal HMIS. The digital approach enables a real time data input while the paper-based approach takes much more time, from one hour to less than one day, for data clerks to finish the data collection and input. According to the interview answers, there are a few problems identified during these steps due to the tedious daily data management routine. For example, the data clerk from Case Clinic claims that data inconsistency occurs when some patients left with their files as they forgot to hand them in to the clerks. This is caused by the hybrid system to collect data that increase the operation errors. Incomplete information is also reported by the data clerk as no diagnosis details for patient are provided in Case Clinic resulting in missing information. In Nigeria, data clerks reported that the repetitive manual data operation using the hybrid system is obsolete and cumbersome resulting in a big label cost. As to data storage, issues are further recognized. For instance, storage is claimed as one of the biggest challenges in Ugandan facilities as the storage is very limited, both physical storage and the memory capacity on computers. This issue makes it particularly difficult to store imaging data for radiology. The physical storage issue caused by using the paper-based system highlights again the problems of low efficiency, and even more serious issues like data security as those paper files are prone to spoilage and damaged. The physical storage manner also hingers data sharing and reuse across facilities as paper files in folders must be transferred physically which is time and labor consuming. When HMIS is installed on computers in the facility (e.g., Case Clinic), digital data transfer becomes possible through the system integration.

Policy stream

Table 9 Policy related questions

Question
The number of OPD registers
Use HMIS? If yes which HMIS?
Any policies and regulations that govern patient data in the hospital/clinic? If yes what are the details?
Tell me about the purpose of patient data collection
Who decides this purpose?
Who has access to the patient data? And who decides this access?
How did you access the patient data?
How did the Ministries of Health access the patient data?

What do you know about the patient data analyses?
What is the analysis purpose?
Who decides the analysis purpose?
Who does the analysis?
Who has access to the analyses?
If the clinic was provided with a generic dashboard for the public with data analytics, what kind of data would the facility want to show? Who would have access to the generic dashboard?
If the clinic was provided with an internal and customized dashboard with the purpose of data analytics, what kind of data would the facility want to show? Who would have access to the internal dashboard?

Both internal and government requested HMISs are used in the facilities. For example, Case Clinic uses both the internal system and the MoH HMIS, while DHIS2 is used in all the Ethiopian facilities. This finding reinforces the previous discussion of currently used HMIS in VODAN member countries, and especially shows that DHIS2 plays a dominant role in the market. Most facilities are still leveraging paper OPD, although the number varies from one, two to ten. All the interviewed facilities in Somalia share the same format of OPD register which consists of two categories, i.e., under five years registers and above five years registers.

With regard to the policies and regulations that govern patient data in the health facilities, confidentiality, ethical clearance, privacy and retention policy are mostly mentioned by the interviewees. For instance, patients are not allowed to leave the facilities with the data files, and only those authorized can access the data for the purpose of timely reporting or recording data in Uganda, while there is a standard operation procedure which aimed at data confidentiality, data segregation, reporting procedures, data security, and data storage and cleaning in Somalia. The objectives of data collection, data accessibility and data analysis as well as key data protection roles are further studied in line with the current policies and regulations. The purpose of data collection is mostly synchronized among different facilities across member countries which is to improve healthcare decision making by currying out data analysis. The decisions making includes many aspects of the healthcare such as overall performance of the healthcare facility, stock management, patient profile management, in order to optimize treatment quality and customization. The respondent from Beacon Hospital in Kenya pointed out that data collection is “to improve communication between healthcare worker and the patient, and to ensure quality of care to the patient to help the healthcare worker in decision making”. This answer is supported by another respondents from Somalian facilities that data collection is “to make proper diagnostic and treatment for future reference, and for surveillance of disease morbidity, mortality, resource planning and allocation”. Data providers, data processors and data controller have the authority to access data according to all the respondents. Data providers are health professionals such as doctors, nurses, lab techs and patients, while data processors are data stewards, billing and insurance companies. One exception is identified that only health providers have access to the patient information in all the interviewed Somalian facilities.

Table 10 The summary of how data controller, data provider and data processor access to data

Country	How facilities access data	How MoHs access data

Uganda	Through hospital system, claim forms and government system	Through the government system
Nigeria	During consultations and ward round	N/A
	Through clearance from the departments and the ethics committee of the directorate.	Not applicable or through written approval from the medical ethics board if need arise
Kenya	- Partners, through partner developed templates - Doctors, through Hospital Health Information system - Data Stewards, through the registers	through MOH reporting tools, registers and DHIS
Somalia	Through reviewing, patient registers, cards, prescription, and lab results.	MOH receive summary reports forms (hard copy) on monthly basis, this form filled by health provider, and send to District HMIS officer, then DHMI, enter to the DHS2

The difference of how data controller, data provider and data processor get access to data are summarized in Table 10. It shows that data controller (e.g., MoH) has the direct data access simply through the HMIS, while data provider and data processor either have to request the authority for data access that is complicated or can only visit data through paper-based records. The difference of data access in local facilities shows a top-down policy system and a low data ownership at the facility level. Similar to understanding the objectives of data collections, all the respondents provided concrete feedbacks about how they see the purpose of data analysis showing that staff at the facility level know well about each stage of data lifecycle. Ugandan data clerks see the purpose as "detecting fraud risk, ensuring data security, tracking individual practitioner performance, tracking the health of populations and identify people at risk for chronic diseases, identifying risk factors in patients, creating a more holistic picture of patients to drive treatment decisions, and increasing engagement by interacting with patients on an ongoing basis", while clerks from Kenya, Nigeria and Somalia have similar opinion about data analysis, it is to "monitor and predict the performance of the health facility and to formulate policies and decisions by building models". All the data analysis is performed by data processors such as data clerks, health record and information officer, while data providers take the responsibility in Somalian facilities. The analysis results are accessible to different groups of people (e.g., government and executive committee member, facility manager, authorized facility staff and supported agencies).

Respondents were further asked about their opinions of the BI solutions based on VODAN architecture, especially regarding the type of KPIs that needs to be indicated as well as the data accessibility. According to respondents, the generic dashboard should be able to show KPIs like daily patient visits, diagnosis, admissions, discharges, deaths, ambulance calls, emergencies etc. The accessibility of the generic dashboard should be differentiated to staff with different job responsibility. For example, data stewards and physicians should have full access to the dashboard, while other personnel such as nurses, pharmacists should have limited access right. On the contrary, the internal and customized dashboards should include extra data besides what the generic also shows. The extra information are lab tests, pharmacy prescriptions,

radiology examinations, maternal and postnatal death, and most common diagnosis etc. The access right should be granted to heads of departments, managers and data processors.

Politics stream

Table 11 Politics relatred quesitons

Question
Current roles/responsibilities Ag. Director of Health Services- Years of experience
Description of roles/responsibilities
Interviewee experience with computer
Type of Facility and who operates the facilities
How many data clerks in this facility?
Would you tell me more about facilities patients?
Major economic activities of the people living in the region
Who decides this purpose?
Who has access to the patient data? And who decides this access?
Who decides the analysis purpose?
Who does the analysis?
Who has access to the analyses?

Different data roles of stakeholders are identified based on the output of respondents, which are the data provider, the data processor, the data controller, and the data owner (see Table 12).

Table 12 Different data roles of stakeholders and the details

Data role	**Stakeholder**	**Detail**
Data provider	IT manager, medical director, chief administrative officer, patient records and care	Working experience from 4 to 15 years
Data processor	Data clerk	2 levels: facility level and district level
Data controller	MoH	Government
Data owner	Facility	Both public and private facilities
	patient	Residents with diverse professionals such as farmer, civil service, trader etc.

Data providers are mainly personnel working in the healthcare facilities. They are IT manager, medical director, chief administrative officer, patient records and care etc., whose responsibility is to collect data from patient, whereas data processors are usually data clerks who inputs the data into either paper or computer-based systems and tackles the management. Yet it is noted that there are two levels of data processors, i.e., one level is the data clerks of facilities and the another is data clerks appointed by the government to input data into the data warehouse such as DHIS2. The data controller is each government and respective MoH, who not only defined all the objectives of data collection and data analysis, but also

has the authority to access all the data and analysis results. Patients are the direct data owner, yet they are not allowed to reach their own data directly. For example, the patient data are data controller regulated and patients are not allowed to leave the facilities with the data folders. Facilities are the indirect data owner and only a few MoH authorized people at the executive level can get access to the data.

Policy Entrepreneurs

By analyzing the three streams, we can see that there is potential to improve the current hybrid data management system in most studied local facilities in Africa. Redundant routines during data collection and reporting are spotted due to undeveloped IT infrastructure and the limit of DHIS2 which does not cover facility level and these routines cost huge amount of time and workloads according to the stakeholders. Moreover, the data flows one-way to the central data warehouse that causes data ownership issues on facilities. The policy stream shows the demands of facilities for HMIS and analytics capability. This finding echoes the opinion of J. Braa and S. Sahay to some extent that data processors appointed by MoH have less motivation of leveraging advanced data tools of HMIS such as analytics than those from local facilities. The reason is data processors of MoH are only responsible to input data into DHIS2 and they feel no data ownership as data controller (e.g., MoH) have the full control of all the data. On the other hand, data processors at facility level have the needs to gain more insights by carrying out analysis as they are the data owner and they have responsibility to manage data of their patients, although data only fleets away from local facilities, and complicated procedures are required if data needs to be visited by the owner. The three streams come to together and the policy window is therefore identified as open to introduce a new system that enables a real-time data collection, transfer, storage and analytics while data ownership is promised.

Here VODAN comes to take the responsibility to accelerate the generation of policy window by introducing the new architecture. In addition, VODAN raised attention of key stakeholders by launching the three pillars (i.e., cultural adaptation through GO CHANGE; technical infrastructure GO BUILD; technical training through GO TRAIN), in order to couple both problems and solutions to politics.

6.2 Results

The answers of data clerks from local facilities were analyzed using coding labeling, and the results were used to build the concept list with 67 labels and 11 sub-groups, which are classified by problem stream, policy stream, and politics stream according to the Kingdon's theory (see Appendix B). There are 17 labels defined in the sub-groups of "challenges and initiatives" describing the problem stream. The concepts cover a wide range of challenges that local data clerks are facing from repetitive and tedious manual data collection to difficulties of physical storing and transferring data. Under policy stream category, 3 labels were found regarding currently used HMISs including DHIS2 which echo the findings of chapter 5. Furthermore, as many as 15 labels were found in terms of the perceptions of local data clerks about the objectives of data collection and the importance of data analysis such as BI methods, whereas 12 labels were found about the KPIs they think would be helpful with the data management and running the facility in general. Other labels found under the politics stream define the roles of data provider, data processor, data controller and data owner. From the labels, it is confirmed that a new system is needed by local data clerks to improve the current hybrid data management system by digitalizing the whole process at the point

of care. Most importantly, the new system should solve the issue of low data ownership and enable data owner to access their data easily.

The outputs of interviews show that data clerks in the local facilities know well about data analysis and expect the new architecture to bring them a certain function. The expected capabilities of the generic dashboard include KPIs like daily patient visits, diagnosis, admissions, discharges, deaths, ambulance calls, emergencies etc. The expected KPIs of internal and customized dashboards include lab tests, pharmacy prescriptions, radiology examinations, maternal and postnatal death, and most common diagnosis etc.

With regard to the data accessibility of the dashboards, the interview outputs show that differentiation is needed by different job responsibilities. In the case of generic dashboard, data stewards and physicians should have full access, while other personnel such as nurses, pharmacists should have limited access right. For internal and customized dashboards, the access right should be granted to heads of departments, managers and data processors.

6.3 Conclusion

In conclusion, the findings show that the perceptions of processing and managing patient data in practice is negative. They feel the daily data management routine is tedious as the hybrid data system (e.g., using both paper and computer at different levels) consumes much time and workload. It also caused data inconsistency when some patients left facilities with data folders because they forgot to hand them in to the clerks. Incomplete information is also a problem as no diagnosis details for patient are provided in some facilities resulting in missing information. The paper-based data management approach resulted in big challenges regarding physical storage as the storage space is limited and data security comes to concerns. Paper files are prone to spoilage and damaged, and the physical storage manner makes it harder to share and reuse data across facilities as paper files in folders must be transferred physically which is time and labor consuming. However, some facilities of VODAN member countries (e.g., Uganda) have already fully equipped with computers that enable real time data input and have integration capacity across systems. This reduces workload and improves the data management experience in these facilities.

On the other hand, the need of clerks to perform BI analysis is clarified which supplements the finding of chapter 5 that there is a controverse in the current HMIS, because systems such as DHIS2 do not provide BI solutions at the facility level. This finding reinforces the potential to introduce the FAIR based BI framework that can not only digitalized data input and management, but also provide analysis functions at the point of care. Most importantly, the proposed BI framework can guaranine data ownership by adding FDP through CEDAR, and more options are enabled to create customized ontologies. The architecture in detail is explained in the next chapter.

Furthermore, the convergence of three streams is identified using Kingdon’s MSF which reflects the findings deriving from the coding results. And the role of VODAN Africa as a policy entrepreneur to accelerate the development of proposed architecture is further confirmed.

7. VODAN Architecture

In this chapter, the FAIR based BI framework is introduced in light of VODAN architecture. The workflow of adding FDP to generate semantic data and metadata is explained. Moreover, the important roles of the Center for Expanded Data Annotation and Retrieval (CEDAR) platform and OntoPortal in data FAIRification are also discussed. Then three data pipelines of VODAN architecture are illustrated.

7.1 FAIR and Semantic Data

The design of the BI solution is supported by the VODAN architecture, where FAIR Principles ensure the data quality during all the data activities happened within or across local facilities in Africa. Most of the requirements to ensure findability and accessibility can be achieved at the metadata level, while interoperability and reusability require more efforts at the data level [146]. Figure 10 depicts the FAIRification process focusing on data, but also indicating the required work for metadata.

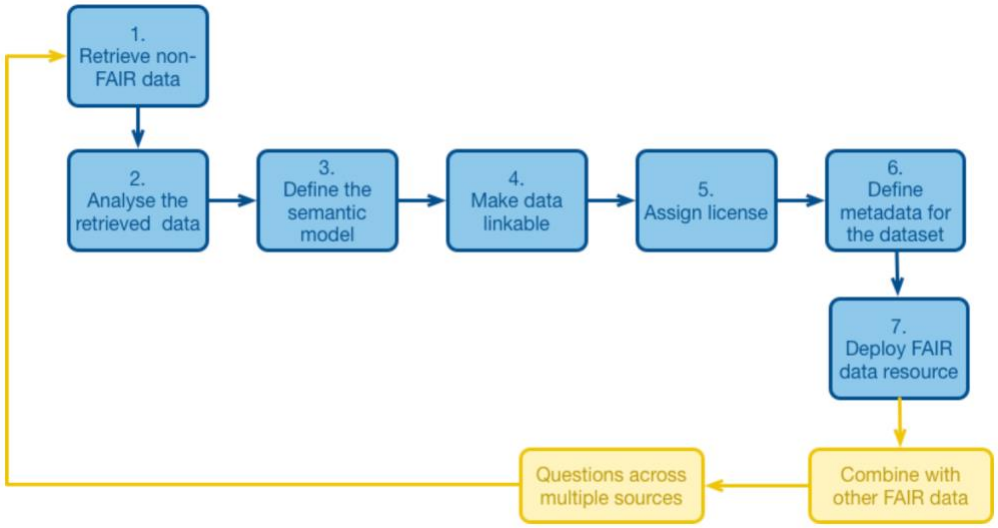

Figure 10 The FAIRification process, source: GO FAIR [146]

After data are accessed, analysis is conducted to inspect the details of the data. If the datasets are not yet FAIR, a semantic model is the defined to describe the meaning of entities and relations in the dataset. Furthermore, “semantic models often contain multiple terms from existing ontologies and vocabularies. A vocabulary is a computer-readable file that captures terms, their URIs, and descriptions. An ontology can be roughly described as a vocabulary with hierarchies, meaningful relations among concepts, and their constraints. These conceptual models allow us to classify our data models and data items using the provided terms, concepts, and conceptual structures” [146]. The next step is to make FAIRified data linkable using Semantic Web so that data can integrate into other data types and systems. This enhances the interoperability and reusability of the data followed by adding a license to keep data reusable. Then metadata needs to be defined to enrich the meaning of the data before the final deployment.

Semantics is regarded as a first class citizen for FAIR implementation as it was clearly stated in I2 of FAIR Principles that "(meta)data use vocabularies that follow FAIR principles", meaning applying semantic artefacts lead to a rapid increase of the number of ontologies and semantic repositories [147]. When a number of semantic data are linked together, the Sematic Web is built to make data on the internet machine-readable. Web ontology and Resource Description Framework (RDF) are commonly used to encode semantic data. Ontology is a set of described concepts in a subject area or domain, including their relations to each other and external concepts, and is usually used together with controlled vocabularies to create metadata. However, semantic metadata are desired to make data FAIR. The difference between metadata and semantic metadata are that metadata summarizes basic information about data, making accessibility and use of particular instances of data easier and is often seen as the description of the data, whereas semantic metadata are deeply interlinked and richly contextualized information about data and is often seen as the meaning of the data. Semantic metadata helps computers to interpret the meaning of the data through references to concepts, formally described in a knowledge graph. Semantic metadata are often part of knowledge graphs itself. To make a metaphor using the barcode normally appeared on a product label, metadata indicates the basic information of the product such as name, price, manufacture etc., while semantic metadata are able to reveal more information through the linkage of other objects also making it easy to search, access and use. In this way, much more granularity of detail to the data are added.

Figure 11 Metadata vs. Semantic Metadata, source: T. Petkova [148]

In the workflow depicted in Figure 10, semantic platforms play an essential role as they are needed for the integration of the science-data, for instance on COVID-19, the Center for Expanded Data Annotation and Retrieval (CEDAR) platform developed by Stanford University can provide convergence to facilitate the queries [149].

The CEDAR platform develops information technologies that simplify authoring complete metadata and facilitate using the metadata in further research. The initiative of CEDAR is to improve metadata and its use in the domain of biomedical sciences. It is noted that CEDAR is not the repository of record for metadata from biomedical studies but is a research collection of metadata. The main objective of using CEDAR is to improve metadata not only for the time being but also in the future by enabling researchers to learn from existing metadata. The main CEDAR system collects the public metadata provided by users and public

systems. The more metadata CEDAR has, the better suggestions and validation capabilities it has [150]. The CEDAR metadata tools provide users with the possibility to create their own metadata templates, the corresponding management of these templates as well as publishing globally. Table 13 shows the current supported functions and the details.

Table 13 CEDAR metadata tools in detail, source: CEDAR [150]

Function	Details
Creating Metadata	To ease the work of entering metadata into form fields, with user tips and other cues User entries are quickly verified according to the field type and other template constraints, auto-complete capabilities that suggest possible content based on the user's initial typing Suggest corrections for user errors To offer predictive metadata entries to pre-fill some fields if their content can be guessed with confidence using machine-learning techniques
Updating Metadata	Changes and Enhancements Track of the provenance of entered metadata values The authority of a certain user or other users to change them Represent the status of any changed values (e.g., Changed, Suggested, or Rejected), along with the provenance of the changes
Validating Metadata	Contribute to better metadata by making it easy to specify and constrain the options for user data entry Validate metadata entry immediately in the user interface to help prevent entry errors before they become real issues
Searching CEDAR Metadata	Keep all the metadata for the domains it addresses, the main CEDAR repository will contain a wide range of metadata for biomedical studies and related content Associate all the metadata with well-defined resources, either uniquely identified in the web, or uniquely specified by defined CEDAR templates Enable researchers to review the metadata, to use it to aid their own data research, and to analyze it with respect to common models and concepts
Analyzing CEDAR Metadata	Publish user interfaces and APIs to support the export and analysis of CEDAR metadata, described as CEDAR evolves Enable basic analysis for most kinds of research data addressed by the system

Publishing Metadata	Support publishing the metadata, and any links to the data sets, to commonly used target metadata repositories as users are not interested in entering all of their metadata twice, once for the target repository and once for CEDAR

According to the CEDAR team from Stanford University, "CEDAR is developing methods to support and accelerate an end-to-end process whereby community-based organizations collaborate to create metadata templates, investigators or curators use the templates to define the metadata for individual experiments, and other scientists search the metadata to access and analyze the corresponding online datasets" [151, p. 1148]. The CEDAR ecosystem is built to create a community-based metadata management system, which consists of an online template repository and a metadata repository. Users annotate their experimental data by assembling composite templates and by filling in the templates using metadata-acquisition forms from the online template repository to create collections of experimental metadata, which is then stored in the metadata repository for future exploration and reuse of datasets. The ecosystem is illustrated in Figure 12.

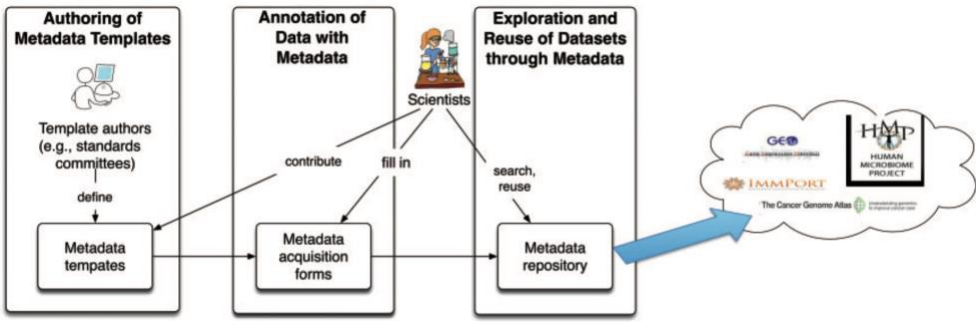

Figure 12 CEDAR architecture, source: M. A. Musen et al. [151, p. 1149]

As semantic artefacts are machine readable models of knowledge such as controlled vocabularies, thesauri, and ontologies that are findable, accessible, interoperable and reusable, meaning that reusing semantic artefacts can FAIRify vocabulary by avoiding proliferation of vocabularies and by increasing interoperability. There are several ways to achieve that such as importing concepts from other semantic resources, mapping own concepts to other concepts and reusing definitions from other specific sources like BioPortal. On the other hand, BioPortal also allows users to create and publish their own vocabularies that can be used later semantic platforms, but it is noted that BioPortal is a repository to only hold biomedical ontologies, as BioPortal is the largest repository of biomedical ontologies with more than 300 ontologies to date. However, it is recommended to reuse already existing vocabularies listed in CEDAR unless at least one of the following rules is fulfilled:

- There is no existing open vocabulary that fully suits the needs
- It is impossible to build upon an existing vocabulary by adding terms to it
- It is impractical to reuse the vocabulary as is (e.g., it is not structured)
- The existing vocabulary is no longer maintained

As the main server of BioPortal is in the U.S., collaboratively developed version of BioPortal will be used under the VODAN architecture, which is called OntoPortal. OntoPortal is a virtual alliance developed to promote semantic services in scientific research based on shared domain-specific ontologies. Particularly,

OntoPortal is based on the BioPortal ontology repository, in dozens of local installations with content and capabilities tailored to users' own needs. It can be seen as a public version of BioPortal at an international level, as public repositories can be hosted on OntoPortal, and these hosts are banding together to advance development and community support for key semantics [152]. In order to enable the community to contribute to OntoPortal's development, dissemination, and documentation, it is necessary to set up a common repository on GitHub for the OntoPortal open source software, and to create other shared resources for technical and strategic collaboration [152]. In this way, the OntoPortal alliance can have a long-term growth and the sustainability is therefore ensured. The capabilities to FAIRify data provided by CEDAR platform and OntoPortal pave the path to the construction of VODAN architecture, which consists of three data pipelines, i.e., the clinical patient data pipeline, the research data pipeline, and the combined pipeline of both clinical patient data and research data.

7.2 VODAN Architecture and Data Pipelines

Data pipelines consist of a source, a processing step or steps, and a destination. In general, a data pipeline is a set of steps that ingest raw data from different sources and move the data to a destination for storage and analysis such as a data warehouse, although specific procedures very at each step that is in accordance with business goals. However, the use case of data pipelines under VODAN architecture is different as data remains in residence by following FAIR Principles and data are not collected and stored outside local health facilities. Furthermore, VODAN architecture supports not only specific analytics at the point of care but also generic analytics through data visiting across facilities by running an algorithm FDP to visit the distributed data and produce aggregate findings [153].

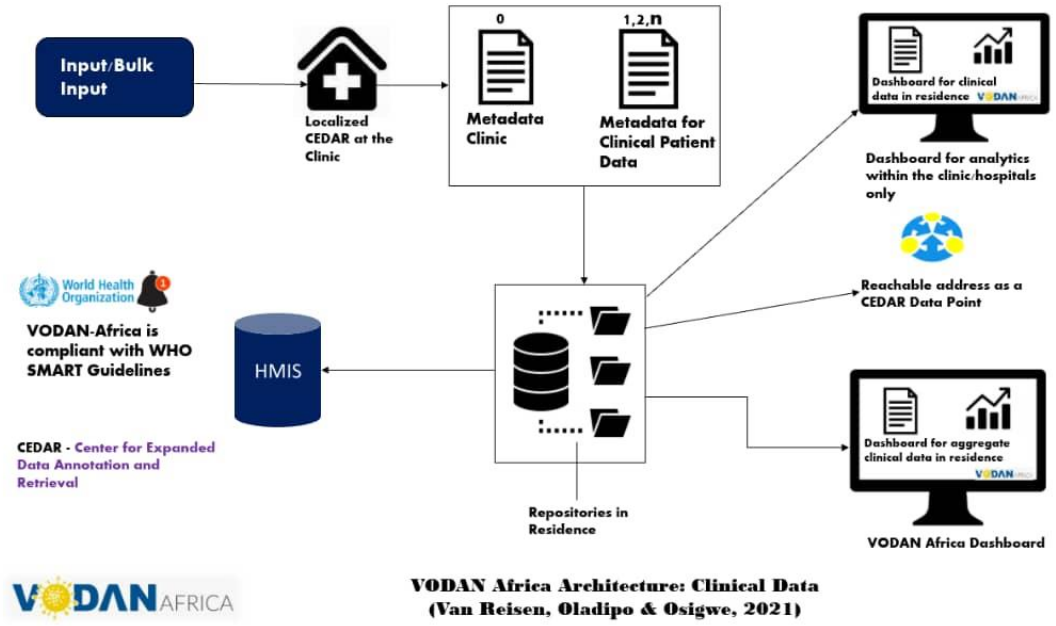

Figure 13 The architecture for clinical patient data, source: M. van Reisen et al. [153, p. 10]

The pipeline of clinical patient data (see Figure 13) depicts that bulk data are input into a localized CEDAR system installed in the health facility and through which two levels of data are produced in machine-

readable metadata: the clinic specification and the clinical patient data. The benefits of installing localized CEDAR system include that data can be reposited locally, local dashboards are supported, and relatively simple development. These are stored as RDF and JSON linked languages in a local repository for data capture within the clinic or under the strict control of the health facilities, and preferably within the countries. The repository has the capacity to export the data to DHIS2, which is a mandatory procedure according to WHO [153]. WHO has also launched its first SMART Guideline, which provides a guidance to generate clinical data and data practices that are Standards-based, Machine-readable, Adaptive, Requirements-based, and Testable [154]. This ensures that the VODAN architecture conforms with all the WHO SMART guidelines, as WHO specifically identifies the need for integrated data with quality of care as the main objective which is exactly one of the main objectives of VODAN architecture. Moreover, "the repository is also identifiable through a reachable address on the Internet that can be indexed by Google. The usability of the data are arranged at two levels: the dashboard within the clinic and the aggregate dashboard of the VODAN community, creating real-time data analysis" [153, p. 9].

The pipeline architecture is equally employable for clinical patient data and research data, which can potentially create a matching of information from different kinds of data including research data. The architecture for the research data is therefore similar (see Figure 14), with the inclusion of a repository within the university. It allows the data to remain in residence and creates a strong localized identity for the data, which strengthens the provenance of the data and adds meaning to it. Yet in the case of research data, metadata should be extensive and specific [153]. Here comes the role of the CEDAR platform with diverse tools mentioned before. The dashboard functionality is also provided so that decision-making could be assisted through KPIs.

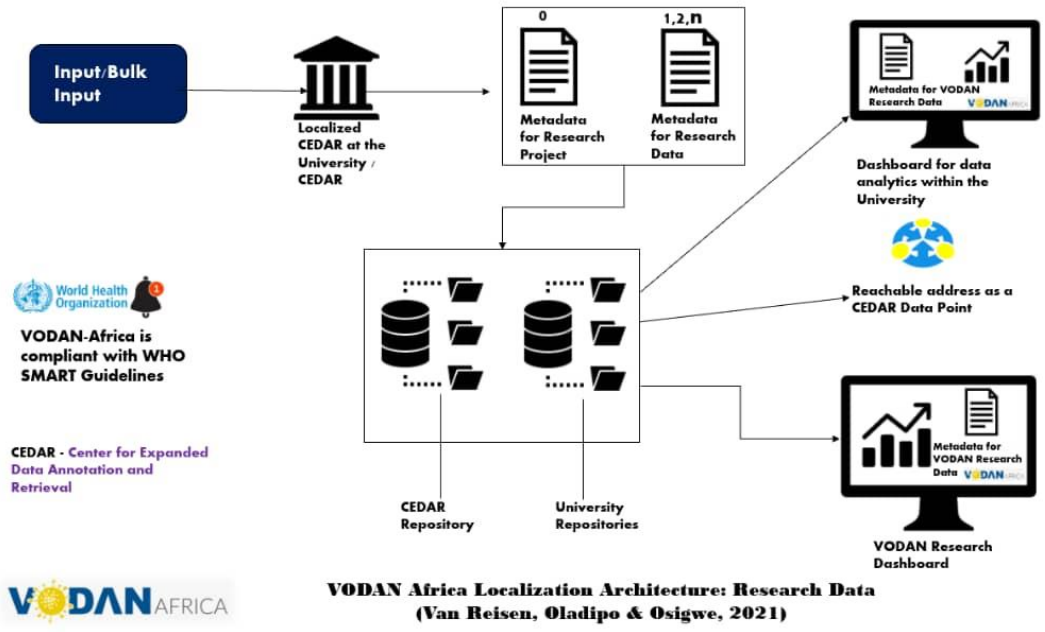

Figure 14 The architecture for research data, source: M. van Reisen et al. [153, p. 10]

Last but not the least, the combined pipeline of clinical and research data is used to create an aggregate dashboard that is accessible to all members in the VODAN community (see Figure 15). When this

architecture was finalized, the community had around 40 stakeholders including data stewards, health practitioners, academics, and people working in health policy [153].

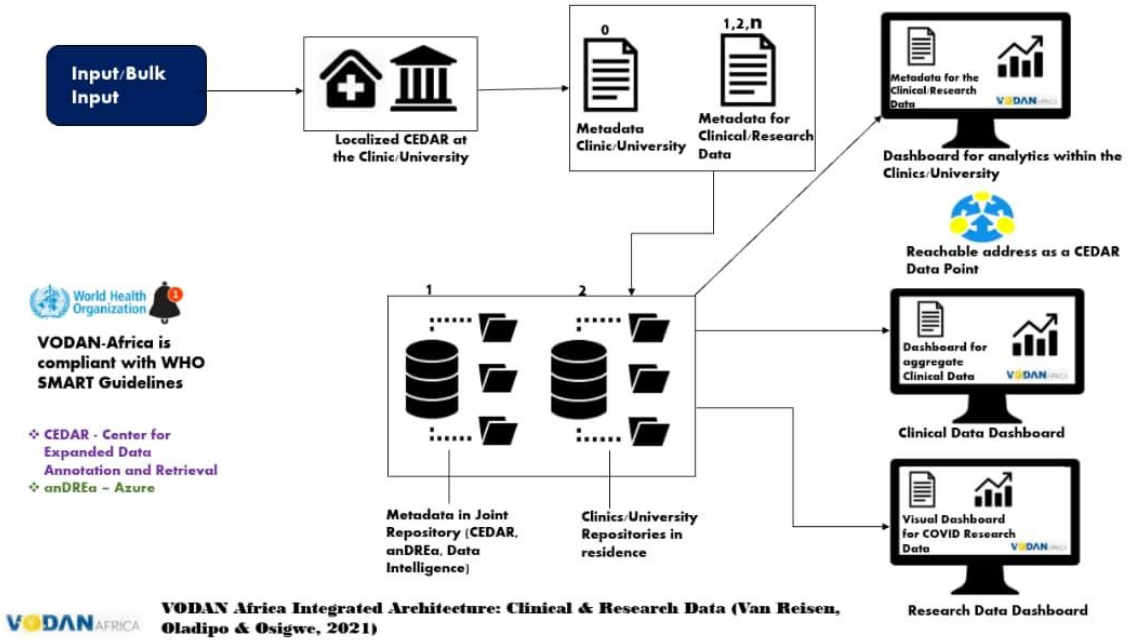

Figure 15 The architecture for patient and research data, source: M. van Reisen et al. [153, p. 11]

7.3 Results

By implementing the FAIR data based VODAN architecture, local healthcare facilities could not only benefit from a digitalized data management approach, but also benefit from the perspective of local data protection, which is the key to trust building among different stakeholders. For instance, the key benefits are emphasized as:

- Data held under regulatory framework that applies in the country where data are produced
- Compliance with the key notions of EU GDPR such as that data belongs to the data-subject and data are collected for well-defined purposes
- Accessibility is as open as possible and as protected as necessary through permission rules for access
- Data are held under control of where it is produced
- Data-visiting of federated data replaces data warehousing
- Rich metadata and data provenance contributes to situational understanding of data
- Training of Metadata templates creation is also delivered to data processors in the local health facilities

With regard to the deployment strategy, the FAIR data host is created first by following all the regulations. Then data as well as metadata templates are made, so that health data could be input into the secured machine-readable format at clinics and hospitals. This step replaces the conventional paper-based procedure. As a result, data analysis using BI solutions is enabled by visiting data stored at the local clinics and

hospitals through APIs, while local facilities have the complete control of their data. It is also highlighted that all the personnel training is provided at no cost.

7.4 Conclusion

The design of the dashboard from an originally centralized BI architecture (see Figure 3) to a localized one (see Figure 13) has been confirmed. In order to realize this design, FDP plays an important role to ensure the residence of the data so that data are not moved while accessibility is still possible. This design upgrades the data governance and protects the data ownership compared to using warehouse that is the traditional method used in common BI architecture. Moreover, FDP is added on data by generating semantic metadata through CEDAR platform which provides the whole structure to collect, add and manage semantic metadata. However, due to the unstable internet connection of Africa health facilities, a locally installable version of CEDAR is required. On top of that, more functions are reachable to create customized ontology that can be used to enrich semantic metadata through constructing a OntoPortal. In this way, FAIRified data can be either exported to WHO required databases or be queried via CEDAR API to perform data analysis through BI dashboards in a manner that the data ownership is protected. The BI dashboards also provide local solutions and cross-clinic solutions which must be in line with all the regulations. In the next chapter, the UI design and creation of the prototype are further explained.

8. BI Dashboard

In this chapter, explanations are given about the details of the creation of the BI dashboard prototype. The design of UI and mock datasets have also been discussed.

8.1 Dashboard Design

The design of the dashboard framework is conducted by following the design stage of the methodology described in the section 3.4. The UI design and prototype are carried out using the Tableau software as Tableau is one of the most advanced BI solution software on the market that provides diverse tools and functions to make dashboard prototypes. And the prototype is open sourced so that stakeholders can easily get access to the outputs. The first type of data pipeline from the VODAN architecture has been adopted (i.e., clinical patient data). And three UI layers have been decided, namely the facility information layer, the facility dashboard layer and the VODAN dashboard layer. The accessibility control has also been defined. The facility information layer and the VODAN dashboard layer are open to all the data processors from different facilities so that generic information can be accessed by interested stakeholders. For example, facility information such as contact and address can be visited at the facility information layer, whereas generic KPIs such as daily patient visits and average diagnosis time can be known at the VODAN dashboard layer by every related personnel. The accessibility of the local dashboard layer is only granted to specific facility as KPIs shown on that layer might be sensitive and therefore are customized by the needs of each facility.

According to the dashboard development methodology (see Figure 4), data sources are then confirmed for the prototype. Based on the interview analysis in terms of needed KPIs for facilities dashboards, mock data have been designed and created using Python. Three datasets have been developed and they are:

- Facilities: holds data about facility information
- Patient visits: holds data about patient visit date, diagnosis time for each visit and prescription drug type
- Other KPIs: holds data about other KPIs such as admission number by date when there is patient visit

The created mock data are stored in .CSV format on Google Drive and the complete data collection has the following quantity:

- Facilities: 35 records, 11 attributes
- Patient visits: 1620 records, 5 attributes
- Other KPIs: 604 records, 11 attributes

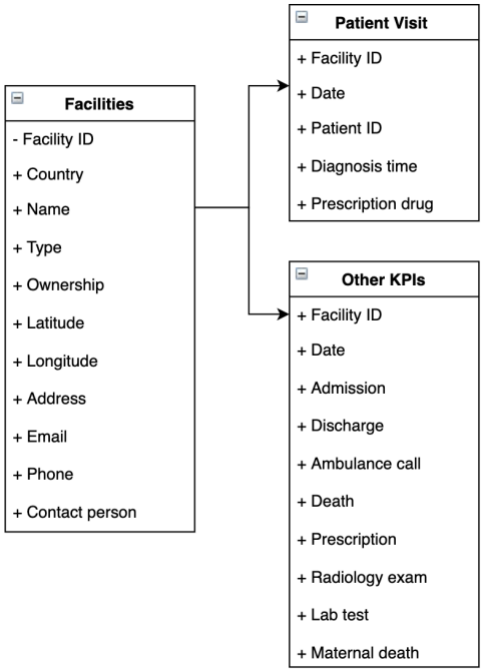

Figure 16 UML class diagram, source: created by the author, Yi Lin

A UML-class diagram of the database is created to describe the relationship of the three datasets (see Figure 16). The facility table links the other two tables through the facility ID attribute. The patient visit table shows the details of each patient visit while the table with other KPIs shows a summary of main indexes by each date. Due to the need of prototype simplicity, mock data of patient visits and other KPIs for only one facility have been generated, which is thought to be enough for the purpose of demonstration. The table below shows a detailed description of data fields and types.

Table 14 Description of dataset "Facility"

Column	**Type**	**Description**
Facility ID	Int	The ID of the facility
Country	Varchar(32)	The country where the facility is located
Name	Varchar(32)	The name of the facility
Type	Varchar(32)	The type of the facility, e.g., private or government owned
Latitude	Decimal(10, 5)	The geolocation of the facility
Longitude	Decimal(10, 5)	The geolocation of the facility
Address	Varchar(32)	The address of the facility
Email	Varchar(32)	The email of the facility
Phone	Int	The phone number of the facility
Contact person	Varchar(32)	The contact person of the facility

Table 15 Description of dataset "Patient Visit"

Column	**Type**	**Description**

Facility ID	Int	The ID of the facility
Date	Datetime	The date of the patient visit
Patient ID	Int	The ID of the patient
Diagnosis time (min)	Decimal(5, 2)	The diagnosis time in minute
Prescription drug	Varchar(32)	The rescripted drug type

Table 16 Description of dataset "Other KPIs"

Column	**Type**	**Description**
Facility ID	Int	The ID of the facility
Date	Datetime	The date of the patient visit
Admission	Int	The admission number of a calendar date
Discharge	Int	The discharge number of a calendar date
Ambulance call	Int	The ambulance call number of a calendar date
Emergency	Int	The emergency number of a calendar date
Death	Int	The death number of a calendar date
Prescription	Int	The prescription number of a calendar date
Radiology exam	Int	The radiology exam number of a calendar date
Lab test	Int	The lab test number of a calendar date
Maternal death	Int	The maternal death number of a calendar date

8.2 Results

The prototype is continually being updated based on the feedback of stakeholders, yet the first version of the result is included in this thesis.

The UI design and prototype are created in this research. Compared to the traditional centralized architecture (e.g., used by DHIS2), local facility has the possibility to perform basic analysis such as sorted monthly patient visit number in total, and the analysis is real-time as datasets of local facility are used yet without being moved to anywhere. The dashboard design has three layers which are the facility information layer, the facility dashboard layer and the VODAN dashboard layer. The facility dashboard layer only grants accessibility to each specific facility as data showed on this layer of dashboard are sensitive and only the data owner facility is able to visit the dashboard to carry out analysis, while the other two layers are open access to all the stakeholders as the facility information layer provide basic information of a facility such as contact and geolocation information, and the VODAN dashboard layer illustrate generic data and corresponding analysis that are not sensitive so that all the stakeholder can share the results.

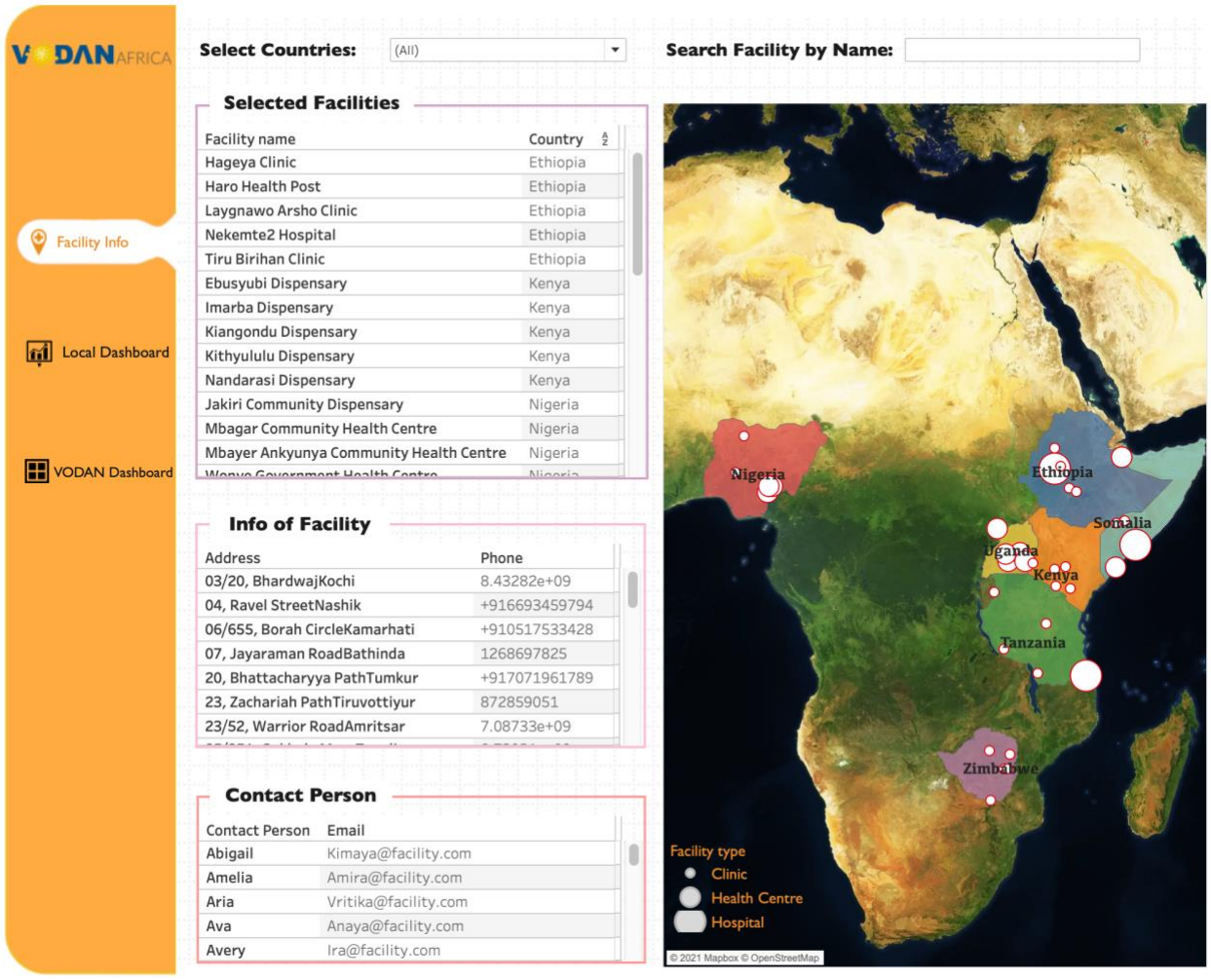

Figure 17 Screenshot of the dashboard layer "Facility Information", source: created by the author, Yi Lin

The capability of each dashboard layer is explained in detail. On the facility information layer (see Figure 17), a map is created to show the geographic information of selected facilities, which is linked with other components, meaning that the map reacts to changes made by clicking specific one or more facilities. A country filter is added so that the scope can be chosen as needed, whereas a search box is provided to target facilities by inputting names. The reason is that the number of facilities in total is big and this design can avoid too many results showed at the same time when using drop down menu, which will block the interface.

Three information blocks are added to show the name and country of selected facilities, while all the information is showed by default if there is no selection has been made. The interface is not blocked as a scroll down function used inside the information box. Similarly, the second box shows the contact information of a facility (i.e., address and phone number), whereas the third box shows the contact person's name and email address. It is noted that the contents showed inside information boxes can be changed depending on the upcoming feedbacks of local data clerks and facility manager.

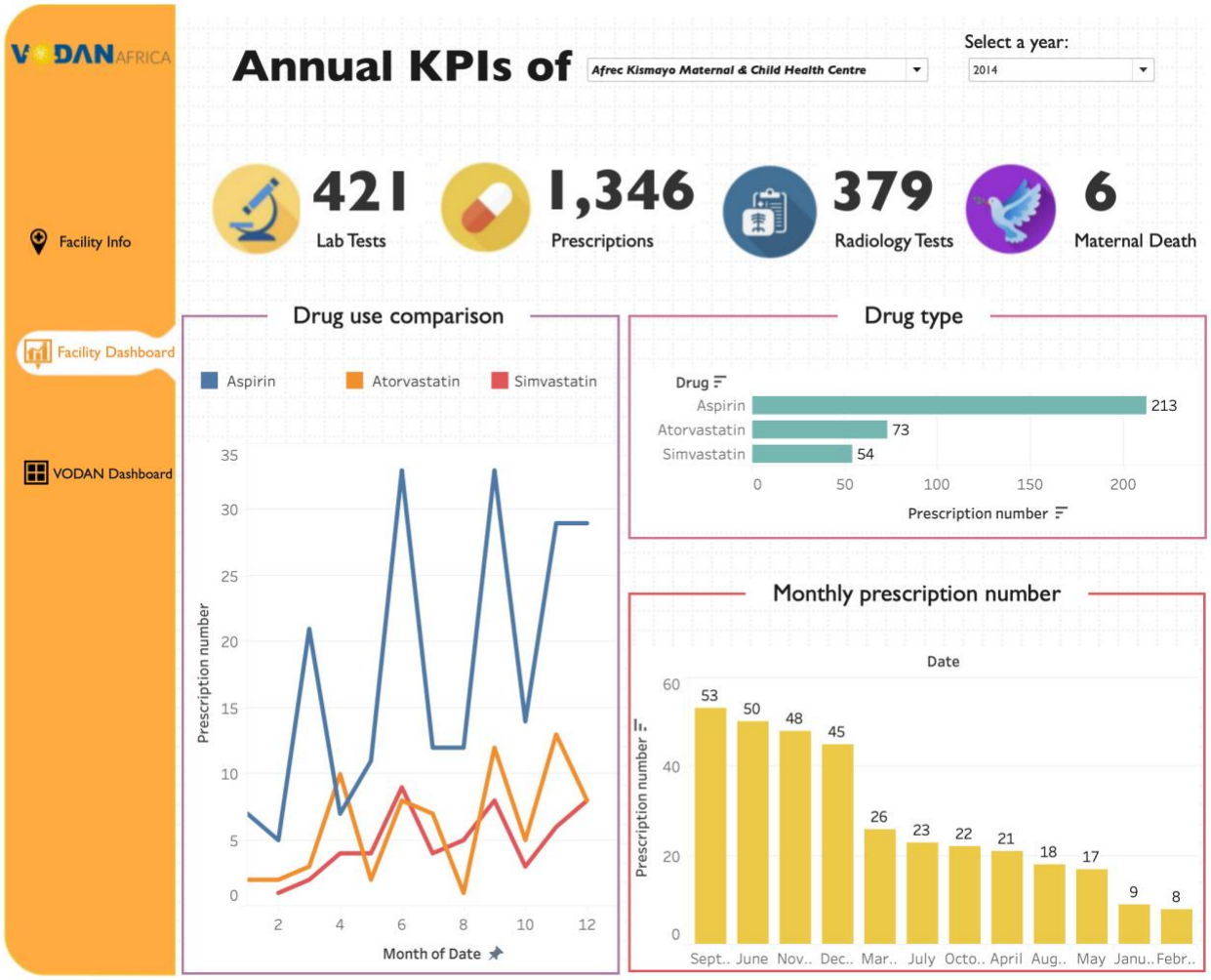

Figure 18 Screenshot of the dashboard layer "Facility Dashboard", source: created by the author, Yi Lin

On the facility dashboard layer (see Figure 18), a year filter is added on top of four KPIs (i.e., lab test number, prescription number, radiology test number and maternal death number) that are showed by selected year. Three analysis charts are provided, which are the line chart to show the used drug type comparison, two bar charts to show the total annual consumption of drugs by type and sortable monthly prescription number. The reason to provide data analysis of drug use and type is based on the interview answers of local clerks, and analysis of drug data is essential for health facilities in general. Similarly, an overview of monthly prescription number can help facilities have the insight of drug prescription, based on which another analysis of drug stock can be further added depending on the need of stakeholders. If future feedbacks indicate that other KPIs would be more wanted to show, modification is always possible.

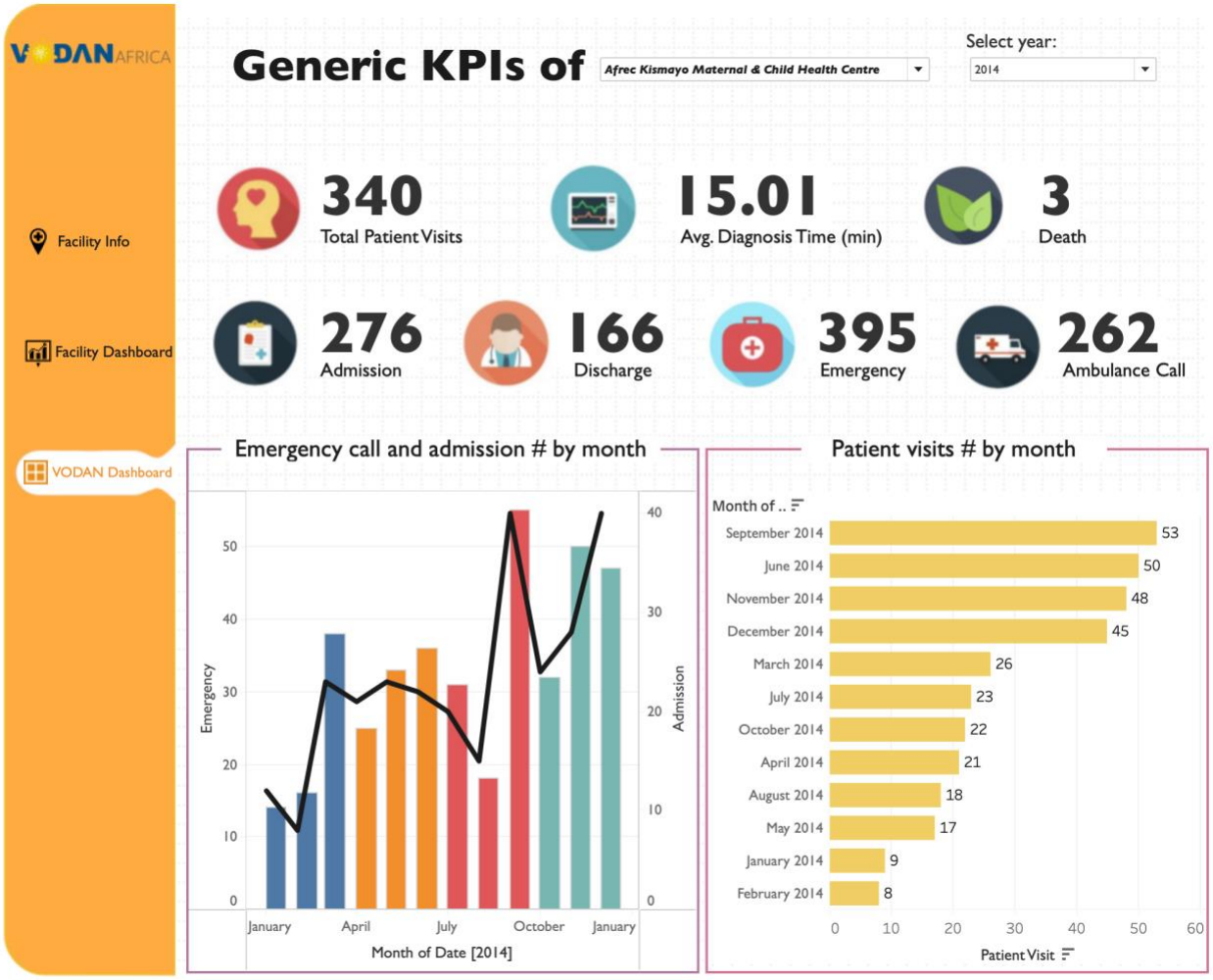

Figure 19 Screenshot of the dashboard layer "VODAN Dashboard", source: created by the author, Yi Lin

On the VODAN dashboard layer (see Figure 19), seven KPIs (i.e., daily patient visits, diagnosis number, admission number, discharge number, death number, ambulance call number and emergency number) are provided besides the same year filter function. On top of KPIs, a dual chart is made to show the relationship between monthly emergency call and admission number, while a sortable bar chart is also added to show patient visit number by month.

8.3 Conclusion

The dashboard UI design has been made and mock datasets have been built. In addition, a three-layer dashboard prototype has been created using Tableau. The prototype allows users to interact with mock datasets such as to show facility information on the map and to perform statistical analysis. However, the prototype only provides a front-end user experience as the mock data has not been FAIRified, meaning that the data are stored in the cloud database of Tableau. More work needs to be scheduled in the future to realize the query of FAIR data through CEDAR architecture.

9. Conclusion

Digital data are growing at exponential rate, especially in the research area such as academia and R&D sections of different industries. The decision-making process is becoming increasingly data-driven, and the need of more accurate and efficient data analysis is getting tremendously huge. The most important thing of handling huge amount of digital data nowadays is that the data should be machine-readable so that data can be found and reused by different information systems from repositories. As a supplementary, human readable information should be included as metadata in order to generate semantic data.

FAIR principles stand for data that are "Findable," "Accessible", "Interoperable," and "Reusable." Implementing the FAIR Principles can increase the quality of scientific data management and stewardship, and therefore data could be visitable on the internet through data-ports. FAIR Principles have widely accepted and implemented globally, but around 95% of the implementation is identified in Western countries, and there is a lack of investigating its use in non-Western geographies. Therefore, this research has studied literature both written in English and local languages about the implementation in non-Western countries (i.e., Africa, China, Indonesia, Japan, Kazakhstan, Russia and the Middle East). According to the Kingdon theory, the convergence of the problem stream, policy stream and politics stream has been confirmed, which means the policy window of global FAIR adoption is open yet at different levels. Implementing FAIR Principles is on the policy agenda of some countries (i.e., Indonesia, Japan, Africa and the Middle East), while more awareness regarding benefits of adopting FAIR needs to be raised in some countries (i.e., China, Russia and Kazakhstan) in order to open the policy window. Especially in Africa, the political environment of accepting FAIR Principles is confirmed and FAIR development is stepping into the next stage to issue relevant regulations and political support, and to build technical infrastructure.

However, in Africa, patient health data have been collected and managed through various HIMSs that are all based on the mechanism of centralized data warehouse. As a result, the data left local facilities in a one-way direction, i.e., it is difficult for local facilities and patients to access those data, let alone there is no analytic feedback returning to clinics or hospitals, while data analysis is possible to perform at the government level. The centralized data warehousing yet reflects the common BI process model. These have been confirmed by the literature analysis launched in this research, as well as by the interviews conducted among local data clerks in this study. The current hybrid data management system has several problems that need to be fixed. The problems include repetitive and tedious manual data entry caused by paper-based data collection, data inconsistency and data damage caused by physical storage, time- and labor-consuming data sharing caused by physical transfer, data security issue caused by the design of open data at the central database, and lack of data analysis as well as low data ownership due to the data warehousing mechanism. Therefore, this research has proposed a FAIR data based BI framework to solve the found issues.

The proposed architecture supported by VODAN Africa enables clinical health data and research data to be collected at the point of care at the facility or institute level and transfers them into human- and machine-readable data that is locally governed. This new approach upgrades paper-based data management system to a fully digitalized one that solves all the issues caused by physical data collection, storage and management. Full integration with other systems such as local HMISs and DHIS2 is also provided allowing the new system to follow all the regulatory frameworks and guidelines. In this way, the reporting routine required by WHO and MoH remains the same while the efficiency of managing data in general at facility

level is going to be boosted. On the other hand, data analysis is allowed by the new architecture at the point of patient visit through either the generic or the facility dashboard which echoes the needs of local data clerks to perform data analysis by making it available in the beginning of the data cycle. It also encourages data clerks to leverage this function in an easier way compared to the current system where analysis is barely used due to the complexity and inconvenience. Based on the literature analysis in this research, there is hardly capacity conflict between the proposed architecture and currently used ones.

Furthermore, the new system has the potential to bridge trust between African communities and the globe by protecting African data ownership and by offering help with IT capacity building. This will reinforce the participation of the African continent in sensitive research areas, such as patient data of COVID- 19. It also helps African health facilities improve digital capacity to understand and develop semantic web architectures. Therefore, FAIR Principles lead the architecture to establish responsible data in Africa, that acknowledges the authority of the continent to manage, analyze and innovate its digital capabilities, and helps local communities govern their own data as the valuable resources. The FAIR data supported architecture has been deployed in nine African countries, i.e., Uganda, Ethiopia, Liberia, Nigeria, Kenya, Somalia, Tanzania, Zimbabwe, and Tunisia.

In conclusion, the proposed FAIR data based BI framework is pioneering to create BI solutions using health data that are findable, accessible, interoperable, and reusable at local African hospitals and clinics. This new system increases the value of data at point of care by facilitating data analytics in health facilities using interoperable data. The proposed BI framework further embodies the VODAN architecture that not only aims to strengthen local data ownership and benefits to healthcare with quality in African communities, but also enhances the interoperability and re-use of data under strict access and control conditions of collaboration for research by making data FAIR. The output of this research also provides an ethical response to the massive data extraction. It is then possible to visit needed data as before but without taking the data away. Therefore, the data quality in the local health domain is improved.

10. Discussion

This research is the first, to our knowledge, that has investigated the implementation of FAIR Principles in non-Western geographies and has concluded and compared popular HMISs in Africa. The comparison of the architecture and capabilities of DHIS2 and the proposed solution helps to discover the cause of low data ownership that local facilities are struggling with.

Particularly, the analysis of interview answers collected from local data clerks not only approved the previous findings, but also contributed to understanding the perspectives of local healthcare staff about problems of current systems, and their needs and suggestions of the new system. The interview data collected in this research have societal contribution as well because the data reflect the voice of data owners and processors in local facilities and help us understand challenges local facilities are encountering, which further increases mutual trust between the west world and local communities. As a result, the willingness of accepting the proposed VODAN architecture has been confirmed by local facilities. The technical contribution then comes from the novel integration of FAIR Principles into a BI framework that could potentially solve the main challenges regarding low data ownership local African facilities have been struggling with. A prototype of the BI dashboard has been created in this research, but it is just the first step of building such a sophisticated system.

As to the limitation of this research, there are several points to point out. First, there are many non-Western geographies that have not been investigated yet due to the language limitation of team members, such as South America. The situation of FAIR implementation in those areas remains unclear. Secondly, the literature analysis based on Kingdon's MSF may be biased due to the centralized policy making system in some countries, which may affect the convergence of the three streams and therefore the open of the policy window is hard to identify. Thirdly, the created prototype only reflects the need of a part of the local facilities as the interviews are still ongoing in some countries and the progress is slow due to the current pandemic. Moreover, feedbacks of the prototype are also being collected from local data clerks and other stakeholders. As a result, functionalities and data accessibility provided by the current prototype might not be accepted by some facilities, and it is possible to need frequent modification. Fourthly, only one data pipeline, i.e., the clinical data pipeline, has been implemented into the prototype in this research. Lastly, the prototype only provides limited capabilities although the purpose is to show stakeholders how users can interact with data and what type of insights are useful by checking KPIs. Particularly, the prototype was created using Tableau which is not open soured and has limitation in promising data ownership. Therefore, a more independent solution is needed in the future to build the real system.

In the future, there are a number of tasks that could be fulfilled. For example, literature reviews of FAIR implementation in non-English speaking geographies could be considered as there are still many literatures published in local languages other than English even in Western countries. Moreover, further analysis will be conducted as the interviews are finishing which will lead to several versions of modification of the prototype. And more efforts are needed to combine the research data pipeline with the BI framework in order to build the corresponding prototype. Last but not the least, a development plan will be drafted before moving to the next step of building the dashboard. By considering the importance of protect the data ownership as well as local IT infrastructure, another solution to the dashboard development will be considered such as JavaScript-based framework.

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Appendix

A. Data Processing Agreements

THE REPUBLIC OF UGANDA
IN THE MATTER OF THE CONTRACTS ACT 2010
AND
IN THE MATTER OF THE DATA PROTECTION AND PRIVACY 2019
AND
IN THE MATTER OF A DATA PROCESSING AGREEMENT

This Data Processing Agreement is executed this November Day of 2020.

BETWEEN

VODAN-AFRICA (hereinafter referred to as **the "Company")** hosted in Uganda by **KAMPALA INTERNATIONAL UNIVERSITY** of P.O.BOX 20000, Kansanga, Kampala (hereinafter referred to as **"the Company ")**

which expression may where the context so admits include its successors and assigns) on the one part,

AND

Addis Ababa University, Ethiopia (hereinafter referred to as *"The Data Processor")* which expression may where the context so admits include its successors and assigns) on the one part,

Both Parties together are hereinafter referred to as the "**Parties**")

WHEREAS:

(i) The Parties are cognsant of the fact that this *Agreement* forms part of the Contract for Services *("Principal Agreement")* executed between them and is specifically intended to provide for terms and conditions relating to data processing between them,

(ii) The Company represented by the Company in the context of this agreement will act as the Data Controller in respect of all the data processed under this agreement, while the Sub Contracted entity will be the Data Processor.

(iii) The Company wishes to Sub-Contract certain Services, which imply the processing of personal data, to the Data Processor, in accordance with the provisions of the applicable laws relating to Data Protection and Privacy in Uganda, Zimbabwe and Ethiopia, on the strict understanding that it shall be the duty of the Data Processor to ensure compliance with the said applicable.

(iv) The Parties seek to implement a data processing agreement that complies with the requirements of the current legal framework in Ethiopia to data processing to

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wit; the Data Protection and Protection Privacy Act for Uganda or other applicable laws or equivalent provisions in the relevant laws of Ethiopia and to ensure that the terms herein are in tandem with the said law, especially in terms of the protection of natural persons with regard to the processing of personal data.

(v) The Company acts as a Data Controller wishes to sub-contract certain Services, which imply the processing of personal data, to the Data Processor.

(vi) The Parties seek to implement a data processing agreement that complies with the GDPR requirements; the current legal framework in relation to data processing in Addis Ababa University, Ethiopia, and the GO FAIR Foundation Rules of Engagement.

The Parties are now desirous of laying down their rights and obligations in the terms set out hereinafter,

IT IS AGREED AS FOLLOWS:

1. **Definitions and interpretations;**

1.1. Unless otherwise defined herein, capitalized terms and expressions used in this Agreement shall have the following meaning:

1.1.1. "**Agreement**" means this Data Processing Agreement and all Schedules;

1.1.2. "**Company Personal Data**" means any Personal Data Processed by a Contracted Processor on behalf of the Company pursuant to or in connection with the Principal Agreement.

1.1.3. "**Contracted Processor**" means a Sub-Processor.

1.1.4. "**Data Protection Laws**" means the *GDPR, Data Protection and Privacy Act* and other equivalent or applicable data protection or privacy legislation in *Ethiopia* to which this agreement or the Principal Agreement applies to the extent applicable.

1.1.5. "**Services**" means the High Education services that the Company provides.

1.1.6. "**GDPR**" means the General Data Protection Regulation (EU GDPR) – see (EU) 2016/679

1.1.7. **"GFF"** means The Go FAIR Foundation Rules of engagement available at https://www.go-fair.org/resources/rules-of-engagement/

1.1.8. **"Sub-processer"** means any person appointed by or on behalf of Processor to process Personal Data on behalf of the Company in connection with the Agreement.

1.1.9. **Member Countries.** This refers to the countries to which the principal agreement or this agreement relates. In terms of applicable laws, the equivalent provisions of the laws of such member countries shall apply with necessary modifications and qualifications.

1.1.10. Applicable Laws or Data Protection Laws; means the legislation relating to date protection and privacy in Uganda and the equivalent provisions in the legislation of the Member Countries.

2. **Processing of the Company Personal Data**

2.1. Processor shall:

2.1.1. Comply with all applicable Data Protection Laws in countries to which this or the principal agreement relates in Processing of the Company Personal Data and in particular the legal requirements set out in Ethiopia or the equivalent provisions of the applicable laws in the other members states to which this agreement applies.

2.1.2. Not Process Company Personal Data other than on the relevant Company documented instructions.

2.1.3. Not process any personal data save with the prior consent of the data subject, or in accordance with the terms of contract to which the data subject is privy

2.1.4. Not collect, hold or process personal data in a manner that infringes on the privacy of data subject, save where the date is contained in a public record, the data subject has made it public or consented to its collection.

2.1.5. Ensure that the data collected is complete, accurate, upto-date, and not misleading having regard to the purpose of collection or processing.

2.1.6. Secure the integrity of the data in its possession or control by adopting appropriate, reasonable, technical and organizational measures to prevent

loss, damage, unauthorized destruction and unlawful access to unauthorized processing of the personal data.

2.2. The Company instructs Processor to process the Company Personal Data, on condition that the same shall be used in connection with the purposes of this agreement or the principal agreement.

2.3. The Data Processor shall hold the Company free from any third-Party claims in respect of any collected and or processed data the subject of this agreement

3. Processor Personnel

3.1. Processor shall take reasonable steps to ensure the reliability of any employee, agent or contractor of any Contracted Processor who may have access to the Company Personal Data, ensuring in each case that access is strictly limited to those individuals who need to know / access the relevant Company Personal Data, as strictly necessary for the purposes of the Principal Agreement, and to comply with Applicable Laws in the context of that individual's duties to the Contracted Processor, ensuring that all such individuals are subject to confidentiality undertakings or professional or statutory obligations of confidentiality.

4. Security

4.1. Taking into account the state of the art, the costs of implementation and the nature, scope, context and purposes of Processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons, Processor shall in relation to the Company Personal Data implement appropriate technical and organizational measures to ensure a level of security appropriate to that risk, including, as appropriate, the measures to safeguard the information in the manner prescribed by the Data Protection and Privacy Act 2019 of Uganda or the equivalent provisions in the applicable legislations in the other member countries.

4.2. In assessing the appropriate level of security, Processor shall take account in particular of the risks that are presented by Processing, in particular from a Personal Data Breach.

5. Sub-Processing

5.1. Processor shall not appoint (or disclose any Company Personal Data to) any Subprocessor unless required or authorized by the Company.

6. Data Subject Rights

6.1. Taking into account the nature of the Processing, Processor shall assist the Company by implementing appropriate technical and organizational measures,

insofar as this is possible, for the fulfilment of the Company obligations, as reasonably understood by Company, to respond to requests to exercise Data Subject rights under the Data Protection Laws or under the applicable laws in the Member states.

6.2. Processor shall;

6.2.1. promptly notify the Company if it receives a request from a Data Subject under any Data Protection Law of any of the member countries in respect of the Company Personal Data; and

6.2.2. ensure that it does not respond to that request except on the documented instructions of the Company or as required by Applicable Laws to which the Processor is subject, in which case Processor shall to the extent permitted by Applicable Laws inform the Company of that legal requirement before the Contracted Processor responds to the request.

7. Personal Data Breach

7.1. Processor shall notify the Company without undue delay upon Processor becoming aware of a Personal Data Breach affecting the Company Personal Data, providing the Company with sufficient information to allow the Company to meet any obligations to report or inform Data Subjects of the Personal Data Breach under the Data Protection Laws.

7.2. Processor shall co-operate with the Company and take reasonable commercial steps as are directed by the Company to assist in the investigation, mitigation and remediation of each such Personal Data Breach.

8. Data Protection Impact Assessment and Prior Consultation

8.1. Processor shall provide reasonable assistance to the Company with any data protection impact assessments, and prior consultations with Supervising Authorities or other competent data privacy authorities, which the Company reasonably considers to be required by Sections Section 5 of the Data Protection and Privacy Act 2019 or equivalent provisions of any other Data Protection Law, in each case solely in relation to Processing of the Company Personal Data by, and taking into account the nature of the Processing and information available to, the Contracted Processors.

9. Deletion or return of Company Personal Data

9.1. Subject to this clause, Processor shall promptly and in any event within 10 business days of the date of cessation of any Services involving the Processing of the Company Personal Data (the "**Cessation Date**"), delete and procure the deletion of all copies of those Company Personal Data.

9.2. Processor shall provide written certification to the Company that it has fully complied with this clause 9 within 10 business days of the Cessation Date.

10. Audit rights

10.1. Subject to this clause 10, Processor shall make available to the Company on request all information necessary to demonstrate compliance with this Agreement, and shall allow for and contribute to audits, including inspections, by the Company or an auditor mandated by the Company in relation to the Processing of the Company Personal Data by the Contracted Processors.

10.2. Information and audit rights of the Company only arise under clause 10.1 to the extent that the Agreement does not otherwise give them information and audit rights meeting the relevant requirements of applicable Data Protection Law.

11. Data Transfer

11.1. The Processor may not transfer or authorize the transfer of Data to countries outside the East African Community or the Party States to the Principal Agreement, or those countries envisaged under the Principal Agreement without the prior written consent of the Company. If personal data processed under this Agreement is transferred from a country within the East African Community or the Party States to the principal agreement or envisaged under the said agreement, the Parties shall ensure that the personal data are adequately protected. To achieve this, the Parties shall, unless agreed otherwise, rely on approved standard contractual clauses for the transfer of personal data, in accordance with the applicable Data Protection laws.

12. General Terms

12.1. **Confidentiality.** Each Party must keep this Agreement and information it receives about the other Party and its business in connection with this Agreement (“**Confidential Information**”) confidential and must not use or disclose that Confidential Information without the prior written consent of the other Party except to the extent that:

i) disclosure is required by law;

ii) the relevant information is already in the public domain.

12.2. **Notices.** All notices and communications given under this Agreement must be in writing and will be delivered personally, sent by post or sent by email to the address or email address set out in the heading of this Agreement at such other address as notified from time to time by the Parties changing address.

13. Governing Law and Jurisdiction

This Agreement is governed by the applicable laws as herein above defined, relating to Data protection and privacy for each of the Member Countries to which the agreement applies.

14. Dispute Resolution

In the event of any dispute arising out of interpretation or enforceability of any of the terms herein, such dispute shall be resolved through arbitration in accordance with the Arbitration and Conciliation Act Cap 4 of any other replacement legislation, in Uganda or the equivalent legislation relating to Arbitration in the Member Countries to which the agreement applies without prejudice to the right of any Party to seek interim reliefs from a court of competent jurisdiction in Uganda.

IN WITNESS WHEREOF, this Agreement is entered into with effect from the date first set out below.

SIGNED FOR AND ON BEHALF OF
VODAN Africa Foundation

Signature _____
Name: Francisca O Oladipo
Title: Executive Coordinator
Date Signed: 09 November 2020

Processor Company [this will be the partners in the member country]

Signature 

Name: Wondimu Ayele
Title Assistant Professor and Director, Health Information system capacity building and Mentorship program, School of Public Health Addis Ababa University.
Date Signed November, 2020

THE REPUBLIC OF UGANDA
IN THE MATTER OF THE CONTRACTS ACT 2010
AND
IN THE MATTER OF THE DATA PROTECTION AND PRIVACY 2019
AND
IN THE MATTER OF A DATA PROCESSING AGREEMENT

This Data Processing Agreement is executed this.....09.....Day of ...NOV...2020.

BETWEEN

VODAN-AFRICA (hereinafter referred to as **the "Company")** hosted in Uganda by **KAMPALA INTERNATIONAL UNIVERSITY** of P.O.BOX 20000, Kansanga, Kampala (hereinafter referred to as **"the Company ")**

which expression may where the context so admits include its successors and assigns) on the one part,

AND

IBBUL-NIGERIA.[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] (hereinafter referred to as ***"The Data Processor")*** which expression may where the context so admits include its successors and assigns) on the one part,

Both Parties together are hereinafter referred to as the "**Parties**")

WHEREAS:

(i) The Parties are cognsant of the fact that this ***Agreement*** forms part of the Contract for Services ***("Principal Agreement")*** executed between them and is specifically intended to provide for terms and conditions relating to data processing between them,

(ii) The Company represented by the Company in the context of this agreement will act as the Data Controller in respect of all the data processed under this agreement, while the Sub Contracted entity will be the Data Processor.

(iii) The Company wishes to Sub-Contract certain Services, which imply the processing of personal data, to the Data Processor, in accordance with the provisions of the applicable laws relating to Data Protection and Privacy in Uganda, Zimbabwe and Ethiopia, on the strict understanding that it shall be the duty of the Data Processor to ensure compliance with the said applicable.

(iv) The Parties seek to implement a data processing agreement that complies with the requirements of the current legal framework in ..NIGERIA.....[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] to data processing to

wit; the Data Protection and Protection Privacy Act for Uganda or other applicable laws or equivalent provisions in the relevant laws of NIGERIA..... [insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] and to ensure that the terms herein are in tandem with the said law, especially in terms of the protection of natural persons with regard to the processing of personal data.

(v) The Company acts as a Data Controller wishes to sub-contract certain Services, which imply the processing of personal data, to the Data Processor.

(vi) The Parties seek to implement a data processing agreement that complies with the **GDPR** requirements; the current legal framework in relation to data processing in NIGERIA..... [member country as appropriate], and the GO FAIR Foundation Rules of Engagement.

The Parties are now desirous of laying down their rights and obligations in the terms set out hereinafter,

IT IS AGREED AS FOLLOWS:

1. **Definitions and interpretations;**

1.1. Unless otherwise defined herein, capitalized terms and expressions used in this Agreement shall have the following meaning:

1.1.1. "**Agreement**" means this Data Processing Agreement and all Schedules;

1.1.2. "**Company Personal Data**" means any Personal Data Processed by a Contracted Processor on behalf of the Company pursuant to or in connection with the Principal Agreement.

1.1.3. "**Contracted Processor**" means a Sub-Processor.

1.1.4. "**Data Protection Laws**" means the ***GDPR, Data Protection and Privacy Act*** and other equivalent or applicable data protection or privacy legislation in NIGERIA..... ***[insert partner country as appropriate]*** to which this agreement or the Principal Agreement applies to the extent applicable.

1.1.5. "**Services**" means the _____ services that the Company provides.

1.1.6. **"GDPR"** means the General Data Protection Regulation (EU GDPR) – see (EU) 2016/679

1.1.7. **"GFF"** means The Go FAIR Foundation Rules of engagement available at https://www.go-fair.org/resources/rules-of-engagement/

1.1.8. "**Sub-processer**" means any person appointed by or on behalf of Processor to process Personal Data on behalf of the Company in connection with the Agreement.

1.1.9. **Member Countries.** This refers to the countries to which the principal agreement or this agreement relates. In terms of applicable laws, the equivalent provisions of the laws of such member countries shall apply with necessary modifications and qualifications.

1.1.10. Applicable Laws or Data Protection Laws; means the legislation relating to date protection and privacy in Uganda and the equivalent provisions in the legislation of the Member Countries.

2. **Processing of the Company Personal Data**

2.1. Processor shall:

2.1.1. Comply with all applicable Data Protection Laws in countries to which this or the principal agreement relates in Processing of the Company Personal Data and in particular the legal requirements set out in .NIGERIA.....[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] or the equivalent provisions of the applicable laws in the other members states to which this agreement applies.

2.1.2. Not Process Company Personal Data other than on the relevant Company documented instructions.

2.1.3. Not process any personal data save with the prior consent of the data subject, or in accordance with the terms of contract to which the data subject is privy

2.1.4. Not collect, hold or process personal data in a manner that infringes on the privacy of data subject, save where the date is contained in a public record, the data subject has made it public or consented to its collection.

2.1.5. Ensure that the data collected is complete, accurate, upto-date, and not misleading having regard to the purpose of collection or processing.

2.1.6. Secure the integrity of the data in its possession or control by adopting appropriate, reasonable, technical and organizational measures to prevent

loss, damage, unauthorized destruction and unlawful access to unauthorized processing of the personal data.

2.2. The Company instructs Processor to process the Company Personal Data, on condition that the same shall be used in connection with the purposes of this agreement or the principal agreement.

2.3. The Data Processor shall hold the Company free from any third-Party claims in respect of any collected and or processed data the subject of this agreement

3. **Processor Personnel**

3.1. Processor shall take reasonable steps to ensure the reliability of any employee, agent or contractor of any Contracted Processor who may have access to the Company Personal Data, ensuring in each case that access is strictly limited to those individuals who need to know / access the relevant Company Personal Data, as strictly necessary for the purposes of the Principal Agreement, and to comply with Applicable Laws in the context of that individual's duties to the Contracted Processor, ensuring that all such individuals are subject to confidentiality undertakings or professional or statutory obligations of confidentiality.

4. **Security**

4.1. Taking into account the state of the art, the costs of implementation and the nature, scope, context and purposes of Processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons, Processor shall in relation to the Company Personal Data implement appropriate technical and organizational measures to ensure a level of security appropriate to that risk, including, as appropriate, the measures to safeguard the information in the manner prescribed by the Data Protection and Privacy Act 2019 of Uganda or the equivalent provisions in the applicable legislations in the other member countries.

4.2. In assessing the appropriate level of security, Processor shall take account in particular of the risks that are presented by Processing, in particular from a Personal Data Breach.

5. **Sub-Processing**

5.1. Processor shall not appoint (or disclose any Company Personal Data to) any Subprocessor unless required or authorized by the Company.

6. **Data Subject Rights**

6.1. Taking into account the nature of the Processing, Processor shall assist the Company by implementing appropriate technical and organizational measures,

insofar as this is possible, for the fulfilment of the Company obligations, as reasonably understood by Company, to respond to requests to exercise Data Subject rights under the Data Protection Laws or under the applicable laws in the Member states.

6.2. Processor shall;

6.2.1. promptly notify the Company if it receives a request from a Data Subject under any Data Protection Law of any of the member countries in respect of the Company Personal Data; and

6.2.2. ensure that it does not respond to that request except on the documented instructions of the Company or as required by Applicable Laws to which the Processor is subject, in which case Processor shall to the extent permitted by Applicable Laws inform the Company of that legal requirement before the Contracted Processor responds to the request.

7. **Personal Data Breach**

7.1. Processor shall notify the Company without undue delay upon Processor becoming aware of a Personal Data Breach affecting the Company Personal Data, providing the Company with sufficient information to allow the Company to meet any obligations to report or inform Data Subjects of the Personal Data Breach under the Data Protection Laws.

7.2. Processor shall co-operate with the Company and take reasonable commercial steps as are directed by the Company to assist in the investigation, mitigation and remediation of each such Personal Data Breach.

8. **Data Protection Impact Assessment and Prior Consultation**

8.1. Processor shall provide reasonable assistance to the Company with any data protection impact assessments, and prior consultations with Supervising Authorities or other competent data privacy authorities, which the Company reasonably considers to be required by Sections Section 5 of the Data Protection and Privacy Act 2019 or equivalent provisions of any other Data Protection Law, in each case solely in relation to Processing of the Company Personal Data by, and taking into account the nature of the Processing and information available to, the Contracted Processors.

9. **Deletion or return of Company Personal Data**

9.1. Subject to this clause, Processor shall promptly and in any event within 10 business days of the date of cessation of any Services involving the Processing of the Company Personal Data (the "**Cessation Date**"), delete and procure the deletion of all copies of those Company Personal Data.

9.2. Processor shall provide written certification to the Company that it has fully complied with this clause 9 within 10 business days of the Cessation Date.

10. **Audit rights**

10.1. Subject to this clause 10, Processor shall make available to the Company on request all information necessary to demonstrate compliance with this Agreement, and shall allow for and contribute to audits, including inspections, by the Company or an auditor mandated by the Company in relation to the Processing of the Company Personal Data by the Contracted Processors.

10.2. Information and audit rights of the Company only arise under clause 10.1 to the extent that the Agreement does not otherwise give them information and audit rights meeting the relevant requirements of applicable Data Protection Law.

11. **Data Transfer**

11.1. The Processor may not transfer or authorize the transfer of Data to countries outside the East African Community or the Party States to the Principal Agreement, or those countries envisaged under the Principal Agreement without the prior written consent of the Company. If personal data processed under this Agreement is transferred from a country within the East African Community or the Party States to the principal agreement or envisaged under the said agreement, the Parties shall ensure that the personal data are adequately protected. To achieve this, the Parties shall, unless agreed otherwise, rely on approved standard contractual clauses for the transfer of personal data, in accordance with the applicable Data Protection laws.

12. **General Terms**

12.1. **Confidentiality.** Each Party must keep this Agreement and information it receives about the other Party and its business in connection with this Agreement (**"Confidential Information"**) confidential and must not use or disclose that Confidential Information without the prior written consent of the other Party except to the extent that:

i) disclosure is required by law;

ii)the relevant information is already in the public domain.

12.2. **Notices.** All notices and communications given under this Agreement must be in writing and will be delivered personally, sent by post or sent by email to the address or email address set out in the heading of this Agreement at such other address as notified from time to time by the Parties changing address.

13. **Governing Law and Jurisdiction**

This Agreement is governed by the applicable laws as herein above defined, relating to Data protection and privacy for each of the Member Countries to which the agreement applies.

14. **Dispute Resolution**

In the event of any dispute arising out of interpretation or enforceability of any of the terms herein, such dispute shall be resolved through arbitration in accordance with the Arbitration and Conciliation Act Cap 4 of any other replacement legislation, in Uganda or the equivalent legislation relating to Arbitration in the Member Countries to which the agreement applies without prejudice to the right of any Party to seek interim reliefs from a court of competent jurisdiction in Uganda.

IN WITNESS WHEREOF, this Agreement is entered into with effect from the date first set out below.

SIGNED FOR AND ON BEHALF OF
VODAN Africa Foundation

Signature _____
Name: Francisca O Oladipo
Title: Executive Coordinator
Date Signed: 09 November 2021

Processor Company [this will be the partners in the member country]
Signature _____
Name MUSA ANGO ABDULLAHI
Title REGISTRAR
Date Signed 9TH NOVEMBER, 2020

THE REPUBLIC OF UGANDA
IN THE MATTER OF THE CONTRACTS ACT 2010
AND
IN THE MATTER OF THE DATA PROTECTION AND PRIVACY 2019
AND
IN THE MATTER OF A DATA PROCESSING AGREEMENT

This Data Processing Agreement is executed this 4th Day of November 2020.

BETWEEN

VODAN-AFRICA (hereinafter referred to as the "Company") hosted in Uganda by KAMPALA INTERNATIONAL UNIVERSITY of P.O.BOX 20000, Kansanga, Kampala (hereinafter referred to as "the Company") which expression may where the context so admits include its successors and assigns) on the one part,

AND

Kenya (hereinafter referred to as *"The Data Processor")* which expression may where the context so admits include its successors and assigns) on the one part,

Both Parties together are hereinafter referred to as the "Parties")

WHEREAS:

(i) The Parties are cognizant of the fact that this *Agreement* forms part of the Contract for Services *("Principal Agreement")* executed between them and is specifically intended to provide for terms and conditions relating to data processing between them,

(ii) The Company represented by the Company in the context of this agreement will act as the Data Controller in respect of all the data processed under this agreement, while the Sub Contracted entity will be the Data Processor.

(iii) The Company wishes to Sub-Contract certain Services, which imply the processing of personal data, to the Data Processor, in accordance with the provisions of the applicable laws relating to Data Protection and Privacy in Uganda, Zimbabwe and Ethiopia, on the strict understanding that it shall be the duty of the Data Processor to ensure compliance with the said applicable.

(iv) The Parties seek to implement a data processing agreement that complies with the requirements of the current legal framework in Kenya to data processing to

with the Data Protection and Protection Privacy Act for Uganda or other applicable laws or equivalent provisions in the relevant laws of Kenya and to ensure that the terms herein are in tandem with the said law, especially in terms of the protection of natural persons with regard to the processing of personal data.

(v) The Company acts as a Data Controller wishes to sub-contract certain Services, which imply the processing of personal data, to the Data Processor.

(vi) The Parties seek to implement a data processing agreement that complies with the GDPR requirements; the current legal framework in relation to data processing in Kenya, and the GO FAIR Foundation Rules of Engagement.

The Parties are now desirous of laying down their rights and obligations in the terms set out hereinafter,

IT IS AGREED AS FOLLOWS:

1. Definitions and interpretations;

1.1. Unless otherwise defined herein, capitalized terms and expressions used in this Agreement shall have the following meaning:

1.1.1. "Agreement" means this Data Processing Agreement and all Schedules;

1.1.2. "Company Personal Data" means any Personal Data Processed by a Contracted Processor on behalf of the Company pursuant to or in connection with the Principal Agreement.

1.1.3. "Contracted Processor" means a Sub-Processor.

1.1.4. "Data Protection Laws" means the *GDPR, Data Protection and Privacy Act* and other equivalent or applicable data protection or privacy legislation in ***Kenya*** to which this agreement or the Principal Agreement applies to the extent applicable.

1.1.5. "Services" means the _____ services that the Company provides.

1.1.6. "GDPR" means the General Data Protection Regulation (EU GDPR) – see (EU) 2016/679

1.1.7. "GFF" means The Go FAIR Foundation Rules of engagement available at https://www.go-fair.org/resources/rules-of-engagement/

1.1.8. "Sub-processer" means any person appointed by or on behalf of Processor to process Personal Data on behalf of the Company in connection with the Agreement.

1.1.9. Member Countries. This refers to the countries to which the principal agreement or this agreement relates. In terms of applicable laws, the equivalent provisions of the laws of such member countries shall apply with necessary modifications and qualifications.

1.1.10. Applicable Laws or Data Protection Laws; means the legislation relating to date protection and privacy in Uganda and the equivalent provisions in the legislation of the Member Countries.

2. Processing of the Company Personal Data

2.1. Processor shall:

2.1.1. Comply with all applicable Data Protection Laws in countries to which this or the principal agreement relates in Processing of the Company Personal Data and in particular the legal requirements set out in Kenya or the equivalent provisions of the applicable laws in the other members states to which this agreement applies.

2.1.2. Not Process Company Personal Data other than on the relevant Company documented instructions.

2.1.3. Not process any personal data save with the prior consent of the data subject, or in accordance with the terms of contract to which the data subject is privy

2.1.4. Not collect, hold or process personal data in a manner that infringes on the privacy of data subject, save where the date is contained in a public record, the data subject has made it public or consented to its collection.

2.1.5. Ensure that the data collected is complete, accurate, upto-date, and not misleading having regard to the purpose of collection or processing.

2.1.6. Secure the integrity of the data in its possession or control by adopting appropriate, reasonable, technical and organizational measures to prevent

loss, damage, unauthorized destruction and unlawful access to unauthorized processing of the personal data.

2.2. The Company instructs Processor to process the Company Personal Data, on condition that the same shall be used in connection with the purposes of this agreement or the principal agreement.

2.3. The Data Processor shall hold the Company free from any third-Party claims in respect of any collected and or processed data the subject of this agreement

3. Processor Personnel

3.1. Processor shall take reasonable steps to ensure the reliability of any employee, agent or contractor of any Contracted Processor who may have access to the Company Personal Data, ensuring in each case that access is strictly limited to those individuals who need to know / access the relevant Company Personal Data, as strictly necessary for the purposes of the Principal Agreement, and to comply with Applicable Laws in the context of that individual's duties to the Contracted Processor, ensuring that all such individuals are subject to confidentiality undertakings or professional or statutory obligations of confidentiality.

4. Security

4.1. Taking into account the state of the art, the costs of implementation and the nature, scope, context and purposes of Processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons, Processor shall in relation to the Company Personal Data implement appropriate technical and organizational measures to ensure a level of security appropriate to that risk, including, as appropriate, the measures to safeguard the information in the manner prescribed by the Data Protection and Privacy Act 2019 of Uganda or the equivalent provisions in the applicable legislations in the other member countries.

4.2. In assessing the appropriate level of security, Processor shall take account in particular of the risks that are presented by Processing, in particular from a Personal Data Breach.

5. Sub-Processing

5.1. Processor shall not appoint (or disclose any Company Personal Data to) any Subprocessor unless required or authorized by the Company.

6. Data Subject Rights

6.1. Taking into account the nature of the Processing, Processor shall assist the Company by implementing appropriate technical and organizational measures,

insofar as this is possible, for the fulfilment of the Company obligations, as reasonably understood by Company, to respond to requests to exercise Data Subject rights under the Data Protection Laws or under the applicable laws in the Member states.

6.2. Processor shall;

6.2.1. promptly notify the Company if it receives a request from a Data Subject under any Data Protection Law of any of the member countries in respect of the Company Personal Data; and

6.2.2. ensure that it does not respond to that request except on the documented instructions of the Company or as required by Applicable Laws to which the Processor is subject, in which case Processor shall to the extent permitted by Applicable Laws inform the Company of that legal requirement before the Contracted Processor responds to the request.

7. Personal Data Breach

7.1. Processor shall notify the Company without undue delay upon Processor becoming aware of a Personal Data Breach affecting the Company Personal Data, providing the Company with sufficient information to allow the Company to meet any obligations to report or inform Data Subjects of the Personal Data Breach under the Data Protection Laws.

7.2. Processor shall co-operate with the Company and take reasonable commercial steps as are directed by the Company to assist in the investigation, mitigation and remediation of each such Personal Data Breach.

8. Data Protection Impact Assessment and Prior Consultation

8.1. Processor shall provide reasonable assistance to the Company with any data protection impact assessments, and prior consultations with Supervising Authorities or other competent data privacy authorities, which the Company reasonably considers to be required by Sections Section 5 of the Data Protection and Privacy Act 2019 or equivalent provisions of any other Data Protection Law, in each case solely in relation to Processing of the Company Personal Data by, and taking into account the nature of the Processing and information available to, the Contracted Processors.

9. Deletion or return of Company Personal Data

9.1. Subject to this clause, Processor shall promptly and in any event within 10 business days of the date of cessation of any Services involving the Processing of the Company Personal Data (the "Cessation Date"), delete and procure the deletion of all copies of those Company Personal Data.

9.2. Processor shall provide written certification to the Company that it has fully complied with this clause 9 within 10 business days of the Cessation Date.

10. Audit rights

10.1. Subject to this clause 10, Processor shall make available to the Company on request all information necessary to demonstrate compliance with this Agreement, and shall allow for and contribute to audits, including inspections, by the Company or an auditor mandated by the Company in relation to the Processing of the Company Personal Data by the Contracted Processors.

10.2. Information and audit rights of the Company only arise under clause 10.1 to the extent that the Agreement does not otherwise give them information and audit rights meeting the relevant requirements of applicable Data Protection Law.

11. Data Transfer

11.1. The Processor may not transfer or authorize the transfer of Data to countries outside the East African Community or the Party States to the Principal Agreement, or those countries envisaged under the Principal Agreement without the prior written consent of the Company. If personal data processed under this Agreement is transferred from a country within the East African Community or the Party States to the principal agreement or envisaged under the said agreement, the Parties shall ensure that the personal data are adequately protected. To achieve this, the Parties shall, unless agreed otherwise, rely on approved standard contractual clauses for the transfer of personal data, in accordance with the applicable Data Protection laws.

12. General Terms

12.1. Confidentiality. Each Party must keep this Agreement and information it receives about the other Party and its business in connection with this Agreement ("Confidential Information") confidential and must not use or disclose that Confidential Information without the prior written consent of the other Party except to the extent that:

i) disclosure is required by law;

ii)the relevant information is already in the public domain.

12.2. Notices. All notices and communications given under this Agreement must be in writing and will be delivered personally, sent by post or sent by email to the address or email address set out in the heading of this Agreement at such other address as notified from time to time by the Parties changing address.

13. Governing Law and Jurisdiction

This Agreement is governed by the applicable laws as herein above defined, relating to Data protection and privacy for each of the Member Countries to which the agreement applies.

14. Dispute Resolution

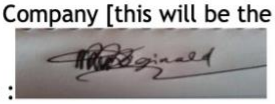
In the event of any dispute arising out of interpretation or enforceability of any of the terms herein, such dispute shall be resolved through arbitration in accordance with the Arbitration and Conciliation Act Cap 4 of any other replacement legislation, in Uganda or the equivalent legislation relating to Arbitration in the Member Countries to which the agreement applies without prejudice to the right of any Party to seek interim reliefs from a court of competent jurisdiction in Uganda.

IN WITNESS WHEREOF, this Agreement is entered into with effect from the date first set out below.

SIGNED FOR AND ON BEHALF OF
VODAN Africa Foundation

Signature Oladipo
Name: Francisca O Oladipo
Title: Executive Coordinator
Date Signed: November 4 2020

Processor Company [this will be the partners in the member country]

Signature : 
Name: Dr. Reginald Nalugala
Title : Kenya Country Lead
Date Signed : 4th November 2020

THE REPUBLIC OF UGANDA
IN THE MATTER OF THE CONTRACTS ACT 2010
AND
IN THE MATTER OF THE DATA PROTECTION AND PRIVACY 2019
AND
IN THE MATTER OF A DATA PROCESSING AGREEMENT

This Data Processing Agreement is executed this.....Day of .....2020.

BETWEEN

VODAN-AFRICA (hereinafter referred to as **the "Company")** hosted in Uganda by **KAMPALA INTERNATIONAL UNIVERSITY** of P.O.BOX 20000, Kansanga, Kampala (hereinafter referred to as **"the Company ")**

which expression may where the context so admits include its successors and assigns) on the one part,

AND

Ethiopia.....[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] (hereinafter referred to as ***"The Data Processor")*** which expression may where the context so admits include its successors and assigns) on the one part,

Both Parties together are hereinafter referred to as the "**Parties**")

WHEREAS:

(i) The Parties are cognsant of the fact that this ***Agreement*** forms part of the Contract for Services ***("Principal Agreement")*** executed between them and is specifically intended to provide for terms and conditions relating to data processing between them,

(ii) The Company represented by the Company in the context of this agreement will act as the Data Controller in respect of all the data processed under this agreement, while the Sub Contracted entity will be the Data Processor.

(iii) The Company wishes to Sub-Contract certain Services, which imply the processing of personal data, to the Data Processor, in accordance with the provisions of the applicable laws relating to Data Protection and Privacy in Uganda, Zimbabwe and Ethiopia, on the strict understanding that it shall be the duty of the Data Processor to ensure compliance with the said applicable.

(iv) The Parties seek to implement a data processing agreement that complies with the requirements of the current legal framework in .....Ethiopia.....[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] to data processing to

wit; the Data Protection and Protection Privacy Act for Uganda or other applicable laws or equivalent provisions in the relevant laws of ...Ethiopia... [insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] and to ensure that the terms herein are in tandem with the said law, especially in terms of the protection of natural persons with regard to the processing of personal data.

(v) The Company acts as a Data Controller wishes to sub-contract certain Services, which imply the processing of personal data, to the Data Processor.

(vi) The Parties seek to implement a data processing agreement that complies with the **GDPR** requirements; the current legal framework in relation to data processing in ....Ethiopia..... [member country as appropriate], and the GO FAIR Foundation Rules of Engagement.

The Parties are now desirous of laying down their rights and obligations in the terms set out hereinafter,

IT IS AGREED AS FOLLOWS:

1. **Definitions and interpretations;**

1.1. Unless otherwise defined herein, capitalized terms and expressions used in this Agreement shall have the following meaning:

1.1.1. "**Agreement**" means this Data Processing Agreement and all Schedules;

1.1.2. "**Company Personal Data**" means any Personal Data Processed by a Contracted Processor on behalf of the Company pursuant to or in connection with the Principal Agreement.

1.1.3. "**Contracted Processor**" means a Sub-Processor.

1.1.4. "**Data Protection Laws**" means the ***GDPR, Data Protection and Privacy Act*** and other equivalent or applicable data protection or privacy legislation in ...Ethiopia... ***[insert partner country as appropriate]*** to which this agreement or the Principal Agreement applies to the extent applicable.

1.1.5. "**Services**" means the _____ services that the Company provides.

1.1.6. "**GDPR**" means the General Data Protection Regulation (EU GDPR) – see (EU) 2016/679

1.1.7. **"GFF"** means The Go FAIR Foundation Rules of engagement available at https://www.go-fair.org/resources/rules-of-engagement/

1.1.8. "**Sub-processer**" means any person appointed by or on behalf of Processor to process Personal Data on behalf of the Company in connection with the Agreement.

1.1.9. **Member Countries.** This refers to the countries to which the principal agreement or this agreement relates. In terms of applicable laws, the equivalent provisions of the laws of such member countries shall apply with necessary modifications and qualifications.

1.1.10. Applicable Laws or Data Protection Laws; means the legislation relating to date protection and privacy in Uganda and the equivalent provisions in the legislation of the Member Countries.

2. **Processing of the Company Personal Data**

2.1. Processor shall:

2.1.1. Comply with all applicable Data Protection Laws in countries to which this or the principal agreement relates in Processing of the Company Personal Data and in particular the legal requirements set out in .....Ethiopia.....[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] or the equivalent provisions of the applicable laws in the other members states to which this agreement applies.

2.1.2. Not Process Company Personal Data other than on the relevant Company documented instructions.

2.1.3. Not process any personal data save with the prior consent of the data subject, or in accordance with the terms of contract to which the data subject is privy

2.1.4. Not collect, hold or process personal data in a manner that infringes on the privacy of data subject, save where the date is contained in a public record, the data subject has made it public or consented to its collection.

2.1.5. Ensure that the data collected is complete, accurate, upto-date, and not misleading having regard to the purpose of collection or processing.

2.1.6. Secure the integrity of the data in its possession or control by adopting appropriate, reasonable, technical and organizational measures to prevent

loss, damage, unauthorized destruction and unlawful access to unauthorized processing of the personal data.

2.2. The Company instructs Processor to process the Company Personal Data, on condition that the same shall be used in connection with the purposes of this agreement or the principal agreement.

2.3. The Data Processor shall hold the Company free from any third-Party claims in respect of any collected and or processed data the subject of this agreement

3. **Processor Personnel**

3.1. Processor shall take reasonable steps to ensure the reliability of any employee, agent or contractor of any Contracted Processor who may have access to the Company Personal Data, ensuring in each case that access is strictly limited to those individuals who need to know / access the relevant Company Personal Data, as strictly necessary for the purposes of the Principal Agreement, and to comply with Applicable Laws in the context of that individual's duties to the Contracted Processor, ensuring that all such individuals are subject to confidentiality undertakings or professional or statutory obligations of confidentiality.

4. **Security**

4.1. Taking into account the state of the art, the costs of implementation and the nature, scope, context and purposes of Processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons, Processor shall in relation to the Company Personal Data implement appropriate technical and organizational measures to ensure a level of security appropriate to that risk, including, as appropriate, the measures to safeguard the information in the manner prescribed by the Data Protection and Privacy Act 2019 of Uganda or the equivalent provisions in the applicable legislations in the other member countries.

4.2. In assessing the appropriate level of security, Processor shall take account in particular of the risks that are presented by Processing, in particular from a Personal Data Breach.

5. **Sub-Processing**

5.1. Processor shall not appoint (or disclose any Company Personal Data to) any Subprocessor unless required or authorized by the Company.

6. **Data Subject Rights**

6.1. Taking into account the nature of the Processing, Processor shall assist the Company by implementing appropriate technical and organizational measures,

insofar as this is possible, for the fulfilment of the Company obligations, as reasonably understood by Company, to respond to requests to exercise Data Subject rights under the Data Protection Laws or under the applicable laws in the Member states.

6.2. Processor shall;

6.2.1. promptly notify the Company if it receives a request from a Data Subject under any Data Protection Law of any of the member countries in respect of the Company Personal Data; and

6.2.2. ensure that it does not respond to that request except on the documented instructions of the Company or as required by Applicable Laws to which the Processor is subject, in which case Processor shall to the extent permitted by Applicable Laws inform the Company of that legal requirement before the Contracted Processor responds to the request.

7. **Personal Data Breach**

7.1. Processor shall notify the Company without undue delay upon Processor becoming aware of a Personal Data Breach affecting the Company Personal Data, providing the Company with sufficient information to allow the Company to meet any obligations to report or inform Data Subjects of the Personal Data Breach under the Data Protection Laws.

7.2. Processor shall co-operate with the Company and take reasonable commercial steps as are directed by the Company to assist in the investigation, mitigation and remediation of each such Personal Data Breach.

8. **Data Protection Impact Assessment and Prior Consultation**

8.1. Processor shall provide reasonable assistance to the Company with any data protection impact assessments, and prior consultations with Supervising Authorities or other competent data privacy authorities, which the Company reasonably considers to be required by Sections Section 5 of the Data Protection and Privacy Act 2019 or equivalent provisions of any other Data Protection Law, in each case solely in relation to Processing of the Company Personal Data by, and taking into account the nature of the Processing and information available to, the Contracted Processors.

9. **Deletion or return of Company Personal Data**

9.1. Subject to this clause, Processor shall promptly and in any event within 10 business days of the date of cessation of any Services involving the Processing of the Company Personal Data (the "**Cessation Date**"), delete and procure the deletion of all copies of those Company Personal Data.

9.2. Processor shall provide written certification to the Company that it has fully complied with this clause 9 within 10 business days of the Cessation Date.

10. **Audit rights**

10.1. Subject to this clause 10, Processor shall make available to the Company on request all information necessary to demonstrate compliance with this Agreement, and shall allow for and contribute to audits, including inspections, by the Company or an auditor mandated by the Company in relation to the Processing of the Company Personal Data by the Contracted Processors.

10.2. Information and audit rights of the Company only arise under clause 10.1 to the extent that the Agreement does not otherwise give them information and audit rights meeting the relevant requirements of applicable Data Protection Law.

11. **Data Transfer**

11.1. The Processor may not transfer or authorize the transfer of Data to countries outside the East African Community or the Party States to the Principal Agreement, or those countries envisaged under the Principal Agreement without the prior written consent of the Company. If personal data processed under this Agreement is transferred from a country within the East African Community or the Party States to the principal agreement or envisaged under the said agreement, the Parties shall ensure that the personal data are adequately protected. To achieve this, the Parties shall, unless agreed otherwise, rely on approved standard contractual clauses for the transfer of personal data, in accordance with the applicable Data Protection laws.

12. **General Terms**

12.1. **Confidentiality.** Each Party must keep this Agreement and information it receives about the other Party and its business in connection with this Agreement (**"Confidential Information"**) confidential and must not use or disclose that Confidential Information without the prior written consent of the other Party except to the extent that:

i) disclosure is required by law;

ii)the relevant information is already in the public domain.

12.2. **Notices.** All notices and communications given under this Agreement must be in writing and will be delivered personally, sent by post or sent by email to the address or email address set out in the heading of this Agreement at such other address as notified from time to time by the Parties changing address.

13. **Governing Law and Jurisdiction**

This Agreement is governed by the applicable laws as herein above defined, relating to Data protection and privacy for each of the Member Countries to which the agreement applies.

14. **Dispute Resolution**

In the event of any dispute arising out of interpretation or enforceability of any of the terms herein, such dispute shall be resolved through arbitration in accordance with the Arbitration and Conciliation Act Cap 4 of any other replacement legislation, in Uganda or the equivalent legislation relating to Arbitration in the Member Countries to which the agreement applies without prejudice to the right of any Party to seek interim reliefs from a court of competent jurisdiction in Uganda.

IN WITNESS WHEREOF, this Agreement is entered into with effect from the date first set out below.

SIGNED FOR AND ON BEHALF OF
VODAN Africa Foundation

Signature _____
Name: Francisca O Oladipo
Title: Executive Coordinator
Date Signed: 03 February 2021

Processor Company [this will be the partners in the member country]
Signature _____
Name _____
Title _____
Date Signed 03/02/2021

THE REPUBLIC OF UGANDA
IN THE MATTER OF THE CONTRACTS ACT 2010
AND
IN THE MATTER OF THE DATA PROTECTION AND PRIVACY 2019
AND
IN THE MATTER OF A DATA PROCESSING AGREEMENT

This Data Processing Agreement is executed this……Day of ……2020.

BETWEEN

VODAN-AFRICA (hereinafter referred to as **the "Company")** hosted in Uganda by **KAMPALA INTERNATIONAL UNIVERSITY** of P.O.BOX 20000, Kansanga, Kampala (hereinafter referred to as **"the Company ")**

which expression may where the context so admits include its successors and assigns) on the one part,

AND

……Nigeria……[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] (hereinafter referred to as ***"The Data Processor")*** which expression may where the context so admits include its successors and assigns) on the one part,

Both Parties together are hereinafter referred to as the "**Parties**")

WHEREAS:

(i) The Parties are cognsant of the fact that this ***Agreement*** forms part of the Contract for Services ***("Principal Agreement")*** executed between them and is specifically intended to provide for terms and conditions relating to data processing between them,

(ii) The Company represented by the Company in the context of this agreement will act as the Data Controller in respect of all the data processed under this agreement, while the Sub Contracted entity will be the Data Processor.

(iii) The Company wishes to Sub-Contract certain Services, which imply the processing of personal data, to the Data Processor, in accordance with the provisions of the applicable laws relating to Data Protection and Privacy in Uganda, Zimbabwe and Ethiopia, on the strict understanding that it shall be the duty of the Data Processor to ensure compliance with the said applicable.

(iv) The Parties seek to implement a data processing agreement that complies with the requirements of the current legal framework in ……Nigeria……[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] to data processing to

wit; the Data Protection and Protection Privacy Act for Uganda or other applicable laws or equivalent provisions in the relevant laws of ……Nigeria…….. [insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] and to ensure that the terms herein are in tandem with the said law, especially in terms of the protection of natural persons with regard to the processing of personal data.

(v) The Company acts as a Data Controller wishes to sub-contract certain Services, which imply the processing of personal data, to the Data Processor.

(vi) The Parties seek to implement a data processing agreement that complies with the **GDPR** requirements; the current legal framework in relation to data processing in ……Nigeria…….. [member country as appropriate], and the GO FAIR Foundation Rules of Engagement.

The Parties are now desirous of laying down their rights and obligations in the terms set out hereinafter,

IT IS AGREED AS FOLLOWS:

1. **Definitions and interpretations;**

1.1. Unless otherwise defined herein, capitalized terms and expressions used in this Agreement shall have the following meaning:

1.1.1. "**Agreement**" means this Data Processing Agreement and all Schedules;

1.1.2. "**Company Personal Data**" means any Personal Data Processed by a Contracted Processor on behalf of the Company pursuant to or in connection with the Principal Agreement.

1.1.3. "**Contracted Processor**" means a Sub-Processor.

1.1.4. "**Data Protection Laws**" means the *GDPR, Data Protection and Privacy Act* and other equivalent or applicable data protection or privacy legislation in *……Nigeria…… [insert partner country as appropriate]* to which this agreement or the Principal Agreement applies to the extent applicable.

1.1.5. "**Services**" means the _____ services that the Company provides.

1.1.6. **"GDPR"** means the General Data Protection Regulation (EU GDPR) – see (EU) 2016/679

1.1.7. **"GFF"** means The Go FAIR Foundation Rules of engagement available at https://www.go-fair.org/resources/rules-of-engagement/

1.1.8. "**Sub-processer**" means any person appointed by or on behalf of Processor to process Personal Data on behalf of the Company in connection with the Agreement.

1.1.9. **Member Countries.** This refers to the countries to which the principal agreement or this agreement relates. In terms of applicable laws, the equivalent provisions of the laws of such member countries shall apply with necessary modifications and qualifications.

1.1.10. Applicable Laws or Data Protection Laws; means the legislation relating to date protection and privacy in Uganda and the equivalent provisions in the legislation of the Member Countries.

2. **Processing of the Company Personal Data**

2.1. Processor shall:

2.1.1. Comply with all applicable Data Protection Laws in countries to which this or the principal agreement relates in Processing of the Company Personal Data and in particular the legal requirements set out in .....Nigeria.....[insert as appropriate Zimbabwe, Kenya, Nigeria, Tunisia and Ethiopia] or the equivalent provisions of the applicable laws in the other members states to which this agreement applies.

2.1.2. Not Process Company Personal Data other than on the relevant Company documented instructions.

2.1.3. Not process any personal data save with the prior consent of the data subject, or in accordance with the terms of contract to which the data subject is privy

2.1.4. Not collect, hold or process personal data in a manner that infringes on the privacy of data subject, save where the date is contained in a public record, the data subject has made it public or consented to its collection.

2.1.5. Ensure that the data collected is complete, accurate, upto-date, and not misleading having regard to the purpose of collection or processing.

2.1.6. Secure the integrity of the data in its possession or control by adopting appropriate, reasonable, technical and organizational measures to prevent

loss, damage, unauthorized destruction and unlawful access to unauthorized processing of the personal data.

2.2. The Company instructs Processor to process the Company Personal Data, on condition that the same shall be used in connection with the purposes of this agreement or the principal agreement.

2.3. The Data Processor shall hold the Company free from any third-Party claims in respect of any collected and or processed data the subject of this agreement

3. Processor Personnel

3.1. Processor shall take reasonable steps to ensure the reliability of any employee, agent or contractor of any Contracted Processor who may have access to the Company Personal Data, ensuring in each case that access is strictly limited to those individuals who need to know / access the relevant Company Personal Data, as strictly necessary for the purposes of the Principal Agreement, and to comply with Applicable Laws in the context of that individual's duties to the Contracted Processor, ensuring that all such individuals are subject to confidentiality undertakings or professional or statutory obligations of confidentiality.

4. Security

4.1. Taking into account the state of the art, the costs of implementation and the nature, scope, context and purposes of Processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons, Processor shall in relation to the Company Personal Data implement appropriate technical and organizational measures to ensure a level of security appropriate to that risk, including, as appropriate, the measures to safeguard the information in the manner prescribed by the Data Protection and Privacy Act 2019 of Uganda or the equivalent provisions in the applicable legislations in the other member countries.

4.2. In assessing the appropriate level of security, Processor shall take account in particular of the risks that are presented by Processing, in particular from a Personal Data Breach.

5. Sub-Processing

5.1. Processor shall not appoint (or disclose any Company Personal Data to) any Subprocessor unless required or authorized by the Company.

6. Data Subject Rights

6.1. Taking into account the nature of the Processing, Processor shall assist the Company by implementing appropriate technical and organizational measures,

insofar as this is possible, for the fulfilment of the Company obligations, as reasonably understood by Company, to respond to requests to exercise Data Subject rights under the Data Protection Laws or under the applicable laws in the Member states.

6.2. Processor shall;

6.2.1. promptly notify the Company if it receives a request from a Data Subject under any Data Protection Law of any of the member countries in respect of the Company Personal Data; and

6.2.2. ensure that it does not respond to that request except on the documented instructions of the Company or as required by Applicable Laws to which the Processor is subject, in which case Processor shall to the extent permitted by Applicable Laws inform the Company of that legal requirement before the Contracted Processor responds to the request.

7. **Personal Data Breach**

7.1. Processor shall notify the Company without undue delay upon Processor becoming aware of a Personal Data Breach affecting the Company Personal Data, providing the Company with sufficient information to allow the Company to meet any obligations to report or inform Data Subjects of the Personal Data Breach under the Data Protection Laws.

7.2. Processor shall co-operate with the Company and take reasonable commercial steps as are directed by the Company to assist in the investigation, mitigation and remediation of each such Personal Data Breach.

8. **Data Protection Impact Assessment and Prior Consultation**

8.1. Processor shall provide reasonable assistance to the Company with any data protection impact assessments, and prior consultations with Supervising Authorities or other competent data privacy authorities, which the Company reasonably considers to be required by Sections Section 5 of the Data Protection and Privacy Act 2019 or equivalent provisions of any other Data Protection Law, in each case solely in relation to Processing of the Company Personal Data by, and taking into account the nature of the Processing and information available to, the Contracted Processors.

9. **Deletion or return of Company Personal Data**

9.1. Subject to this clause, Processor shall promptly and in any event within 10 business days of the date of cessation of any Services involving the Processing of the Company Personal Data (the "**Cessation Date**"), delete and procure the deletion of all copies of those Company Personal Data.

9.2. Processor shall provide written certification to the Company that it has fully complied with this clause 9 within 10 business days of the Cessation Date.

10. Audit rights

10.1. Subject to this clause 10, Processor shall make available to the Company on request all information necessary to demonstrate compliance with this Agreement, and shall allow for and contribute to audits, including inspections, by the Company or an auditor mandated by the Company in relation to the Processing of the Company Personal Data by the Contracted Processors.

10.2. Information and audit rights of the Company only arise under clause 10.1 to the extent that the Agreement does not otherwise give them information and audit rights meeting the relevant requirements of applicable Data Protection Law.

11. Data Transfer

11.1. The Processor may not transfer or authorize the transfer of Data to countries outside the East African Community or the Party States to the Principal Agreement, or those countries envisaged under the Principal Agreement without the prior written consent of the Company. If personal data processed under this Agreement is transferred from a country within the East African Community or the Party States to the principal agreement or envisaged under the said agreement, the Parties shall ensure that the personal data are adequately protected. To achieve this, the Parties shall, unless agreed otherwise, rely on approved standard contractual clauses for the transfer of personal data, in accordance with the applicable Data Protection laws.

12. General Terms

12.1. **Confidentiality.** Each Party must keep this Agreement and information it receives about the other Party and its business in connection with this Agreement ("**Confidential Information**") confidential and must not use or disclose that Confidential Information without the prior written consent of the other Party except to the extent that:

i) disclosure is required by law;

ii)the relevant information is already in the public domain.

12.2. **Notices.** All notices and communications given under this Agreement must be in writing and will be delivered personally, sent by post or sent by email to the address or email address set out in the heading of this Agreement at such other address as notified from time to time by the Parties changing address.

13. **Governing Law and Jurisdiction**

This Agreement is governed by the applicable laws as herein above defined, relating to Data protection and privacy for each of the Member Countries to which the agreement applies.

14. **Dispute Resolution**

In the event of any dispute arising out of interpretation or enforceability of any of the terms herein, such dispute shall be resolved through arbitration in accordance with the Arbitration and Conciliation Act Cap 4 of any other replacement legislation, in Uganda or the equivalent legislation relating to Arbitration in the Member Countries to which the agreement applies without prejudice to the right of any Party to seek interim reliefs from a court of competent jurisdiction in Uganda.

IN WITNESS WHEREOF, this Agreement is entered into with effect from the date first set out below.

SIGNED FOR AND ON BEHALF OF
VODAN Africa Foundation

Signature _____
Name: Francisca O Oladipo
Title: Executive Coordinator
Date Signed: 10th November 2020

Processor Company [this will be the partners in the member country]
Signature _____
Name Sakinat Folorunso
Title Dr.
Date Signed 8th November 2020

THE REPUBLIC OF UGANDA
IN THE MATTER OF THE CONTRACTS ACT 2010
AND
IN THE MATTER OF THE DATA PROTECTION AND PRIVACY 2019
AND
IN THE MATTER OF A DATA PROCESSING AGREEMENT

This Data Processing Agreement is executed this. 30.....day of October.2020.

BETWEEN

VODAN-AFRICA (hereinafter referred to as the "Company") hosted in Uganda by KAMPALA INTERNATIONAL UNIVERSITY of P.O.BOX 20000, Kansanga, Kampala (hereinafter referred to as "the Company")

which expression may where the context so admits include its successors and assigns) on the one part,

AND

Zimbabwe, (hereinafter referred to as "The Data Processor") which expression may where the context so admits include its successors and assigns) on the one part,

Both Parties together are hereinafter referred to as the "Parties")

WHEREAS:

(i) The Parties are cognisant of the fact that this Agreement forms part of the Contract for Services ("Principal Agreement") executed between them and is specifically intended to provide for terms and conditions relating to data processing between them,

(ii) The Company represented by the Company in the context of this agreement will act as the Data Controller in respect of all the data processed under this agreement, while the Sub Contracted entity will be the Data Processor.

(iii) The Company wishes to Sub-Contract certain Services, which imply the processing of personal data, to the Data Processor, in accordance with the provisions of the applicable laws relating to Data Protection and Privacy in Uganda, Zimbabwe and Ethiopia, on the strict understanding that it shall be the duty of the Data Processor to ensure compliance with the said applicable.

(iv) The Parties seek to implement a data processing agreement that complies with the requirements of the current legal framework in Zimbabwe to data processing to wit; the Data Protection and Protection Privacy Act for Uganda or other applicable laws or equivalent provisions in the relevant laws of Zimbabwe and to ensure that the terms herein are in tandem with the said law, especially in terms of the protection of natural persons with regard to the processing of personal data.

(v) The Company acts as a Data Controller wishes to sub-contract certain Services, which imply the processing of personal data, to the Data Processor.

(vi) The Parties seek to implement a data processing agreement that complies with the GDPR requirements; the current legal framework in relation to data processing in Zimbabwe and the GO FAIR Foundation Rules of Engagement.

The Parties are now desirous of laying down their rights and obligations in the terms set out hereinafter,

IT IS AGREED AS FOLLOWS:

1. Definitions and interpretations;

1.1. Unless otherwise defined herein, capitalized terms and expressions used in this Agreement shall have the following meaning:

1.1.1. "Agreement" means this Data Processing Agreement and all Schedules;

1.1.2. "Company Personal Data" means any Personal Data Processed by a Contracted Processor on behalf of the Company pursuant to or in connection with the Principal Agreement.

1.1.3. "Contracted Processor" means a Sub-Processor.

1.1.4. "Data Protection Laws" means the GDPR, Data Protection and Privacy Act and other equivalent or applicable data protection or privacy legislation in Zimbabwe to which this agreement or the Principal Agreement applies to the extent applicable.

1.1.5. "Services" means the Data FAIRification services that the Company provides.

1.1.6. "GDPR" means the General Data Protection Regulation (EU GDPR) – see (EU) 2016/679

1.1.7. "GFF" means The Go FAIR Foundation Rules of engagement available at https://www.go-fair.org/resources/rules-of-engagement/

1.1.8. "Sub-processer" means any person appointed by or on behalf of Processor to process Personal Data on behalf of the Company in connection with the Agreement.

1.1.9. Member Countries. This refers to the countries to which the principal agreement or this agreement relates. In terms of applicable laws, the equivalent provisions of the laws of such member countries shall apply with necessary modifications and qualifications.

1.1.10. Applicable Laws or Data Protection Laws; means the legislation relating to date protection and privacy in Uganda and the equivalent provisions in the legislation of the Member Countries.

2. Processing of the Company Personal Data

2.1. Processor shall:

2.1.1. Comply with all applicable Data Protection Laws in countries to which this or the principal agreement relates in Processing of the Company Personal Data and in particular the legal requirements set out in Zimbabwe or the equivalent provisions of the applicable laws in the other members states to which this agreement applies.

2.1.2. Not Process Company Personal Data other than on the relevant Company documented instructions.

2.1.3. Not process any personal data save with the prior consent of the data subject, or in accordance with the terms of contract to which the data subject is privy

2.1.4. Not collect, hold or process personal data in a manner that infringes on the privacy of data subject, save where the date is contained in a public record, the data subject has made it public or consented to its collection.

2.1.5. Ensure that the data collected is complete, accurate, up-to-date, and not misleading having regard to the purpose of collection or processing.

2.1.6. Secure the integrity of the data in its possession or control by adopting appropriate, reasonable, technical and organizational measures to prevent loss, damage, unauthorized destruction and unlawful access to unauthorized processing of the personal data.

2.2. The Company instructs Processor to process the Company Personal Data, on condition that the same shall be used in connection with the purposes of this agreement or the principal agreement.

2.3. The Data Processor shall hold the Company free from any third-Party claims in respect of any collected and or processed data the subject of this agreement

3. Processor Personnel

3.1. Processor shall take reasonable steps to ensure the reliability of any employee, agent or contractor of any Contracted Processor who may have access to the Company Personal Data, ensuring in each case that access is strictly limited to those individuals who need to know / access the relevant Company Personal Data, as strictly necessary for the purposes of the Principal Agreement, and to comply with Applicable Laws in the context of that individual's duties to the Contracted Processor, ensuring that all such individuals are

subject to confidentiality undertakings or professional or statutory obligations of confidentiality.

4. Security

4.1. Taking into account the state of the art, the costs of implementation and the nature, scope, context and purposes of Processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons, Processor shall in relation to the Company Personal Data implement appropriate technical and organizational measures to ensure a level of security appropriate to that risk, including, as appropriate, the measures to safeguard the information in the manner prescribed by the Data Protection and Privacy Act 2019 of Uganda or the equivalent provisions in the applicable legislations in the other member countries.

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6.2. Processor shall;

6.2.1. promptly notify the Company if it receives a request from a Data Subject under any Data Protection Law of any of the member countries in respect of the Company Personal Data; and

6.2.2. ensure that it does not respond to that request except on the documented instructions of the Company or as required by Applicable Laws to which the Processor is subject, in which case Processor shall to the extent permitted by Applicable Laws inform the Company of that legal requirement before the Contracted Processor responds to the request.

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7.1. Processor shall notify the Company without undue delay upon Processor becoming aware of a Personal Data Breach affecting the Company Personal Data, providing the Company with sufficient information to allow the Company to meet any obligations to report or inform Data Subjects of the Personal Data Breach under the Data Protection Laws.

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8.1. Processor shall provide reasonable assistance to the Company with any data protection impact assessments, and prior consultations with Supervising Authorities or other competent data privacy authorities, which the Company reasonably considers to be required by Sections Section 5 of the Data Protection and Privacy Act 2019 or equivalent provisions of any other Data Protection Law, in each case solely in relation to Processing of the Company Personal Data by, and taking into account the nature of the Processing and information available to, the Contracted Processors.

9. Deletion or return of Company Personal Data

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10. Audit rights

10.1. Subject to this clause 10, Processor shall make available to the Company on request all information necessary to demonstrate compliance with this Agreement, and shall allow for and contribute to audits, including inspections, by the Company or an auditor mandated by the Company in relation to the Processing of the Company Personal Data by the Contracted Processors.

10.2. Information and audit rights of the Company only arise under clause 10.1 to the extent that the Agreement does not otherwise give them information and audit rights meeting the relevant requirements of applicable Data Protection Law.

11. Data Transfer

11.1. The Processor may not transfer or authorize the transfer of Data to countries outside the East African Community or the Party States to the Principal Agreement, or those countries envisaged under the Principal Agreement without the prior written consent of the Company. If personal data processed under this Agreement is transferred from a country within the East African Community or the Party States to the principal agreement or envisaged under the said agreement, the Parties shall ensure that the personal data are adequately protected. To achieve this, the Parties shall, unless agreed otherwise, rely on approved standard contractual clauses for the transfer of personal data, in accordance with the applicable Data Protection laws.

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12.1. Confidentiality. Each Party must keep this Agreement and information it receives about the other Party and its business in connection with this Agreement ("Confidential Information") confidential and must not use or disclose that Confidential Information without the prior written consent of the other Party except to the extent that:

i) disclosure is required by law;

ii) the relevant information is already in the public domain.

12.2. Notices. All notices and communications given under this Agreement must be in writing and will be delivered personally, sent by post or sent by email to the address or email address set out in the heading of this Agreement at such other address as notified from time to time by the Parties changing address.

13. Governing Law and Jurisdiction

This Agreement is governed by the applicable laws as herein above defined, relating to Data protection and privacy for each of the Member Countries to which the agreement applies.

14. Dispute Resolution

In the event of any dispute arising out of interpretation or enforceability of any of the terms herein, such dispute shall be resolved through arbitration in accordance with the Arbitration and Conciliation Act Cap 4 of any other replacement legislation, in Uganda or the equivalent legislation relating to Arbitration in the Member Countries to which the agreement applies without prejudice to the right of any Party to seek interim reliefs from a court of competent jurisdiction in Uganda.

IN WITNESS WHEREOF, this Agreement is entered into with effect from the date first set out below.

SIGNED FOR AND ON BEHALF OF
VODAN Africa Foundation

Signature _____
Name: Prof. Francisca O. Oladipo
Title: Executive Coordintor
Date Signed: 30 October 2020

Processor Company [this will be the partners in the member country]
Signature _____
Name ANDREW CHINDANYA
Title PRO VICE CHANCELLOR
Date Signed 30-10-20

B. Coding Concept List of Global FAIR Implementation

Purpose	Category	Sub-Category	Label	Number
Kingdon's Multi Stream Framework	Problem Stream	Challenges and initiatives	#data_in_explosive_scale	1
			#improve_research_environment	2
			#increase_research_data_legitimacy	3
			#improve_data_query	4
			#improve_data_archive	5
			#improve_data_management	6
			#central_data_management_issue	7
			#difficult_custermization_of_function_and_design	8
			#data_accessibility_issue	9
			#more_option_to_add_metadata	10
			#add_agricultural_terminology	11
			#require_dashboards	12
			#require_custermized_user_interface	13
			#lack_of_professionals_and_technological_skills	14
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C. Coding Concept List of Interview Analysis

Purpose	Category	Sub-Category	Label	Number
Kingdon's Multi Stream Framework	Problem Stream	Challenges and initiatives	#bad_or_no_internet_connection	1
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			#hybrid_data_management_system	3
			#paper-based_data_collection_at_facility_level	4
			#manual_data_collection_is_time_consuming_and_repetitive	5
			#data_inconsistency	6
			#increase_operation_errors	7
			#incomplete_information	8
			#big_label_cost	9
			#paper-based_data_physically_stored_in_folders	10
			#low_memory_capacity_on_computers	11
			#low_capacity_to_physically_store_data	12
			#low_healthcare_data_ownership	13
			#data_loss	14
			#paper_files_are_prone_to_spoilage_and_damaged	15
			#physical_data_sharing_and_reuse_across_facilities_is_difficult	16
			#underdeveloped_IT_infrastracture	17
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			#use_government_requested_HMISs	19
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		Confidential policy	#ethical_clearance_and_privacy_and_retention_policy_are_present	21
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			#FAIR_allows_users_to_add_unique_ID_on_metadata_with_explanatory_information	23
		Data collection & analysis purpose	#improve_healthcare_decision_making	24
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			#optimize_treatment_quality_and_customization	27
			#improve_communication_between_healthcare_worker_and_the_patient	28
			#ensure_quality_of_care_to_the_patient	29
			#make_proper_diagnostic_and_treatment_for_future_reference	30
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			#track_individual_practitioner_performance	33
			#track_the_health_of_populations	34
			#identify_people_at_risk_for_chronic_diseases	35
			#create_a_more_holistic_picture_of_patients_to_drive_treatment_decisions	36
			#formulate_policies_and_decisions_by_building_models	37
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		KPIs	#daily_patient_visits	39
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			#lab_tests	46
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			#radiology_exams	48
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			#data_provider_has_low_accessibility	52
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			#patients	56
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			#chief_administrative_officer	58
			#nurses	59
		Data controller	#MoH	60
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			#data_stewards_at_reginal_level	62
			#billing_and_insurance_companies	63
		Data owner	#patient	64

			#no_access_to_data	65
		Policy entrepreneurs	#VODAN_Africa	66
			#MoH	67