# AN ADOPTION MODEL FOR A BIG DATA ANALYTICS SYSTEM FOR IMPROVING HEALTHCARE SERVICES IN BURUNDI'S PUBLIC HOSPITALS

**BY**

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## Declaration by the Candidate

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## DEDICATION

I dedicate this thesis to my parents and son.

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## ABSTRACT

One of the key responsibilities of a government is to provide efficient healthcare services to its citizens that are better and affordable. In its 2011-2015 National Health Development Plan, the Burundian government acknowledges that the use of health information systems is effective in the planning, monitoring-evaluation at all levels of the healthcare sector. In Burundi today, patients' health records are collected using handwritten forms and stored in filing cabinets after which the statistical analysis is done manually before the reports are submitted to the ministry after a month. In addition, there are insufficient standards in gathering the data, irregularities of surveys, incompatibility of internal media, poor completion of data collection tools, lack of archival systems for data and feedback at the various levels. These challenges are the origin of the delay in gathering information for analysis in order to gain useful insights. Evidence based research and practice shows that adoption of a Big Data Analytics (BDA) system that comprises a centralized Electronic Health Records (EHR) database and a real-time data analysis system that extracts useful insights from the medical data can significantly address these challenges. Unfortunately, BDA adoption models and automated assessment tools that address the Burundian context is lacking not to mention the dearth caused by researchers' predominant focus on the technical aspects and system development. Therefore, this study's aim was to propose a BDA system adoption model for improving healthcare services in Burundi's public hospitals. This was achieved by examining the factors that influence the adoption of BDA in public healthcare services using the Technology Organization Environment (TOE) adoption theory through a desk research and investigating the methods used by the ministry of health to collect, store and analyze medical data. A sample of 9 public hospitals of Burundi were selected from which 6 responded positively. Semi-structured interviews accompanied by observations and documents review were used to collect information for the assessment of the readiness of Burundi in adopting a BDA system in its public hospitals using the ARAT an automated web-based assessment tool. Lastly a tailored BDA system adoption model for improving Burundi's public healthcare services was developed. The findings showed a high level of readiness in Burundi's public hospitals for adoption of BDA systems. The country has adequate telecommunication infrastructures and has started using information systems like OpenClinic and DHIS2 in some hospitals. But there is still a lot of improvements to make in order to assure that the adoption is successful. The tailored adoption model developed points out the need of a private network that interconnects all the public hospitals with the ministry of health, the implementation of OpenClinic in all the public hospitals, implementation of standardized health records system and policies, increase ICT training programs for the staff and allow patients to access their health records. Overall, all the objectives of the study were met.

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## ABREVIATIONS

**ACID:** Atomicity Consistency Isolation and Durability

**ARAT:** Adoption Readiness Assessment Tool

**BDA:** Big Data Analytics

**CPU:** Central Processing Unit

**DHIS2:** District Health Information System

**DOI:** Diffusion Of Innovation

**EHR:** Electronic Health Records

**ERP:** Enterprise Resource Planning

**GE:** General Electric

**GFT:** Google Flu Trend

**GPS:** Global Positioning System

**HIV:** Human Immunodeficiency Virus

**ICT:** Information and Communication Technology

**IT:** Information Technology

**LAN:** Local Area Network

**NHDP:** National Health Development Plan

**OLAP:** Online Analytic Processing

**OLTP:** Online Transaction Processing

**RAM:** Random Access Memory

**RDBMS:** Relational Data Base Management System

**RFI:** Radio France Internationale

**RFID:** Radio-Frequency Identification

**TAM:** Technology Acceptance Model

**TOE:** Technology, Organization, Environment

**UN:** United Nations

**UTAUT:** Unified Theory of Acceptance and Use of Technology

**WEF:** World Economic Forum

**WHO:** World Health Organization

# CHAPTER ONE

# INTRODUCTION

## 1.0 Theoretical Background

Big Data Analytics (BDA) has proven within the past years that it has the potential to transform positively every industry as firms have been investing more in analytics to gain knowledge that can directly feedback into improving planning, business processes and operations (Matthew, 2016). Gartner defines Big Data as high volume, velocity and variety information assets that demand cost-effective, innovative forms of information processing for improved insight and decision making. As for BDA, it consists of analyzing big data with the aim of providing a path to extract new knowledge or create value which has the potential to change markets, organizations, and government due to the large-scale nature of today's information (Mayer-Schonberger & Cukier, 2013).

BDA is applied in various areas that provide a sense of its vast scope and impact: healthcare, natural processes, government and the public sector, social networking, business and economic systems, experimental processes (Karthik et. al, 2014). Ruppel (2017) stated that a government gains in four ways using BDA: Improved services for citizens, better allocation of taxpayer money, the aptitude to visualize difficult problems, and reduced cases of fraud and abuse.

A good example is the USA which has clearly proved how BDA can be applied in government services by using them in Law Enforcement Agencies, Department of Transportation, in Education, in the US department of Agriculture, Healthcare Government Agencies (Marr, 2015). Another example is eCitizen (www.ecitizen.go.ke) implemented by the Kenyan government which facilitates public service delivery like driving license, Kenya Revenue Authority numbers, visa, and

many more. Consequently, this should in return encourage other countries to adopt them.

The number of BDA systems available in healthcare has been increasing within the past few years; Explorys, HealthCatalyst, and GE Healthcare are examples of some of the best systems in the market used for medical data collection, storage and analysis.

BDA is becoming a growing and influential practice in various sectors. According to Ravishankar (2016) spending in BDA is expected to increase and reach $41.5 billion by 2018. But the question that remains is: how many organizations are actually adopting it? Within the past years, a number of BDA tools have emerged to help transform business processes of farmers, small-business owners, policymakers and international stakeholders that want to invest in Africa. The continent has started timidly to invest in BDA (Nicholas, 2016).

According to Data Center Map only 11 countries in Africa have Data Centers (Algeria, Angola, DR Congo, Ghana, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tanzania and Tunisia) with a total number of 53 data centers which represent 1.2% of the total number (4136) of data centers worldwide. Only a few countries such as Algeria, South Africa, Cameroun, Zambia, Ghana and Uganda have taken a step forward in adopting BDA systems in healthcare. This shows how slow the adoption and implementation of BDA has taken off in African countries. Applications are available on the market but there is absence of adoption and implementation models of BDA largely due to researchers focus that is more slanted on the technical aspects and systems development of BDA (Kwon et al., 2015).

Burundi has 61 public hospitals scattered in the country. The Ministry of Health collects, stores and analyses health data from all the hospitals through the national

health information system that is under the direct management of the Permanent Secretary of the Ministry of Health. The ministry gathers monthly reports from hospitals every 30 to 35 days and produces a full report annually.

The World Health Organization (WHO) acknowledges that Africa is confronting the world's most dramatic public health crisis. In its 2018 global annual report, the statistics show that Africa has the highest maternal mortality rate, highest under-five mortality rate, highest HIV infection rate, highest malaria infection rates and the lowest healthcare services coverage rate (World Health Organization, 2018). The same report shows that 156.2 out of every 1000 Burundians were infected by malaria in 2016. Unfortunately, it was only in March 2017 that the government of Burundi, through its Ministry of Health reported in a survey done by Burundian health experts using the annual reports from hospitals, announced that there was at least 1.8 million malaria cases in 2015 and 2016, and over 3800 deaths due to the disease prompting the ministry to declare it an epidemic (World Health Organization, 2017).

The reason behind the delay in gathering information and analyzing to provide insight on the national healthcare situation is the methods used to collect, store and analyze information that take time, lack of standards in gathering the data and irregularities of surveys. According to the Burundian National Health development Plan published in 2010, there is a lack of updated data due to the responsible services not being aware of sources of information, overlaps and double-usage when performing surveys among the population. Additionally, healthcare facilities management face difficulties related to incompatibility of internal media, insufficient completion of data collection tools, inadequate archival systems for data and feedback at the various levels. Moreover, the

epidemiology statistics service suffers from a lack of equipment, financial and human resources.

Ganjir et al. (2016) indicated that BDA possesses the potential to transform the way healthcare providers use technologies to gain insight from medical and other data repositories to enable them to make well-informed decisions. A centralized EHR database and a data analysis system to extract insights in real-time can solve the issues mentioned above. The knowledge gained using BDA systems can be used in reducing avoidable overuse of resources and reducing fraud by analyzing large historical datasets to detect anomalies and patterns (McDonald, 2017). Additionally, the BDA system can be used to track weak links in the quality chain by analyzing patients' collection rates, managing patients' movements in different departments, and monitoring how resources are used and their supply chain (Bresnick, 2017).

Research gap in BDA adoption models has been reported (Nayem, 2016). The author attributes the gap to researcher's focus on developing systems and the technical aspects more, ignoring other areas of concern. Thus, the aim of this research was to study in depth the factors that influence the adoption of a BDA system in healthcare then develop a tailored adoption model for Burundi to improve its healthcare services in public hospitals.

### 1.1 Problem Statement

One of the key responsibilities of a government is to provide efficient healthcare services to its citizens that are better and affordable (Ruppel, 2017). In its 2011-2015 National Health Development Plan, the Burundian government acknowledges that the use of health information systems is effective in the planning, monitoring-evaluation at all levels of the healthcare sector. Thus, the Ministry of Health collects information

from hospitals throughout the country to analyze it and gain knowledge that supports them in decision making to improve healthcare.

In Burundi today, patients' health records are collected using handwritten forms and stored in filing cabinets after which the statistical analysis is done manually before the reports are submitted to the ministry after a month. In addition, there is a lack of standards in gathering the data, irregularities of surveys incompatibility of internal media, insufficient completion of data collection tools, lack of archival systems for data and feedback at the various levels (NHDP 2010-2015). These challenges are the origin of the delay in gathering information for analysis in order to gain useful insights. A case in point is the March 2017 ministry of Health declaration of malaria as an epidemic disease that came only after a recording of 1.8 million infections and more than 3000 death cases (RFI Afrique, 2017). In an ideal situation, the government could have prevented this by using a Big Data Analytics (BDA) system to enable them to take preventive measures before the disease became epidemic.

This system would provide decision makers with knowledge that enables them to increase access to efficient healthcare services, medicines, vaccines, reliable and affordable laboratory and diagnosis services.

Therefore, the Burundian government needs an appropriate adoption model to implement successfully a BDA system in its healthcare services. Unfortunately, BDA adoption models and automated assessment tools that address the Burundian context is lacking not to mention the dearth caused by researchers' predominant focus on the technical aspects and system development (Nayem, 2016).

Therefore, Understanding the factors that influence the adoption and implementation of BDA systems as well as assessing Burundi's BDA adoption readiness is essential for the development of a tailored adoption model for Burundi's healthcare services.

### 1.2 Aim

The study examined the factors influencing the adoption of Big Data Analytics in Public Hospitals in Burundi with a view of proposing an adoption model for improving healthcare services in the country.

### 1.3 Objectives

1. Examine the factors that influence the adoption of BDA in public healthcare services using the TOE adoption theory.
2. Develop a web-based automated adoption readiness assessment tool based on the findings from the first objective.
3. Investigate the methods used by the ministry of health to collect, store and analyze medical data from public hospitals of Burundi.
4. Assess the readiness of Burundi in adopting a BDA system in its public hospitals using the ARAT developed in objective two.
5. Propose a tailored BDA system adoption model for improving Burundi's public healthcare services.

### 1.4 Research Questions

1. What informs the adoption of BDA in public healthcare services?
2. How can a BDA adoption readiness assessment tool be developed?
3. How is the medical data collected, stored and analyzed in public hospitals of Burundi?

4. What is the level of readiness of Burundi in adopting a BDA system in its public hospitals?
5. What is the appropriate BDA system adoption model for Burundi's public hospitals?

### 1.5 Justification

It is crucial to assess the ability of an organization or a government to adopt a new technology before implementing it. This is measured using technology adoption models. This research fills in three main gaps. The first one is to study in depth the factors that influence the adoption of BDA in healthcare services on the government level. This will contribute in filling a research gap mentioned by Nayem (2016). Nayem stipulated that there is a lack of BDA adoption models due to the fact that researchers have been focusing more on developing more systems and the technical aspects of systems development. The terms Big Data Analytics, Big Data Analytics Adoption and Big Data Analytics Adoption in Africa were searched on Google scholar, African Journal Online, IEEE, Springer and Taylor & Francis. The search results shown in the figures below exhibited how published studies are more on technical aspects and system development and less on adoption.

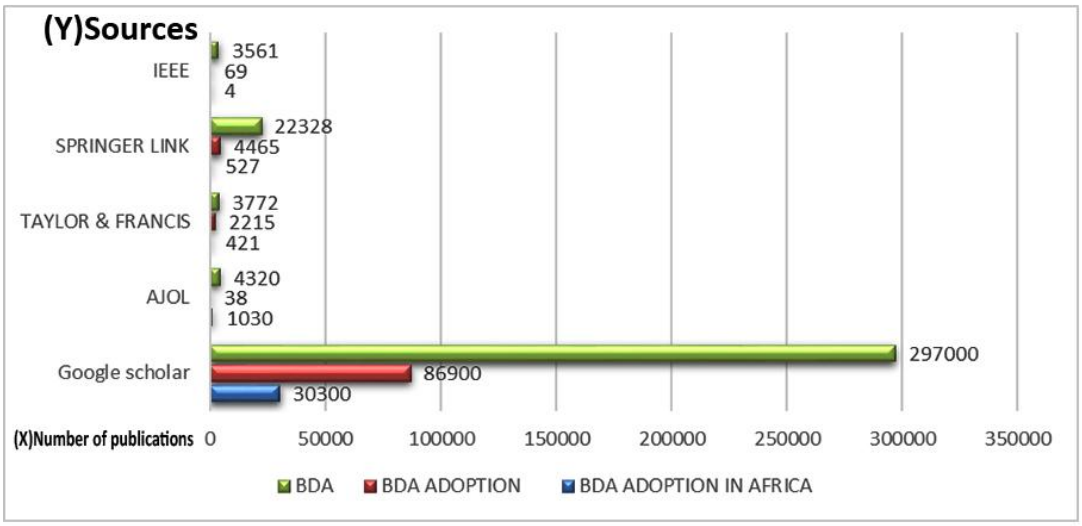



**Figure 1: Google scholar and other scholarly online journals search results**

The second gap is the lack of automated adoption readiness assessment tools. For the studies done on technology adoption, the assessments were conducted manually therefore this research is providing a web-based automated assessment readiness tool developed using a TOE-Based adoption framework. The tool is an Open source software application that can be customized by any future researcher who would want to conduct an adoption assessment. Lastly, the study provides a tailored BDA adoption model for Burundi's public hospitals after assessing the level of readiness using the developed automated assessment tool. This would allow the government to reduce the amount of time that takes to produce a national report to a day instead of a year.

### 1.6 Significance of the Study

The results obtained from the assessment on public hospitals in Burundi will contribute in offering a detailed status on the health information system of the country. The tailored BDA adoption model proposed provides a comprehensive adoption and implementation process that the government can follow to adopt a BDA system to improve its healthcare services. Comprising of a centralized EHR database and a data

analysis system to extract insights in real-time, the BDA system will enable the government to gain knowledge that can be used in monitoring disease spreading, reducing avoidable overuse of resources, reducing fraud and monitoring how resources are used. In consequence, this will allow the government to offer better healthcare services to Burundians by allocating resources like medicine, money, transport facilities and staff where they should. And it will also allow the government to save time by monitoring the spreading of diseases in the country and taking preventive measures earlier.

### 1.7 Scope and Limitations

This study was limited to public hospitals in Burundi. Due to the limited time and resources, 9 of the 61 public hospitals were surveyed. Three provincial hospitals, three national referral hospitals, two district hospitals and one regional hospital were included in the study. All 4 categories of public hospitals were considered and in sampling which are scattered in 5 different provinces which helped in reducing any bias.

### 1.8 Definition of Operational Terms

**Big Data Analytics:** high volume, velocity and variety information assets that demand cost-effective, innovative forms of information processing for improved insight and decision making.

**BDA Adoption model:** In the context of this study, an adoption model is a descriptive process that needs to be followed in order to adopt the BDA system. It describes the phases from the awareness stage to the implementation then to the evaluation phase.

**Assessment:** the term assessment in the context of this study is the evaluation of the level at which the country fulfils the requirements of adopting a BDA system.

**Readiness:** the readiness is the level of willingness or being able to adopt the BDA system.

**Tool:** a web-based system with inputs, outputs and an inference engine that runs the assessment of the readiness of the country in adopting the BDA system.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.0 Introduction

The literature review was guided by the study's aim and objectives as well as the research questions. Therefore, a focused review was conducted on BDA and its adoption models in healthcare. This chapter begins with defining what BDA is and how it is used in healthcare. Information technology adoption models are discussed in order to point out the models and factors used for BDA adoption in healthcare services. To further understand the adoption of BDA an overview of its requirements was established. The chapter concludes with a section that briefly discusses BDA adoption in African countries in healthcare services and empirical studies that have been conducted.

## 2.1 Big Data

Big Data Analytics (BDA) has the power to improve two-way communication and real-time decision making that enables effective development outcomes (Jessica & Brindley, 2013). Matthew (2016) added that BDA has proven within the past years that it has the potential to positively transform every industry as firms have been investing more in analytics to gain knowledge that can directly feedback into improving planning, business processes and operations.

### 2.1.1 Big Data Elements

Most of definitions of Big Data used in the literature focus more on the size of the data. But there are also other considerable attributes of big data which are Variety and Velocity. The three attributes constitute a comprehensive definition of Big Data namely the three Vs (Volume, Variety and Velocity) (Russom, 2011).

Gartner defines Big Data as high volume, velocity and variety information assets that demand cost-effective, innovative forms of information processing for improved insight and decision making (Beyer & Laney, 2012). And according to Stuart & Barker (2013), Big Data describes large and complex data sets that use a series of specialized techniques like NoSQL, MapReduce and Machine Learning for its storage and analysis.

The volume of data from new sources like social media, machines sensors, weather forecast and GPS location tracking devices is growing faster than ever since sources have increased (Lanham, 2016). For instance, around 2.5 quintillion bytes of data is created each day (Forbes, 2018). Per minute Snapchat users share 527,760 photos, 120 professionals join LinkedIn, 4,146,600 users watch YouTube videos 456,000 tweets are sent on Twitter and 46,740 photos are posted on Instagram (domo.com, 2018).

Velocity **is** the ability of processing large amounts of data in real-time in order to give an organization competitive advantage over its competitors. According to Lanham (2016), this depends on the business objectives and how quickly they need the data to be processed.

There are three types of data variety; structured, unstructured and semi-structured. These data come from a large variety of sources which includes social networks, images, sensor readings, consumer reviews, and other online content that can help a company improve its business.

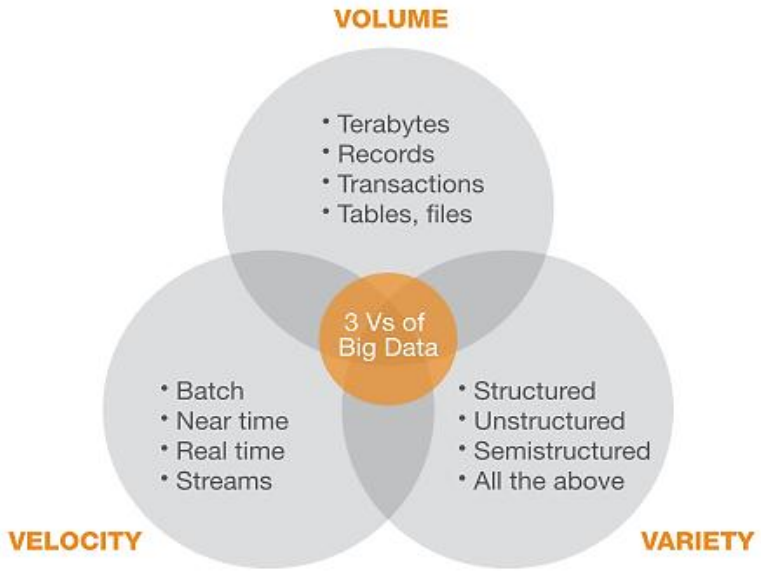



**Figure 2: The Three Vs of Big Data; Source: (Russom, 2011)**

### 2.2 Big Data Analytics (BDA)

According to Russom (2011) BDA is mainly about two things: Big data and Analytics. These two have teamed up to create the biggest trend today in business intelligence. Providing gigantic statistical samples, which enhance analytic tool results. Nik & McClure (2016) also stated that BDA is one of the most important priorities in IT today. Vibha et.al. (2016) classifies BDA in three main types: Descriptive analytics, Predictive analytics, and Prescriptive analytics. Back in 2016, Nik and McClure had already observed that BDA was one of the most important priorities in IT. Rahm (2016) defined BDA as the application of advanced analytics techniques on big data sets. Rahm added that most tools designed for data mining or statistical analysis thus tend to be optimized for large data sets. In fact, the general rule is that the larger the data sample, the more accurate are the statistics and other products of the analysis.

### 2.2.1 Benefits of BDA

Matthew (2016) outlined the following as some of the most key benefits of BDA: increased productivity and profitability (companies that invest in BDA increase their productivity and profitability at a rate of 5% to 6%), reduced costs (BDA helps in reducing costs by upgrading existing architectures with big data technologies like cloud-based analytics), faster and better decision making (BDA increases the speed of data processing to understand better the customer base), innovation and new markets (retailers study details collected from customers to study what they like and what they need with aim of discovering new patterns in what the customers need or might need in the future). For instance, a company called Target in America found out that women were buying larger quantities of unscented lotion around the beginning of their second trimester. Also, when someone suddenly starts buying lots of scent-free soap and extra-big bags of cotton balls, in addition to hand sanitizers and washcloths, it signals they could be getting close to their delivery date. So, they decided to offer them coupons on baby items.

According to Davenport (2014) BDA allows companies to reduce costs, provide faster decisions and supports them in creating new products and services. For instance, AirAsia saved $10 million on fuel in 2014 by using GE (General Electric BDA systems), Google researchers showed how Influenza could be tracked without requiring to any medical check-up records but using BDA, Google's Flu Trends (GFT) was enabled to identify an outbreak within a day based on the correlation of key words searches. Furthermore, in a survey conducted by DELL (2015), they discovered that organizations that use BDA systems have a revenue growth rate of 50%.

The benefits of BDA that have already been manifested by other industries can be applicable in the healthcare sector. African healthcare providers can increase productivity, reduce costs and improve decision making.

### 2.2.2 Tasks of BDA

One of the top companies that provide BDA solutions IBM stated that a BDA platform can extract insights from a large volume of data including a wide variety of types with high velocity. BDA can enable an organization into completing the following tasks: Analyze a variety of information consisting of relational and non-relational data types and schemas, analyze information in motion and stream data analysis, and analyze extremely huge volumes of data (petabytes of information). Discover and experiment patterns in big data sets, manage and plan data structures to ensure consistency for repeatable queries.

### 2.2.3 Examples of organizations that are using BDA

According to a study conducted by Dresner Advisory Services (2017), about 53% of North America and Asian companies use BDA already. Global companies like Google, Amazon, IBM, Oracle, Microsoft, HP and Netflix are using information to their advantage by gaining insights into their market and improving their overall performance (James, 2015). For example, Amazon uses BDA to analyze massive amounts of customer data to optimize their supply chain and Google uses BDA to mine data and place ads in front of customers based on their interests and behaviors (statista.com, 2018).

These companies are able to take advantage of the benefits that BDA has to offer because they invested enough in the technology. BDA requires powerful processing resources and huge data storage infrastructures depending on how big the datasets are.

Nevertheless, some African companies are using BDA like Safaricom with its money transfer service Mpesa, Liquid Telecom, MTN and Orange Telecom Kenya. This is thanks to data centers that have been implemented in Kenya by Safaricom and The East African Data Center.

### 2.3. BDA Technologies

Big data refers to massive, heterogeneous, and often unstructured digital content that is difficult to process using traditional data management tools and techniques like classic relational database management systems (RDBMS) or conventional search engines. According to Talia (2013), extracting valuable insights and knowledge from huge volumes of digital datasets requires smart and scalable analytics techniques, programming tools, and applications like NoSQL (Not Only SQL), NewSQL and Search-based systems.

NoSQL DBMS are distributed, non-relational databases designed for large-scale data storage and for massively-parallel data processing across large numbers of commodity servers. As for NewSQL systems, they are relational databases designed to provide ACID (Atomicity, Consistency, Isolation, and Durability), compliant, real-time OLTP (Online Transaction Processing) and conventional SQL-based OLAP (Online Analytical Processing) in Big Data environments (Moniruzzaman & Hossain, 2013).

The reasons behind the trending use of these new DBMS are: the exponential growth of the volume of data generated by users, systems and sensors, and the increasing interdependency and complexity of data accelerated by the Internet, Web2.0, social networks and open and standardized access to data sources from a large number of systems (Moniruzzaman & Hossain, 2013).

NoSQL classifies data in three different ways depending on the objectives of the organizations: Key-value stores, column-oriented databases, and document-based stores (Moniruzzaman & Hossain, 2013).

Current solutions are based on open source systems such as Apache, Hadoop and SciDB and other solutions are provided by big companies like IBM, Google, BigML, InsightsOne. The top three commercial databases suppliers in the world, which are Oracle, IBM and Microsoft, adopted Hadoop framework as their BDA platform (Lydia et.al. 2014). Nevertheless, to implement a BDA systems there are some technical aspects that need to be considered regarding the memory and storage space, processing power, network resources, power supply, virtualization techniques (Kambatla et al., 2014).

### 2.3.1 BDA in healthcare

Large amounts of heterogeneous data are being generated by healthcare services. But they are useless if they are not treated with proper data analysis methods. Approximatively 16,000 hospitals collect data on patients worldwide, 4.9 million patients use remote monitoring devices and 80% of health data is unstructured (Fatima & Kudzai, 2016). Big Data in healthcare is all the information related to patient care reports, X-ray reports, Lab reports, lists of doctors and nurses in hospitals and health registries (Archenaa & Mary, 2015). Therefore, health organizations and institutions need BDA technologies to get insight from those data.

According to Ashwin et al. (2015), the rapidly expanding application of big data analytics has started to play a critical role in the evolution of healthcare. It has provided tools to accumulate, manage, analyze, and assimilate large volumes of disparate, structured, and unstructured data produced by current healthcare systems. A small

glimpse on the potential of BDA in healthcare is a report done by the McKinsey Global Institute suggests that if the US healthcare department was to use big data creatively and effectively, the sector could create more than $300 billion in value every year (Ashwin et al. 2015).

Chen et al. (2012) stated that the health community has been facing a tsunami of health content related data generated from various patient care points of contact, web-based health communities and medical instruments. They put health big data sources into two main categories: genomics-driven big data (gene expression, genotyping, sequencing data) and payer-provider big data (EHR, insurance records, pharmacy prescriptions).

Vibha et al. (2016) mentioned that big data in healthcare refers to electronic health data sets so large and complex that they are difficult to manage with traditional software and hardware; nor can they be easily managed with traditional data management tools and methods.

The ability of BDA to analyze structured and unstructured data sets from different data sources helps in providing accurate patients diagnosis results, matching treatments with the results and allows also to predict patients at high risks of disease or readmission (McDonald, 2017; Bresnick, 2017). Moreover, this ability of analyzing data sets from various sources helps in mapping disease events putting them within their geographic contexts to allow decision makers to take effective measures (Reddy & Kumar, 2016).

Referring to Shankar (2016), BDA can be applied in the following areas: diagnosis of diseases, treatment of illnesses and also can help to reduce the number of readmitted patients that go to hospitals. We can add geographical disease monitoring and centralized EHR databases to these application areas. Adding to the list, Bram et al. (2015) notes that patients' health data can be applied in the identification of health

trends and epidemics, tracking of immunization coverage, targeting of health research efforts and interventions and the allocation of healthcare resources.

Due to new types of health data like Lab reports, x-rays, sensor data that are in different formats and from different sources shown in the discussion above, there is a need of using new technology to collect, store and analyze them. That is why BDA is the right technology to use according to past studies. But the question is whether African countries collect all types of health data which includes physician notes, Lab reports, X-Ray reports, case history, social media post, sensor data, diet regime, list of doctors and nurses and national health register data. Furthermore, this data is in different formats like texts, images, audios and videos. Healthcare providers can only get BDA full potential if they collect all these types and format of data.

### 2.3.2 Impact of BDA on healthcare

The Big Data Value Association, believe that the healthcare industry as a whole (doctors, patients, insurance, and politics) can significantly profit from BDA technologies. Big Data could be useful in improving healthcare in two significant ways: population health and personalized health care (Vibha et.al. 2016). The association lists the following areas that BDA has impacted the healthcare sector:

**Right living**: Patients can build value by taking an active role in their own treatment, including disease prevention.

**Right care**: This pathway involves ensuring that patients get the most timely, appropriate treatment available.

**Right provider**: This pathway proposes that patients should always be treated by high-performing professionals that are best matched to the task and will achieve the best outcome.

**Right value**: providers and payers continuously enhance healthcare value while preserving or improving its quality.

**Right innovation**: involves the identification of new therapies and approaches to delivering care, across all aspects of the system, and improving the innovation engines.

Archenaa & Mary (2015) on the other hand state that BDA has the potential to improve healthcare services by: providing patient centric services, detecting spreading diseases in certain regions on an early stage, monitoring hospitals' quality of services delivered to their patients and improving treatment methods.

Looking at the impact that BDA has on healthcare, African countries can benefit significantly from using this technology. Nonetheless, the cases discussed above are from studies done in American and European countries. This implies the need of putting them into the African context before assuming that BDA can have the same impact in Africa.

### 2.3.3 Types of health data used with BDA

There are different types of data used in BDA in healthcare (Priyanka & Kulennavar, 2014): Clinical data, Publications (clinical research and medical reference material), Clinical references (e.g., drug information) data, Genomic data – represents significant amounts of new gene sequencing data, Streamed data (e.g., home monitoring, telehealth, handheld and sensor-based wireless or smart device), Web and social networking data (consumer use of Internet, data from search engines and social

networking sites), and Business, organizational and external data (administrative data such as billing and scheduling and other non-health data).

It is important to point out the fact that these types of data existed before the creation of BDA. Furthermore, there are technologies that were used to collect and store these data as pointed out by Priyanka & Kulennavar (2014). Unfortunately, this might not be the case in African countries. Therefore, during the adoption assessment on objective 4 of the study an investigation on technologies currently used will be conducted to establish if the BDA can be adopted. It is noteworthy that BDA system collect information from existing systems.

### 2.3.4 BDA Platforms used in Healthcare

Paige (2017) classified BDA platforms into the following categories: Big Data Solutions (Zephyr Health, HBI Solutions), Diagnostic solutions (MeMed), Digital Therapeutics (Virta Health), EHR Solutions (CareCloud, drchrono), Care management (medCPU), Population Health Solutions (ZeOmega) and Imaging solutions (Bay Labs). These platforms have been developed to improve health facilities' workflows and patients' care. Each application has specific tasks that it has to accomplish. Therefore, they complement each other, meaning that health facilities use a combination of multiple applications to monitor disease spreading, clinical support systems, heritage health price (to identify patients who will be admitted to a hospital within next year using historical claims data), provide predictive insights, to deliver personalized medical care, support health innovations, and implement EHRs (Koppad & Kumar, 2016).

The fact that there is already a large variety of BDA systems on the market is an advantage for African countries. This allows countries that have not yet adopted BDA to choose from tested and improved systems.

## 2.4 Electronic Health Records (EHR) and descriptive data analysis systems in BDA

### 2.4.1 Electronic Health Records (EHR)

An electronic health record (EHR) is a repository of electronically maintained information about an individual's lifetime health status and health care, stored such that it can serve the multiple legitimate users of the record (Paul & McDonald, 2006).

According to the department of health and human services of the U.S government, an Electronic Health Record (EHR) is a digital version of a patient medical record paper chart of data acquired and created during a patient's course through the health care system. They are real-time and patient centered records that avail information instantly and in a secure way to authorized users. Office-based physicians that adopted EHR systems went from 18.2% in 2001 up to 71.8% in 2012.

EHR data can be unstructured (e.g., clinical notes) or structured (e.g., ICD-9 diagnosis codes, administrative information, chart, and medication). These clinical notes describe a patient's condition and are considered to be the most efficient and human-intuitive way to document clinical data (Po-Yen et.al. 2017). The authors categorize EHR data into two main classes: administrative data that includes those data that remain unchanged during the entire course of a clinical encounter like demographic data, and those that keep updating over time like diagnoses and procedures.

As for an EHR system, according to Paul and McDonald (2006), it adds on information management tools that provide clinical alerts and extract knowledge for healthcare decision makers. An EHR system has a number of advantages over paper-based record systems: they are flexible and adaptable, integrate multimedia information, easy access. Figure 3 shows an example of an architecture that integrates data from multiple source systems.

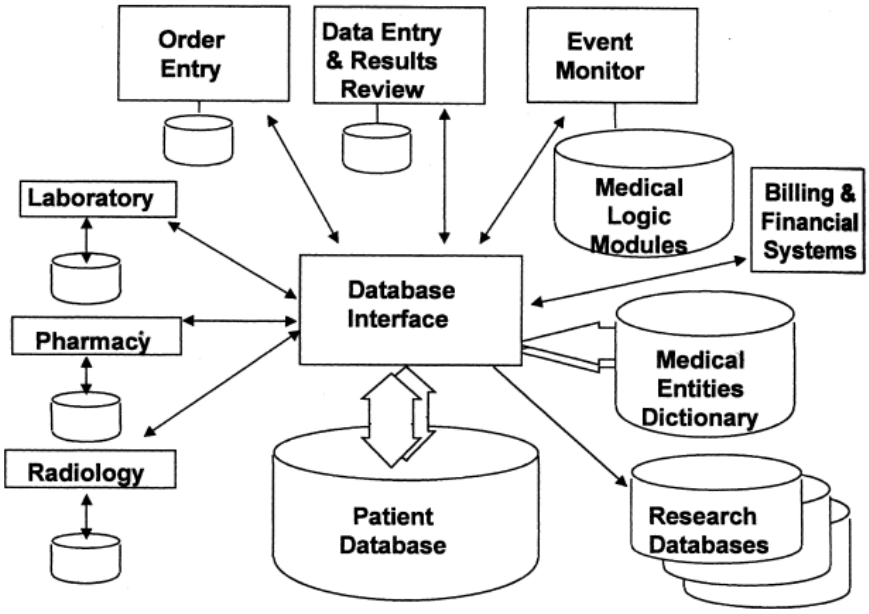



**Figure 3: EHR architecture, source: (Paul & McDonald, 2006)**

Examples of available EHR systems include drchrono (drchrono.com), AdvancedMD (advancedmd.com), MediTouch (healthfusion.com), NueMD (nuemd.com), athenahealth (athenahealth.com), iSalus healthcare (isalushealthcare.com), prognoCIS (prognocis.com), , Meditech (ehr.meditech.com), Medhost (medhost.com), HealthLand (healthlandspa.com).

### 2.4.2 Descriptive Data Analysis Systems

Descriptive analytics is simply an insight on the past. It uses data aggregation and data mining to describe an event that has occurred. Sofiya & Joshi (2015) estimated that

more than 80% of business analytics, most social analytics, are descriptive. Thus, descriptive analytic systems are used in healthcare to understand what is going on and to describe the different aspects of the health sector. Descriptive analysis systems perform their task in three steps: evaluation, classification and categorization. There are some existing tools available on the market like: Data Wrangler, The R Project, Time Flow, Table Plateau, L&T technologies, SAS Analytics, ScienceSoft, IBM, Oracle, Truven Health Solutions, Allscripts, Cerner, Mede Analytics.

### 2.5 BDA Adoption

Aurelija and Pipiriene (2013) underscore the need to assess the ability of an organization or a government to adopt a new information system (IS) to determine if they can respond and adapt to challenges adequately. They note that IS adoption is a process through which a problem is resolved through an assessment and evaluation of possible solutions. According to the World Economic Forum (WEF) report on information technology infrastructure, affordability, skills, individuals and government are the key drivers of adopting new technology.

Pramanick (2013), the IoT leader at IBM Analytics, opines that in order to successfully implement a BDA system, the following considerations must be focused on: Gather business requirements before gathering data, approach BDA solutions from a business perspective, evaluate the data coming into the business, and standardize BDA efforts within an IT governance program. Furthermore, Customer Relationship Management (CRM) Analytics on the other hand believe that if an organization takes into consideration: the identification of stakeholders, the culture of the organization for better decision making, finding the right people to define data governance, setting clear goals, linking the implementation plan to the 3Vs that define Big Data, and establishing clear quality metrics organizations can take full advantage of BDA.

Kathrin et al. (2013) identify some key concerns that need attention before implementing a large-scale health information system. They propose that before initiating the project, the problem that the new technology is designed to solve needs to be clarified then a consensus between the professional, managerial and administrative body of the organization needs to be built. Next is to consider your options before choosing a system that fits the healthcare needs and financial capability of the institution. When planning for the implementation of the new system, the infrastructure and staff training capacity and requirements should also be considered. After implementing the system, a continuous evaluation of the performance of the system and the users is needed not forgetting its maintenance. Lastly, the quality of the system should be assessed for any improvement.

### 2.5.1 ICT Adoption models

A literature review done by Oliveira & Martins (2011) on technology adoption models established that the commonly used models are TAM (technology acceptance model), TPB (Theory and planned behavior), UTAUT (unified theory of acceptance and use of technology), DOI (diffusion of innovation) and TOE (technology, organization, and environment). These models generally assess three types of factors: external or environmental factors, organizational or internal factors and technological factors. The TPB model emphasizes more on the anticipated behavior of potential users towards the new technology, the TAM and UTAUT focuses more on the acceptance of the technology in the organization while the DOI and TOE deals with every aspect of the adoption of the technology.

Gupta et al. (2008) used the UTAUT in their study that assessed adoption of ICT by the Indian ministry of Environment and Forest tested the influence of performance expectancy, effort expectancy, social influence, gender and user behavior. They used

questionnaires to collect data from Indian employees in an eGovernment setting. The TAM model was also used in a study conducted by Fengyi et al. (2011) to assess the adoption of e-Government initiatives in Gambia. They evaluated how citizens adopted the systems and the success of the adoption of the information systems introduced in the country focusing on the information system quality, the information quality, the perceived usefulness and ease of use, the attitude of the users towards the system and the behavior intentions. Therefore, it is crucial to consider users attitude and behavior towards the new technology during an adoption assessment. This allows the study to establish if the BDA system will be accepted by the intended users in the hospitals.

### 2.5.2 ICT Adoption factors

Ana and Antonio (2006) itemize factors that affect the adoption of new technologies the three main categories as shown in Table 1.

**Table 1: Technology adoption factors**

| INTERNAL FACTORS | EXTERNAL FACTORS | TECHNOLOGICAL FACTORS |
|---|---|---|
| ▪ Internal resources<br>▪ In-house IT expertise<br>▪ Organizational culture<br>▪ Availability of IT<br>▪ IT selection<br>▪ IT implementation<br>▪ Demographic variables<br>▪ Technical and top management support<br>▪ Training and experience<br>▪ Size<br>▪ IT knowledge | ▪ Organizational environment<br>▪ Industry pressure<br>▪ Government pressure<br>▪ Outside support<br>▪ External resources<br>▪ External environment<br>▪ External pressure<br>▪ Competitive pressure | ▪ Advantage over traditional methods<br>▪ Improved communication<br>▪ Infrastructure and development capability<br>▪ A business tool<br>▪ Market development opportunity<br>▪ Internet cost<br>▪ Consumer sensitivity<br>▪ Connectivity<br>▪ Feasibility |

Source: Ana and Antonio (2006)

In the WEF global IT report of 2015, Klaus (2015) categorize factors that influence the adoption of ICT into five groups: environmental, infrastructure, affordability, IT skills and usage as listed in Table 2. These factors could be used in assessing at which level a country is ready to adopt a new Information System. Since WEF reports are done on

a national scale, the factors used are well fitted for a study that covers all the aspects of the country. Nonetheless, for a study in health care, the factors need to be put in context, meaning that the chosen factors must be defined according to the requirements of the healthcare sectors and their metrics have to be specific to hospitals and other healthcare entities involved in the adoption study.

**Table 2: WEF ICT adoption factors**

| **ENVIRONMENTAL** | | |
|---|---|---|
| Political & regulatory factors:<br>▪ Laws related to ICT<br>▪ Judicial independence<br>▪ Intellectual property protection<br>▪ Number of procedures to enforce a contract | ▪ Business & innovation factors:<br>▪ Availability of latest technologies<br>▪ Venture capital availability<br>▪ Tax rate | ▪ Tertiary education enrollment rate<br>▪ Quality of management schools<br>▪ Government procurement of advanced technology products |
| ▪ **Electricity production**<br>▪ **Mobile network coverage, % of population**<br>▪ **Internet bandwidth** | ▪ Prepaid mobile cellular tariffs<br>▪ Fixed broadband internet tariffs | ▪ Quality of educational systems<br>▪ Quality of math & science education<br>▪ Adult literacy rate, % |
| **USAGE** | | |
| Individual usage factors:<br>▪ Mobile subscription per 100 people<br>▪ % of individuals using internet<br>▪ % of households with computers<br>▪ Use of virtual social media | Business usage factors:<br>▪ Firm-level technology absorption<br>▪ Capacity for innovation<br>▪ Business-to-business internet use<br>▪ Business-to-consumer internet use<br>▪ Staff training | Government usage factors:<br>▪ Importance of ICT to the government vision of the future<br>▪ Government online service index<br>▪ Government success in ICT promotion<br>▪ |

Source: WEF global IT report of 2015

The Unified Theory of Acceptance and Use of Technology (UTAUT) model defined the following five measurement variables of which questionnaires can be made to

assess the level of possibility of a successful adoption of a new ICT (Boonchai et al. 2008):

(1) Performance expectancy (the degree at which the technology will help the user to improve their work performance),
(2) Effort expectancy (the degree of ease of use of the system)
(3) Social influence (the degree at which the user believes the importance others give the system)
(4) Facilitating conditions (the degree at which the user believes the existing systems will help in using the new one)
(5) IT use (IT experience).

Observing previous studies that provided adoption factors we can see that each study selected factors depending on the needs and requirements of their cases. For instance, Ana and Antonio (2006) focused more on the technical aspects while Klaus (2015) focus was at the government level. The factors from these two studies combined were successfully used during the conceptual framework development that was afterwards used to assess the adoption readiness of Burundi in adopting a BDA system.

### 2.5.3 ICT Adoption in Government

To ensure a successful adoption of ICT in a government, Omwoyo (2007) argued that the following components need to be seriously considered: The government needs to have a clearly defined strategy and implementation plan, make sure that there is sufficient telecommunication infrastructure, get all the information on the hardware and software technical specifications, have a strong security and data privacy policy, get the right implementation services, train the employees and last but not least make sure the system is maintained regularly and upgraded.

According to Oracle (2006) the following are mandatory technical factors for a successful implementation of Information System in a government (Onyancha, 2007):

1. Strategy: clearly define the strategy and implementation plan
2. Infrastructure: Interconnection
3. Hardware: technical specifications and descriptions
4. Database management
5. Enabling technologies: Security technologies and web hosting
6. Applications: Software used
7. Middle and workflow tools
8. Implementation services
9. Training of the employees
10. Maintanance and upgradation

A report by Glenn et al. (2009) on factors influencing the adoption of new technologies in the health sector emphasize on the following characteristics as being crucial to an organization intending to adopt a new technology: available resources that can be allocated to new projects, decentralized management, skills base, ability to access new knowledge, knowledge sharing, leadership, middle management, risk-taking climate, goals that are clear and prioritized and the ability of the organization to capture data to gain feedback on the success of the adoption. The authors went on to discuss how the new technology should be diffused in the healthcare sector of a country as shown in Figure 4.

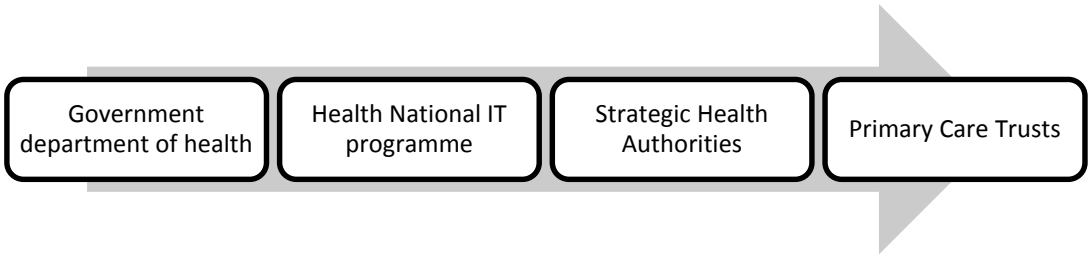



**Figure 4: New technology diffusion in government model**
Source:(Glenn et.al., 2009)

Zakareya & Zahir (2005) proposed an architecture that can be used in adopting ICT in a government. It consists of three main layers; the infrastructure layer, the e-Government layer and the access layer. The access layer comprises all the network infrastructures like servers, LANs, Internet and Intranet. The e-Government layer includes the web portals which can be one or more websites that provide the services to the citizens. The access layer, has two categories: the recipients of the services (citizens, government employees) and the channels through which the population access the services (mobile phones, websites, call centers).

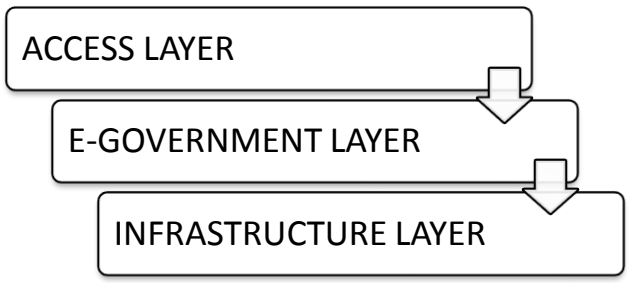



**Figure 5: ICT Adoption Architecture in Government**
Source: (Zakareya & Zahir (2005)

A study done by the United Nations (UN) in 2010 on the presence of e-government in Africa used a five-phase benchmark for the assessment shown in Figure 6.

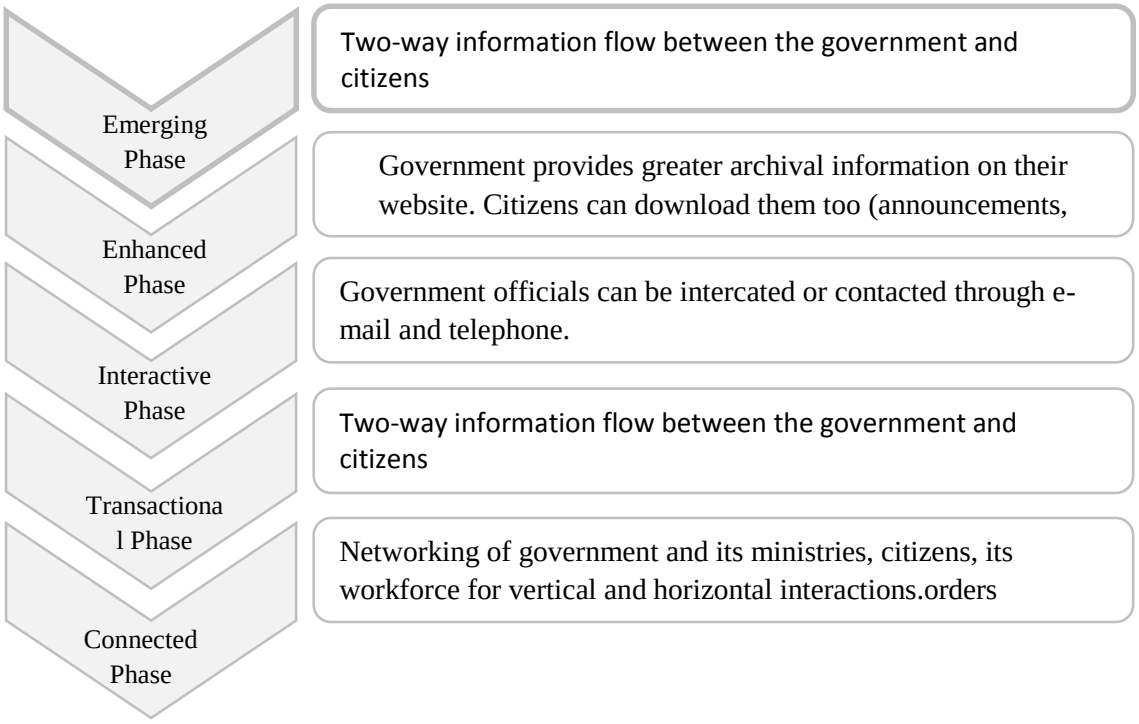



**Figure 6: UN five-phase e-government assessment benchmark, Source: (UN 2010)**

The studies done on ICT adoption in governments discussed above show a common trend; they all focus not on categorizing the factors to assess but the process that needs to be followed when assessing the adoption. This inspires the study to not only provide factors to assess but also establish the exact process that need to be followed.

### 2.5.4 BDA Adoption models and factors

Dale et.al (2016) conceptualized an adoption model for the healthCatalyst BDA system in healthcare as a nine steps process that starts from the collection and storage of data in a data warehouse, proceeding to a standardized patient registry and automated reporting system all the way to the health management of the population and finally a predictive data analytics system as shown in Figure 7.


**Figure 7: BDA adoption model in healthcare**
**Source: (Dale et.al., 2016)**

On his part, Nayem (2016) proposed a list of ten factors that can be used in assessing the adoption of a BDA system in an organization shown in Table 3. These factors are focused on the technological aspect of adoption in an organization. Nayem centered his study on the technology to be adopted and the technology already in use. Although he proposed important factors that need to be considered, a complete adoption study in an organization has to assess the organizational and environmental aspects of the adoption in order to understand the environment in which the technology is being adopted.

**Table 3: BDA adoption factors**

| FACTOR | DETAILS |
|---|---|
| **Perceived advantages** | Technical superiority in terms of costs and functionality on the existing systems |
| **Compatibility** | Compatibility with existing systems, skills, work practices, potential adopters |
| **Ease of use** | Reduced movement once data lands in HDFS from heterogeneous sources, analytical, machine learning and reporting tools |
| **Flexibility** | Consolidated data from various sources into one single place |
| **Real time decision making abilities** | Analysis of the data in real time using streaming technologies and preforming predictive analytics |
| **Security and privacy considerations** | Data privacy, confidentiality and identity issues |
| **Scalability and latency** | In terms of storage, data processing and mining algorithms |
| **Professional vendor support** | Most BDA systems are open source |
| **Organizational size** | Size of the workforce in IT, learning and maintenance tools, company resources, technical expertise |
| **Data storage and processing** | The storage capacity and data processing of BDA technology like Hadoop |

Source: (Nayem, 2016)

In a study done by Maurice & Chris (2008) on the adoption of e-health in South Africa, the authors outlined the factors in Figure 8 to be crucial in the assessment. The benefit of these factors proposed by the authors is that they are specific for the health sector. But we have to note that e-health does not necessarily imply Big Data. Therefore, these factors have to be put into the Big Data context before using them.

1. Public health informatics (ICTs, public health information systems)
2. Interoperability between healthcare facilities and standards of interoperability
3. Access to information by patients and health workers
4. literacy and language level
5. Computer literacy and internet costs
6. E-health capacity building of healthcare workers
7. EHRs
8. Telecommunications and broadband access
9. National e-Health policies

**Figure 8: E-health adoption factors**

**S**ource: (Maurice & Chris, 2008)

Ian et al. (2000) study classified factors influencing adoption of information technology in healthcare into two main categories as shown in the Figure 9.

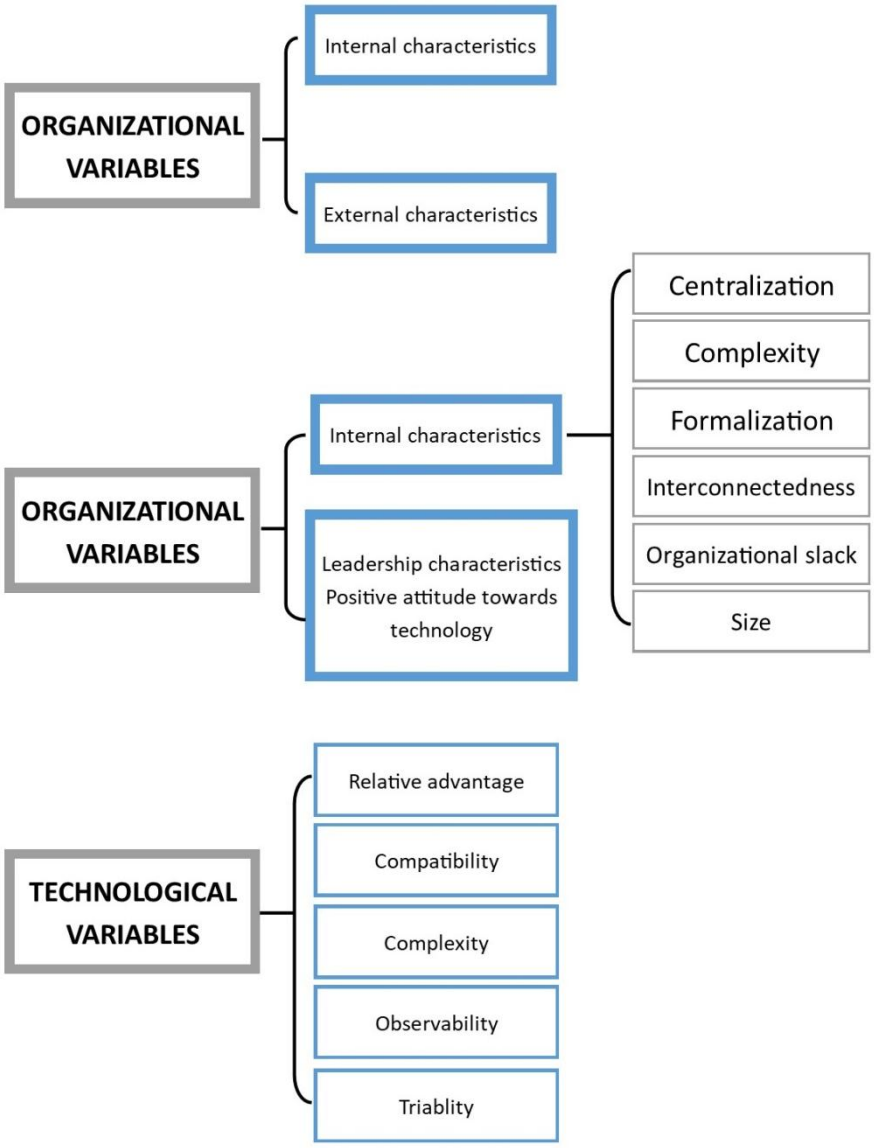



**Figure 9: Adoption of information technology in healthcare factors**

In conclusion, Ana and Antonio (2006) proposed factors categorized in organizational (internal factors to the organization), environmental (external factors to the organization) and technological factors. The other study that proposed similar factors is (Ian et al. 2000) which discussed mostly factors on the organizational and technological aspects of the adoption. But others like the WEF global IT report of 2015 and (Maurice and Chris, 2008) went further to discuss factors that influence the adoption of new technology up to the government level. Only Maurice & Chris (2008) focused on healthcare but only the technological aspects of the adoption. Nayem (2016)

did not only point out the research gap in adoption factors that influence the adoption of BDA but went further to propose a list of technological factors that can be considered for BDA adoption. Additionally, Glenn et al. (2009), Zakariya and Zahari (2005) and (UN, 2010) emphasized on adoption processes. Consequently, to assure a successful adoption assessing the right factors is not sufficient unless an accurate adoption process is used to assure that everything is done according to the adoption model.

### 2.5.5 E-readiness

E-readiness is defined as the ability of an organizational unit to be prepared and willing to use an information technology innovation in order to benefit from its competitive advantages. In other words, it is the evaluation of the level of fulfillment of the requirements in adopting the new technology. Gilani (2007) defines E-readiness in healthcare as the level of preparedness of healthcare institutions or communities in adopting change brought by information and communication technologies.

Several authors have provided parameters that can be used to assess e-readiness. Amongst them include Ahmed et al. (2018), Motau (2016), Nasser et al. (2007), Louise et al. (2001), Ahmed & Hussein (2006), Shariq et al. (2007).

Ahmed et al. (2018) discussed employee readiness for e-business (EREB), a multi-item scale assessment tool developed by Jung-Lu and Chorng Shyong (2001). The assessment tool breaks-up the constructs into 4 dimensions: security, benefits, collaboration and certainty. Ahmed conceptualized these dimensions using the Technology Acceptance Model (TAM) thanks to which every dimension was attributed 2 factors for the assessment.

Motau (2016) discussed factors that influence the assessment of Big Data readiness. The factors to consider are: (1) Management support, (2) IT infrastructure, (3) Security

concerns, (4) Finances, (5) competition, (6) Customers, (7) Vendors, (8) Organization size.

Louise et al. (2001) described in their study a multi-stage readiness assessment process. Termed the Cloverleaf model because of how it identifies the four main requirements for success: market readiness, technology readiness, commercial readiness and management readiness. The assessment tool was customized to be used in different environments for unique situations of users.

Ahmed & Hussein (2006) proposed a readiness assessment model for e-Government. The assessment is done in six phases to guarantee that the implementation is done in the right direction. The model proposed by Ahmed and Hussein (2006) shown in the Figure 10 can be used as a general guideline for e-government initiatives since every government has its own objectives and priorities. This model goes beyond organizational and technological aspects and involves the canonical form of the government performance. It emphasizes on the legal part of the government by evaluating how new procedures that involve new technologies are formally regulated. This includes laws, directives, regularity issues and government service delivery.

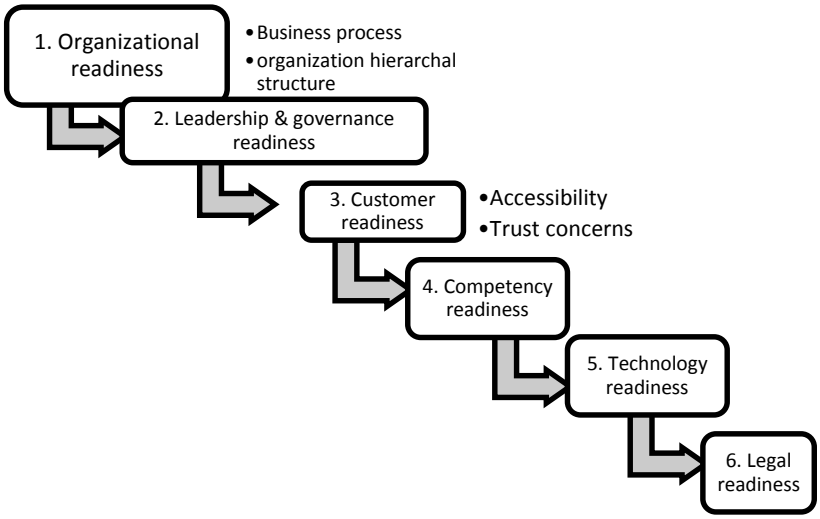



**Figure 10: e-readiness assessment model in government**
Source: (Ahmed & Hussein, 2006)

Nasser et al. (2007) in an empirical study done on the assessment of e-readiness in Arab countries they mentioned that the first step in promoting e-government in developing countries is conducting an e-Readiness assessment. Nasser et al. (2007) also add on that e-Readiness assessment can also be an important tool in evaluating the impact of ICT. In the literature done by the authors on e-Readiness assessment models, the analysis showed that most of the models deal with infrastructure and technology, people and human skills and accessibility and connectivity. But Nasser et al. (2007) chose to work with 3 interrelated variables: human skills, infrastructure and connectivity. They concluded by stating that each assessment tool or model is different and it cannot fit every user's needs. Therefore, the user should choose carefully after establishing a clear understanding of the kind of results they want.

Shariq et al. (2007) study objectives were to develop e-health readiness assessment tools for public and private healthcare institutions for developing countries and to test them in Pakistan. They proposed E-readiness assessment tools that use questionnaires developed using the sequential exploratory design. The questionnaires targeted managers and healthcare providers with 54 questions and 51 questions respectively.

The questions were classified into 5 categories: core readiness, technological readiness, learning readiness, societal readiness and policy readiness. The core readiness category addressed the planning process of the technology to be adopted. The technological category addressed the availability and affordability of the required ICT, the hardware and the software components required. The learning category addressed the issues related to the programs and resources that provide ICT training to healthcare providers. The societal category addressed any existing interaction between the healthcare institutions. Lastly, the policy category addressed the existence of policies at the institutional level and government level. This last category dealt with issues related to the legal and regulatory framework and the political will of the government. The tools used a scoring system of 1 to 5 whereby each item had a score between 1 and 5.

Shariq et al. (2007) study was very crucial to this study in two ways. On one hand it studied the readiness assessment not only at the institutional level but at the government level by giving specific items to assess at each level. And on the other hand, it gives a clear and specific scoring technique. The authors proposed a readiness assessment model shown in Figure 11 which includes specific factors that need to be addressed at each core readiness level.

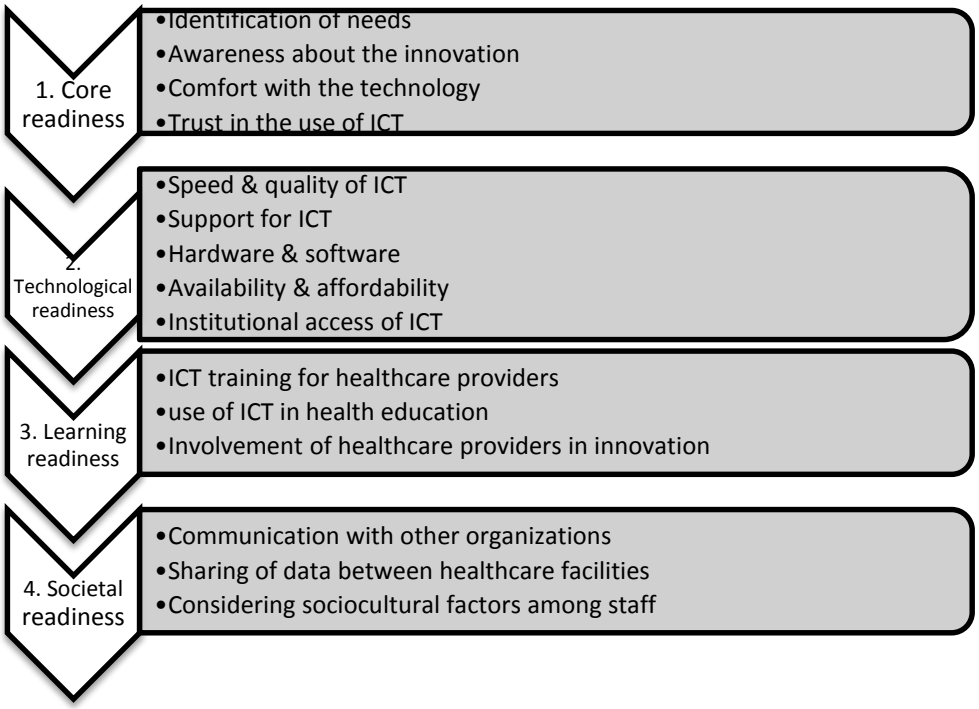



**Figure 11: e-readiness assessment model in healthcare**
Source: (Shariq et al. 2007)

### 2.5.6 BDA adoption requirements

In order to establish the factors to be included the proposed adoption model, an understanding of the requirements of a BDA system in healthcare services was considered necessary. The following section looks at some of these requirements.

#### 2.5.6.1 Technological requirements

One of the first questions that need to be answered before adopting a BDA system is how to select the appropriate hardware for the system. The ideal selection of hardware must provide a balance between performance and affordability. Equally important is to consider is the hardware and software applications that are already being used.

Datameer, a BDA platform company, recommended on their BDA implementation checklist of technical requirements that any organization that want to use a BDA system needs to consider: First, cloud-based solutions because they can get them running up

faster and they are cheaper and secondly, hardware needed including CPU, RAM, Hard Drive storage capacity, network infrastructure and the electricity consumption.

BDA systems have specific infrastructure requirements that need to be considered before implementing them. FedTech Magazine (2017) article on "*4 infrastructure requirements for any Big Data initiative"* identify in their article four main requirements: (1) Storage solutions that are optimized for Big Data, (2) Processing power that can support BDA applications, (3) Select a product that fits exactly the organization's functions and objectives, (4) Robust networking hardware that can support 10 Gigabit connections.

Since the study implies adoption on a national scale and not just in one organization, the main technical aspects to consider are (Nayem, 2016), (Maurice & Chris, 2008), (Shariq et al. 2007) and (Dutta et al. 2015):

- The network infrastructures covering the country for the interconnection of the health facilities and the ministry on one part and the network infrastructures in each facility and the ministry on the other part,
- The storage infrastructures for the collection of the data in the facilities and the ones in the ministry for the centralized data storage.
- The processing infrastructures which are in charge of the data classification and analysis in order to provide useful insights gained from the data collected from the healthcare facilities.

A BDA system collects data from existing systems which means that the healthcare facilities must have software applications that support them in collecting information from patients to store them as health records. Additionally, the facilities must be interconnected to the ministry permanently for it to collect information in real-time to

store it in a centralized database and most importantly to analyze the data with the aim of providing useful knowledge.

#### 2.5.6.2 Organizational requirements

The success of a technology innovation adoption in any organization does not only rely on the technical aspects of the innovation but also on critical organizational aspects. The following are the organizational requirements to take into consideration in order to successfully implement a BDA system in healthcare (Ian et al. 2000), (Dutta et al. 2015) and (Maurice et al. 2015):

- The stakeholders: all the stakeholders should be identified. In this case, all the health workers in the facilities and the ministry of health are to be considered. This identification implies their categorization by role in order to define the level of access to the data for each stakeholder.
- The organization's culture: the organization must be willing to accept a cultural shift which expects data-driven and fact-based decisions. The leadership needs to emphasis on optimizing the organization's performance through quantitative measurements.

According to HealthCatalyst, one of the leading Big Data companies in healthcare, any organization that wants to adopt a BDA system must use data-driven methods that are linked to the organization's strategic priority and ensure that the organization's management fully supports the initiative and provides all the necessary resources. Also, the administration of the organization must partner with the IT department to define the data needed and grant access to data in an efficient and effective manner and equip its employees with the necessary skills.

Turning to the study, these organizational requirements are used to establish the specific factors that need to be considered when discussing the conceptual framework of the study. Based on this literature, defining the key stakeholders, acquiring the leadership's support and training the staff are the most important organizational requirements of BDA adoption in healthcare.

#### 2.5.6.3 Environmental requirements

The environmental requirements reflect the external environment of the organization. For the healthcare facilities this includes the different facilities, health institutions and organizations (Michael, 2016). BDA systems require a strong collaboration between these entities and the proper way to achieve this for them to build trust and improve their way of sharing information. Another environmental requirement discussed by this author is the willing to adapt to the pressure from competitors. This implies that an organization or institution should keep up with new technologies that are being used by competitors to assure that they do not lose their competitive advantage. In order to assure that the adoption of a BDA system on a national level is successful in the public healthcare sector, the facilities must work on similar standards and technologies to facilitate interoperability and sharing of information. In African countries one of the main reasons slowing or even blocking the adoption of BDA systems is that they usually require external financial and technical support to be able to afford them (Kalyan, 2015). Consequently, external support is almost unavoidable for the adoption to take place.

#### 2.5.6.4 Political and regulatory requirements

Any Information Technology that is to be adopted by a government involves a number of major political and regulatory factors that must be taken into consideration. According to the WEF Global IT report of 2015, one of the main requirements for a

BDA adoption to be successful in a government is political stability and security. It further stipulates the need of laws on the protection of intellectual property. This is crucial because the adoption of a BDA system implies the sharing of personal medical data of thousands even millions of patients between healthcare facilities. In addition, Kalyan (2015) stresses on the need for the government to put in place low tax rates on new technologies and adopt supportive policies and regulations on information technologies in healthcare.

### 2.6 BDA Adoption in Africa

Finbarr (2017) stated that over 2.5 quintillion bytes of data are generated worldwide every day and that 80% of the data generated in Africa is unstructured. This shows how the continent needs to adopt BDA systems to gain useful insights from those unstructured data. Nadeen (2017) stated that investments in BDA in Africa in 2016 were concentrated in the government sector, financial sector and telecommunications. As for the other sectors like healthcare and transport have a longer-term growing potential which means that BDA will be more profitable when invested in these sectors for African countries.

Jessica & William (2013) discussed about a survey conducted by Accenture Development Partnerships (ADP) and NetHope on 300 business decision makers, 25 international non-governmental organizations, and 20 thought leaders. The findings showed that 90% believe BDA is becoming the most important tool in delivering better insights on information, 70% are already using BDA to track their activities, 59% are investing in BDA, 57% of African business leaders considered BDA as an investment area for them, and globally 41% are boosting their spending in BDA. According to Africa Data Forum, the Middle East and Africa spending in BDA had reached $2.2

billion in 2017. In 2016, 20.4% was in government sectors, 19.2% in the financial sector while 13.3% went in the telecommunication sector.

Another survey conducted by EMC in South Africa in 2013 was also discussed by Jessica & William (2013) and the outcomes showed 83% reported that decisions in their organizations could be improved with BDA, 53% agreed that senior teams in organizations trust BDA insights and 38% have achieved a considerable competitive advantage. However, 23% of the surveyed companies had no plans to implement BDA while 64% believe that BDA is the most important factor for overall business decision-making and 74% reported that their business sees BDA as a strategic way of achieving their goals.

### 2.6.1 Empirical studies done on Big Data in Africa in Healthcare

A number of studies have been done on big data usage to improve healthcare in African countries. The studies done so far are on the implementation of centralized EHR databases as shown in Table 4. These studies however focus on the technical aspects.

**Table 4: Empirical studies done on BDA in Africa**

| | | |
|---|---|---|
| **BOTSWANA** | Hybrid data capture for monitoring patients on highly active antiretroviral therapy ( HAART) in urban Botswana | Bussmann et.al, 2006 |
| **NIGERIA** | Experience implementing OpenMRS to support maternal and reproductive health in Northern Nigeria | Thompson et.al., 2010 |
| **MALAWI** | Experience implementing a point-of-care electronic medical record system for primary care in Malawi | Waters et.al., 2010 |
| **KENYA** | Leapfrogging paper-based records using handheld technology: Experience from Western Kenya | Martin et.al., 2010 |
| **MOZAMBIQUE** | Implementing OpenMRS for patient monitoring in an HIV/AIDS care and treatment program in rural Mozambique | Manders et.al., 2010 |
| **KENYA, UGANDA, TANZANIA** | Experience implementing electronic health records in three East African countries | William et.al., 2010 |
| **GHANA** | Combining vital events registration, verbal autopsy and electronic medical records in rural Ghana for improved health services delivery. | Ohemeng et.al.,2010 |
| **RWANDA** | Using electronic medical records for HIV care in rural Rwanda | Akimana et.al., 2010 |
| **RWANDA** | Rapid deployment of electronic medical records for ARV rollout in rural Rwanda. | Allen et.al., 2006 |
| **MALI** | Open source challenges for hospital information system (HIS) in developing countries: a pilot project in Mali | Bagayoko et.al., 2010 |
| **SOUTH AFRICA** | Identification of losses to follow-up in a community-based antiretroviral therapy clinic in South Africa using a computerized pharmacy tracking system. | Nglazi et.al., 2010 |

Like earlier observed, Table 4 shows clearly that studies done on BDA adoption in healthcare in African countries are focused only on the technical aspects more specifically on the implementation and deployment of the systems. This points out the

need to study not only how the technology is implemented but also how it can be adopted effectively in African countries.

### 2.6.2 BDA systems implemented in healthcare in Africa

A number of African countries have started using BDA technologies to improve their healthcare services on a national scale. The table below shows successful projects implemented in 6 African countries that have already taken a step forward in using BDA systems in healthcare. (World Health Organization WHO).

**Table 5: African countries using BDA in healthcare**

| COUNTRY | PROJECT | DESCRIPTION |
|---|---|---|
| **Algeria** | Gemalto Electronic Healthcare Project (Chifa) | An EHR centralized database with 700.000 patients used by health professionals to manage patients' records, issue prescriptions. |
| **South Africa & Cameroun** | Genesis Telecare | Health information systems, hospital management systems, confidential data transmission, integrated medical records reports and storage, reports. |
| **Zambia** | Smart Care | EHR system, distributed database systems, Geographic Information System (GIS) data visualization from health surveys. |
| **Ghana** | DHIMS2 (District Health Information Management System) | Health management information solution for reporting and analyzing needs of health facilities at all levels. (covers 170 districts) |
| **Uganda** | mTrac | Enables real-time monitoring of disease surveillance, drug stock and health service delivery built on a web-based data aggregation and analysis platform |

**Source: (Moretlo, 2010) An Assessment of e-Health Projects and Initiatives in Africa Prepared for World Health Organization**

According to *Data Center Map* (2017) 11 countries have implemented Data Center facilities (Algeria, Angola, DR Congo, Ghana, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tanzania and Tunisia) with a total number of 53 which is only 1.2% of the estimated total number (4136) of data centers worldwide.

Some countries have started using them through e-government which consists of public service delivery through web portals like Kenya with eCitizen which qualifies as a big data application due to the amount of data it processes. In the private sector, we have big companies like Safaricom in Kenya that implemented Mpesa; a mobile money transfer application that has literally changed banking in Kenya with 21.8 million registered users with approximatively 19 million active users monthly and Naspers in South Africa.

Even if the continent has a negligible number of data centers, some countries and international organizations have taken advantage of BDA to improve the well-being of Africans. Notable examples include Direct Relief International which uses BDA to analyze weather data to help natural disasters and storms victims, The Grameen Foundation which uses mobile-based information to offer information about crop prices, health issues and weather conditions in developing countries, more specifically in rural areas and a Harvard epidemiologist who used fifteen million mobile phones records from Kenya to track hotspots where malaria was being transmitted (Jessica & Brindley, 2013). According to these authors, Kenya is the first country in Sub-Sahara to implement an open data web portal that allows citizens to track hospitals and doctors in their areas using the MedAfrica application. Later on, another portal was launched in Morocco to allow educators, parents and students to monitor school reports problems and funding. Another example is The Clinton Health Access initiative (CHAI) which uses BDA to provide updated forecasts of demand for medications for HIV/AIDS, tuberculosis and malaria which allows greater availability and also the ability to provide cheaper drugs (WEF, 2015).

BDA is still a new technology that African countries are timidly trying to adopt. The studies done so far on BDA in Africa are focused on technical aspects of the technology

which reveals the need to study the factors that influence its adoption in African countries. The few countries that have taken a step forward in using BDA in healthcare, the projects were initiated by private organizations and foundations like MedAfrica, CHAI and Direct Relief International. This fact proves how little African governments are involved in new technology adoption in Healthcare and that they have to wait for a donor or NGO to initiate such projects.

## 2.7 Conceptual Framework

This section intends to discuss the TOE adoption theory, how it is relevant to this study and conceptualize the TOE-Based adoption model that was used to develop the ARAT.

### 2.7.1 Introduction

The TOE framework has been used in multiple Information Systems adoption studies like ERPs, E-Commerce and patients tracking RFID (Michael, 2016). It provides a proven framework that enables studies of IS adoption across a variety of innovations. The advantage of this framework is that it expands the adoption debate beyond technological aspects and integrates perspectives of the organization and the external environmental aspects.

The automated adoption readiness assessment web-based tool (ARAT) was conceptualized through the TOE adoption framework. The study evaluates theoretically proven factors for new information systems adoption. In order to empirically test the ARAT, an assessment was conducted on 7 public hospitals in Burundi.

### 2.7.2 The TOE adoption framework

The TOE framework identifies three main adoption contexts that influence the process of adoption and implementation of a technological innovation in an organization:

technological context, organizational context, and environmental context shown in the figure 12.

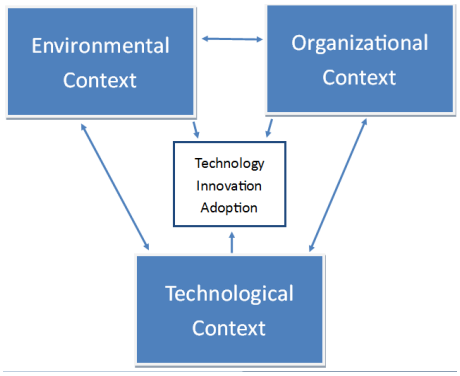



**Figure 12: TOE Model**
(Oliveira et.al., 2011)

The *Technological context* describes the internal and external technologies relevant to the firm. It basically includes the current practices and equipment internal to the organization and the available technologies external to the organization or the technology that is to be adopted. The *Organizational context* describes measures about the organization such as scope, size, and the managerial structure. The *Environmental context* is the arena in which the organization conducts its business, its industry, competitors.

In their study Dal-Woo et al. (2015) proposed an adoption process of BDA using the TOE framework. They cite its ability to describe the process of adoption and implementation of technological innovations as the main reason that influenced their choice of the TOE framework. As shown in Figure 13, the authors added pre-adoption and post-adoption stages to deal with the awareness and the evaluation phases respectively.

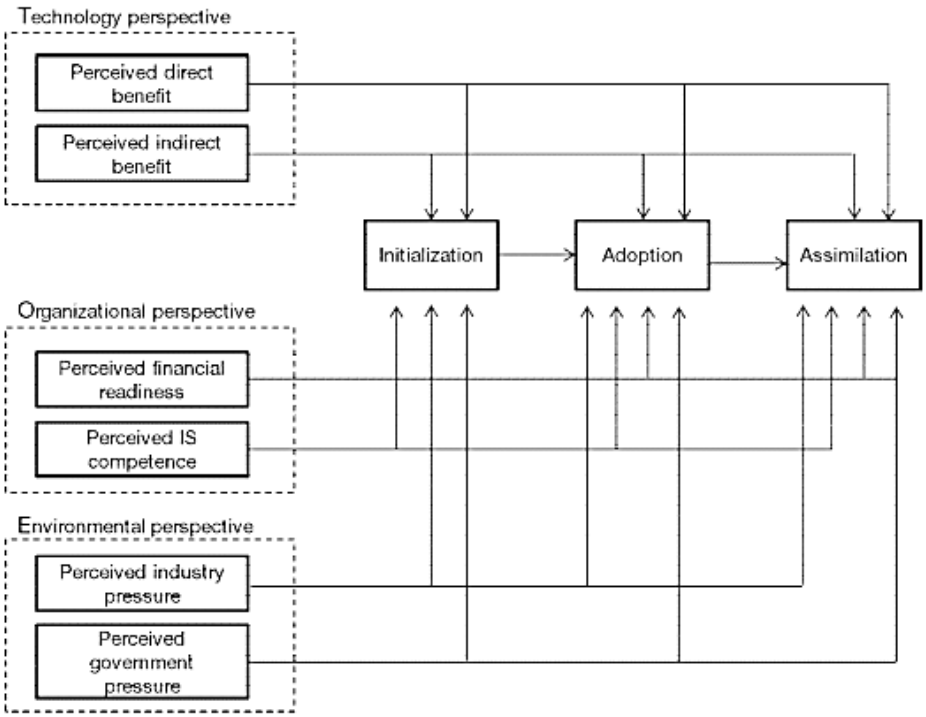



**Figure 13: TOE BDA adoption process**
Source: Dal-Woo et.al., (2015)

### 2.7.3 ARAT Conceptual model

The ARAT was conceptualized through the TOE framework which has three (3) main contexts of adoption (technology, organization, and environment). Since the study is on public healthcare services it involves directly the government therefore another context is added to emphasize on the role of the government in the adoption process. Therefore, the new TOE-based adoption model has 4 main contexts: Technological, Organizational, Environmental and Political and Regulatory as depicted in Figure 14:

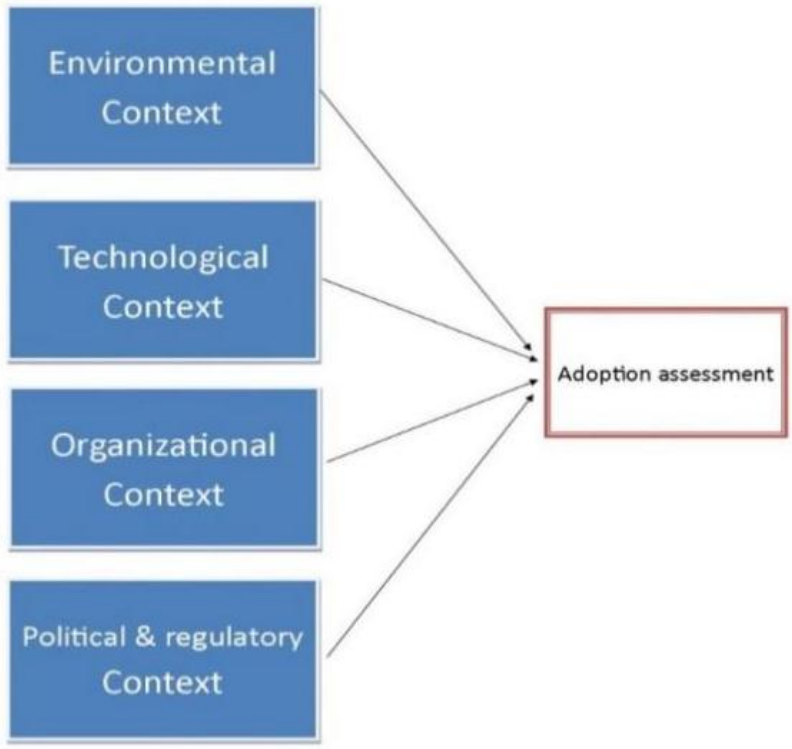



**Figure 14: ARAT Conceptual model**

### 2.7.5 The adoption factors of the new TOE-based adoption model

The factors established in Table 6, 7, 8 and 9 are theoretically proven factors adapted for BDA adoption in healthcare public services.

**Table 6: Technical factors**

| Factor | Reference | Relevance |
|---|---|---|
| **Compatibility** | Nayem Rahman, 2016 | Evaluates if the existing techniques used would be compatible with the system to be adopted. |
| **Connectivity** | Maurice & Chris 2008 | Evaluates the level of internet usage, the level of interconnectivity between the hospitals and the ministry of health. |
| **Consumer sensitivity** | Shariq et al. 2007 | The BDA system would be effective if the ministry and the hospitals are conscious of its importance. |
| **Electricity Production** | Dutta et al. 2015 | Electricity is one of the basic needs that must be provided to assure the success of the adoption of any Information System. |
| **Fixed Broadband** | Dutta et al. 2015 | Evaluates the existing Metropolitan networks in the country. A BDA system requires a permanent network that has a very high availability ratio and a country wide coverage. |
| **Interoperability and standards** | Maurice & Chris, 2008 | To facilitate the collection of data and the analysis standards are a requirement that must be fulfilled. |
| **Public health informatics** | Maurice & Chris, 2008 | BDA systems collect data from existing information systems. So this factor evaluates the existing systems if there are any. |
| **Real-time decision making** | Nayem Rahman, 2016 | Evaluates how fast can the BDA system generate reports. They are best known to be real-time. |
| **Security and privacy issues** | Nayem Rahman, 2016 | Health records are personal information that require high level of privacy and strict security measures. |

**Table 7: Organizational factors**

| Factor | Reference | Relevance |
|---|---|---|
| **Awareness about the innovation** | Shariq et al. 2007 | The first step in adopting a new technology is to make sure that the organization adopting it is aware of it. |
| **Demographic variables** | Dutta et al. 2015 | Evaluates the demographic variables to see if the intended system is needed or relevant. |
| **E-health capacity building of healthcare workers** | Maurice & Chris, 2008 | Evaluates how often the employees that will use the system are trained. |
| **IT knowledge** | Maurice & Chris, 2008 | Evaluates if the IT officers are academically qualified. |
| **Leardership attitude towards the innovation** | Ian et al. 2000 | The level of support from the ministry officials |
| **Organizational culture** | Ian et al. 2000 | This factor evaluates if the use of ICT is included in the hospital's and ministry's culture |
| **Resource availability (Finances)** | Dutta et al. 2015 | Adopting a new technology requires availability of resources. |
| **Size** | Ian et al. 2000 | The number of employees in the hospitals |
| **Top management support** | Ian et al. 2000 | The willingness of the government to support financially the adoption of the system |
| **Training and experience** | Dutta et al. 2015 | BDA systems require employees that already have IT usage experience or training. |
| **Trust in the use of ICT** | Shariq et al. 2007 | The BDA system will be effective if only the users (hospitals and the ministry of health) trust it. |

**Table 8: Environmental factors**

| Factors | Reference | Relevance |
|---|---|---|
| **Access to information by patients and health workers** | Maurice & Chris, 2008 | One of the importance of EHR centralized databases is to allow patients to access their health records. |
| **Communication with other organizations** | Shariq et al. 2007 | Insights gained from the collected data using the BDA system is not only useful to the ministry but also to its national and international partners. |
| **Competitive pressure** | Shariq et al. 2007 | This factor evaluates the pressure coming from other competitors that have already started using BDA systems. |
| **External environment** | Shariq et al. 2007 | Using the same technologies strengthen partnerships between neighboring countries. |
| **External pressure** | Shariq et al. 2007 | This factor evaluates if there is any Regional and/or international interconnectivity of healthcare institutions |
| **External resources** | Dutta et al. 2015 | The adoption of a new technology like a BDA system requires most of the time external financial support for African countries. |
| **Government pressure** | Dutta et al. 2015 | Any pressure coming from the central government can push the adoption of the BDA system. |
| **Involvement of healthcare providers in innovation** | Shariq et al. 2007 | This factor evaluates if healthcare providers (hospitals) contribute in technology innovation |
| **Outside support** | Dutta et al. 2015 | The adoption of the BDA system for African countries may require external technical support. |
| **Sharing of data between healthcare facilities** | Shariq et al. 2007 | This factor evaluates the level at which hospitals share information among them. |

**Table 9: Political and regulatory factors**

| FACTORS | REFERENCE | RELEVANCE |
|---|---|---|
| **Intellectual property protection** | Dutta et al. 2015 | Health records are very sensitive information that need to be under strict protection and privacy policies. |
| **Procedures to enforce a contract** | Dutta et al. 2015 | BDA systems are developed by big companies and buying them is sometimes a long administrative process. |
| **Tax rate** | Dutta et al. 2015 | The tax rates on new technologies can impact the adoption of the system. |
| **Importance of ICT to the government vision of the future** | Dutta et al. 2015 | This factor evaluates if the government include the importance of using ICT in healthcare in its vision for the future |
| **Government success in ICT promotion** | Dutta et al. 2015 | The adoption the BDA system may be influenced by previous technology adoptions. |
| **National e-Health policies** | Maurice & Chris, 2008 | Having a e-Health policy is very important before adopting a BDA system to assure that it is used in a well-defined environment. |

### 2.7.6 The TOE-based BDA adoption model

The Figure 15 shows the conceptual model of the Automated Adoption Readiness Assessment Tool (ARAT).

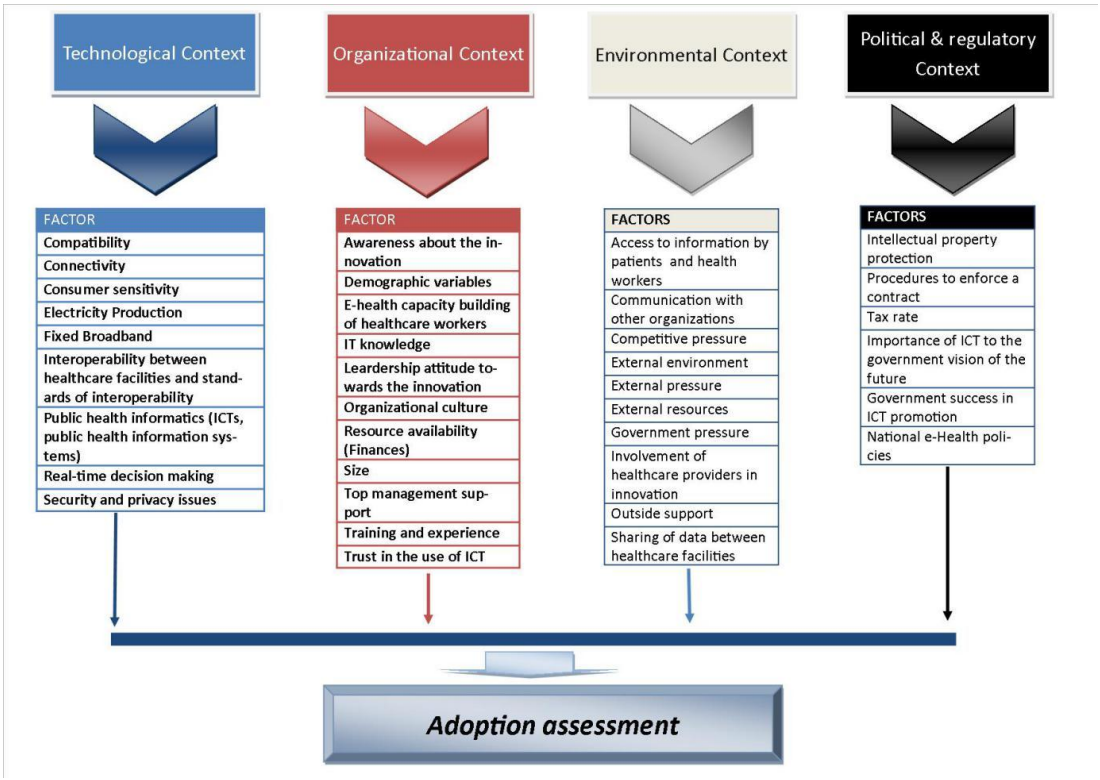



**Figure 15: TOE-Based BDA adoption model**

## 2.8 Chapter Summary

The literature review conducted shows that BDA in healthcare is the analysis of huge data sets of medical data like genomic data, personal health records of patients and web and social networking data. These data are gathered from different types of sources.

As for BDA adoption models and factors, Ana and Antonio (2006) and Ian et al. (2000) proposed in their studies factors on organizational and technological aspects of adoption. But others like the WEF global IT report of 2015 and (Maurice and Chris, 2008) went further to discuss factors that influence the adoption of new technology up to the government level. Only Maurice & Chris (2008) focused on healthcare but only the technological aspects of the adoption. Nayem (2016) pointed out the research gap in adoption factors that influence the adoption of BDA and proposed technological factors that can be considered for BDA adoption. As for Glenn et al. (2009), Zakariya and Zahari (2005) and (UN, 2010) their focus was on adoption processes.

Consequently, to assure a successful adoption assessing the right factors is not sufficient unless an accurate adoption process is used to assure that everything is done according to the adoption model. A list of summarized adoption factors that were considered for this study was given in Table 6. The adoption framework chosen for the study was discussed in the conceptual framework. The adoption framework was conceptualized, shown in Figure 15, to propose a tailored adoption model that was used to develop an automated assessment tool.

The studies done so far on BDA in Africa are focused on technical aspects of the technology which reveals the need to study the factors that influence its adoption in African countries. The few countries that have taken a step forward in using BDA in healthcare, the projects were initiated by private organizations and foundations like MedAfrica, CHAI and Direct Relief International.

Overall the literature review revealed the following:

- The studies done so far are focuses more on the technical aspects of BDA and less on its adoption,
- The adoption models of BDA in healthcare proposed so far deal with the organizational and technological aspect of the adoption,
- About 6 African countries are using BDA in healthcare on a national level,
- African governments are not seriously involved in the adoption of BDA in Africa because the few projects that have been successful were done by private organizations,
- There is no adoption model perfect on itself, the choice of an adoption model depends on the study and factors can be borrowed from other models to customize your model.

# CHAPTER THREE

# RESEARCH METHODOLOGY

The aim of this study was to propose a BDA adoption model for Burundi's healthcare services in public hospitals. To achieve this, five objectives were used:

1. Examine the factors that influence the adoption of BDA in public healthcare services using the TOE adoption theory,
2. Investigate the methods used by the ministry of health to collect, store and analyze medical data from public hospitals of Burundi,
3. Assess the readiness of Burundi in adopting a BDA system in its public hospitals using the ARAT developed in objective two,
4. Propose a tailored BDA system adoption model for improving Burundi's public healthcare services.

## 3.1 Research Design

The intent of this study was to propose a tailored adoption model for a BDA system to improve healthcare services in Burundi. To successfully investigate how the National Health Information System in Burundi works and assess the adoption readiness level in adopting a BDA system with the view to propose a tailored adoption model a descriptive research design was used. This research design allows to obtain information concerning the current state of the National Health Information System and describe it exactly how it is. The study's objectives were achieved using a mixed research method through three main phases using qualitative and quantitative research methods. The first phase was to examine the factors that influence the adoption of BDA in healthcare services using a qualitative research method. The second phase of the study was to survey the sampled public hospitals in order to investigate how the National Health

Information System works using qualitative data collection methods which are semi-structured interviews, observations and document reviews. The third phase was to assess the readiness of Burundi in adopting a BDA system in public hospitals using a quantitative research method and the third phase was to develop a tailored adoption model both using the quantitative research method. Figure 16 shows briefly how the research was conducted.

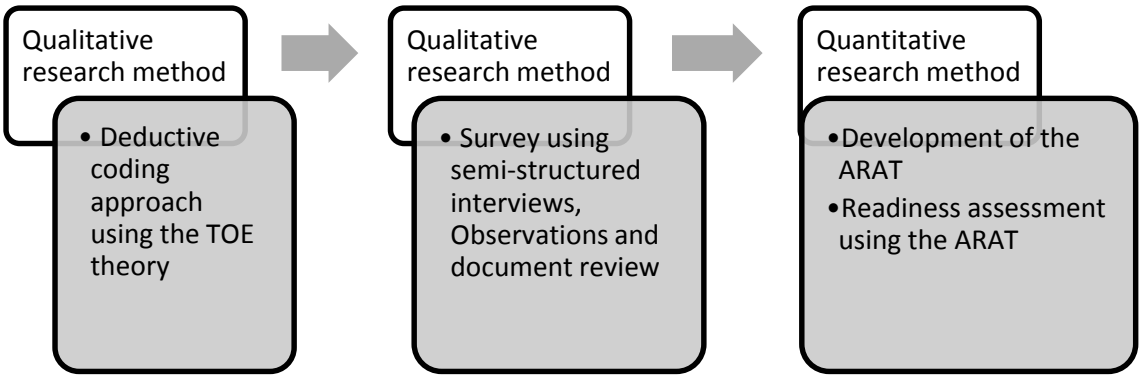



**Figure 16: Research design**

### 3.2 Population and sampling

The study was done on Burundi's public hospitals. The country has 61 public hospitals classified into 4 categories: district hospitals, provincial hospitals, regional hospitals and national referral hospitals. To sample the hospitals, three sampling techniques were used:

- Stratified sampling: is a probability sampling technique that is used to divide the entire population into subgroups. The four categories of Burundi's public hospitals (district hospital, provincial hospitals, regional hospitals and national referral hospitals) were used as the strata.
- Convenience sampling: is a non-probability sampling technique that is used to select subjects by considering their accessibility and proximity. All the

national referral hospitals are located in the capital city of Bujumbura which makes them easily accessible. The provincial and regional hospitals are located each in its respective province, the nearest is at 40 km which requires at least one-hour drive. And the furthest is at 280 km which is a 7-hour drive. Burundi is a mountainous country which makes it hard to access some locations especially district hospitals. Therefore, due to the difficulties in accessing these widely scattered public hospitals and limited resources at the researcher's disposal 3 national referral hospitals, 1 regional hospital, 3 provincial hospitals and 2 district hospitals were selected. Unfortunately, one national referral hospital, one provincial hospital and one district hospital declined to participate leaving only 6 out of the 9 hospitals selected, successfully surveyed.

Figure 17 shows the hospitals at which the data collection was conducted:

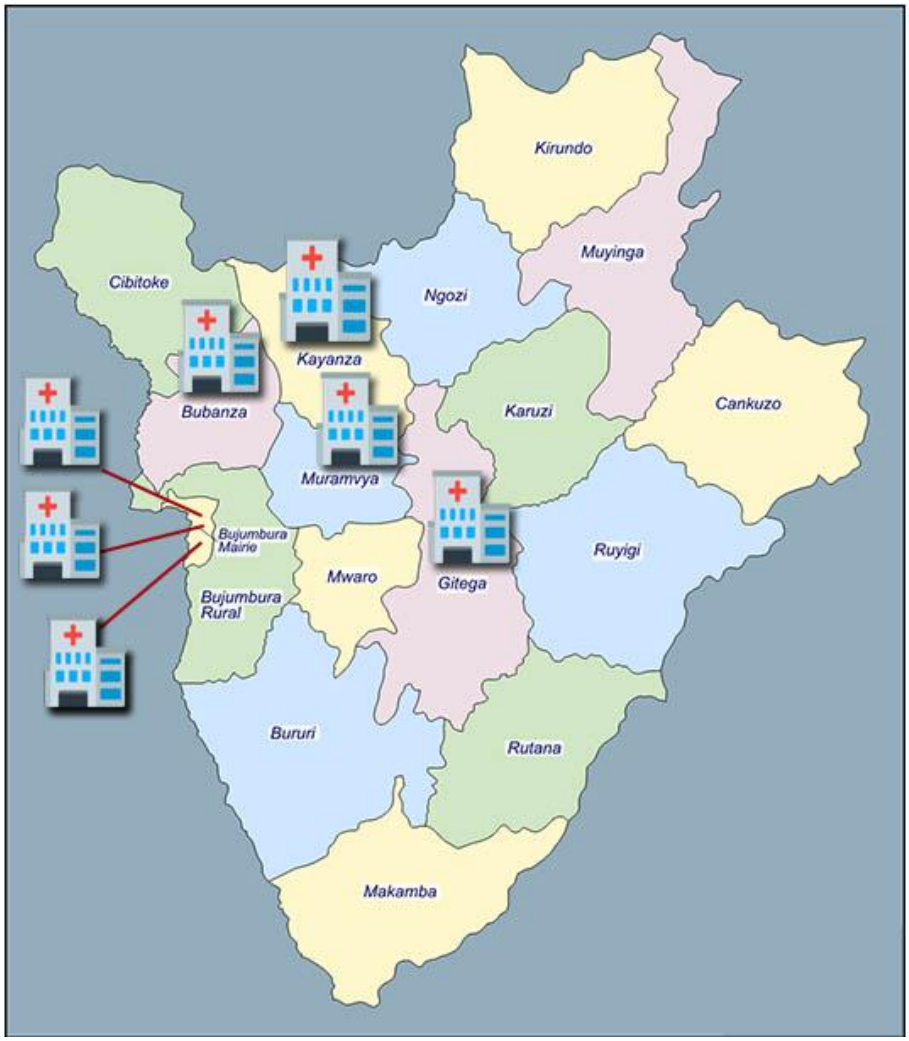



**Figure 17: Hospitals surveyed**

- Purposive expert sampling: this sampling technique is used to sample a population based on the expertise and information needed for the study. In the case of the study, the number of the interviewees was not as critical as the quality of information gained. The targeted interviewees were the IT managers, the hospital directors and officials from the health information system office of the ministry of health as shown in Table 10.

**Table 10: Interviewees**

| Hospitals | Medical Directors | IT Managers |
|---|---|---|
| **National Referral Hospitals** | 2 | 2 |
| **Regional Hospitals** | 1 | 1 |
| **Provincial hospitals** | 2 | 2 |
| **District hospitals** | 1 | 1 |
| **Total** | **6** | **6** |

### 3.3 Desk Research

A desk research was performed to give a general overview of Information Technologies adoption factors and models, BDA and its usage in various sectors, more specifically the healthcare sector. A desk research was conducted to establish the factors that influence the adoption of BDA systems in healthcare services in public hospitals. This was done by reviewing related studies (empirical studies, publications, reports and books) that are found on reliable digital repositories like IEEE, Springer Link, Google Scholar, and others by searching using the following key words: Big Data, BDA, EHR, Descriptive Data analytics, BDA in healthcare, BDA adoption in Africa. This desk research helped in giving a theoretical background of the adoption factors and the adoption model used to build the assessment tool.

### 3.4 ARAT Conceptual Model

After gathering factors that influence the adoption of BDA systems in healthcare, they were categorized using a deductive coding approach. The factors were classified into predefined categories using the TOE adoption theory. As a result, a new TOE-Based model with four main adoption contexts: technological, organizational, environmental, political and regulatory was conceptualized.

### 3.5 System Development Method (SDM)

System Development Method, shown in Figure 18, was used to build the ARAT assessment tool. The development process followed the waterfall development process The programming framework used was a combination of HTML, CSS, PHP and JAVASCRIPT programming languages to design the web-based assessment tool. The inference engine of the tool consists of the metrics from the factors studied on the first objective. At the implementation phase which is the third one, the ARAT was developed following the requirements determined at the previous phase. At the testing phase the web based assessment tool was tested to verify if the backend processing system works as anticipated and if the output is displayed as expected. At the last phase the ARAT was used to proceed with the assessment of Burundi and generate a full report of the assessment which was used to propose a tailored BDA adoption model for public hospitals.

The Waterfall Development Process makes it possible to departmentalize the project into sequential phases. It also kept a relatively static scope of the project and supported the completion of the full design of the system in the early stages which minimized changes throughout the development.

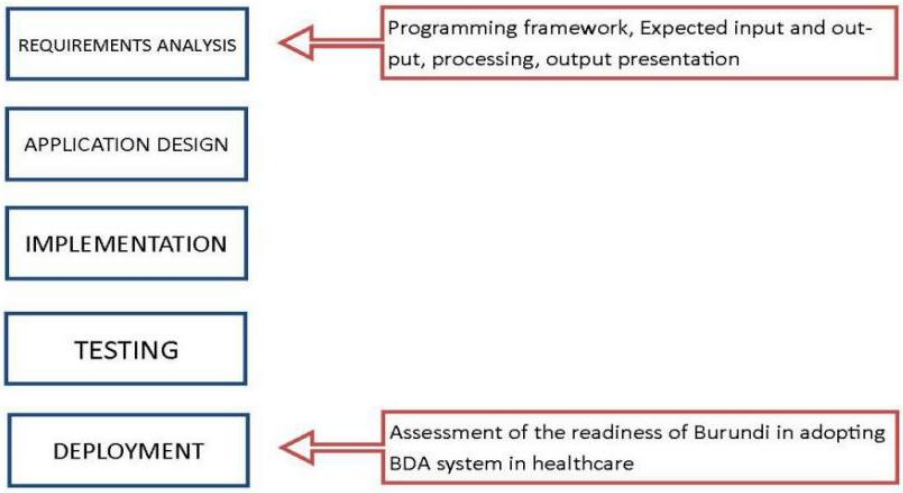



**Figure 18: Waterfall system development**

### 3.6 Data Collection

In order to achieve the last objective of the study, data from the health information system office of the ministry of health and selected public hospitals was collected through semi-structured interviews using interview guides, observations using a checklist and document review of the following documents from the Ministry of Health (CURRENT PROCEDURE MANUAL, ORGANIZATIONAL CHART OF THE NATIONAL HEALTH INFORMATION SYSTEM, DATA TRANSMISSION CIRCUIT). These documents provided by the ministry of health give in detail how the national health information system is structured in Burundi. The information from these documents allowed to achieve part of objective 3 of the study. The interviewees selected included the directors of hospitals, IT managers, and officials of the health information system office of the ministry of health. The Health Information System office is in charge of the National Health Information System which sets the policies used to collect, store and analyse health data in the country. The IT managers are in charge of the ICT resources (software and hardware) that are used by hospitals. Lastly, the directors of the hospitals are in charge of supervising the compilation of monthly reports in their hospitals. Their roles and expertise in the hospitals and the Ministry of

Health enabled them to provide information that was needed in achieving the third objective.

Additionally, observations and document review were used to get more information that was not provided during the interviews or to back the information given. Each category of the interviewees had its specific metrics to measure.

### 3.7 Data Collection Procedure

The data was collected in 3 ways: semi-structured interviews, observations and document review. Depending on their feedback more questions were asked and at the end they were giving supplementary comments. Observations were done to study the equipment used by the IT departments. Lastly, documents with more information were provided by the ministry.

### 3.8 Adoption Readiness Assessment Tool (ARAT) testing

The designed tool to assess the readiness i.e. the level of Burundi's preparedness for adoption of a BDA system in public healthcare to evaluate the level of preparedness was tested to validate if it meets the requirements. The tool measured metrics of the defined factors from objective one. The automated tool was tested to check if the output format is in form of numerical values and representative graphs to verify if the tool works as intended and that if the calculations are done correctly.

### 3.9 Instrument Validation

A pilot survey was conducted in one of the national referral hospital, Kamenge Military Hospital, to validate if the interview guides would help in providing the information needed from the hospitals. At the beginning of the study, 3 interview guides were prepared intended for hospital directors, doctors and IT managers but after the pilot study the guides intended for doctors were no longer considered due to two reasons:

directors of hospitals are also doctors and the information provided by doctors could be provided by the hospitals directors. Additionally, some repetitive questions were deleted from the interview guides.

In order to validate the data collected and the ARAT, the data was first analyzed using Microsoft Excel by attributing every metric a value that is between 1 and 5 to calculate the readiness level out of 5 by generating the average level on every context and their corresponding graphs. After testing the ARAT using the same input the tool generated the same results.

### 3.10 Data Analysis and Presentation

Both data analysis and presentation were done using the ARAT after data collection. The information collected was used as input to the ARAT in form of questions with multiple choices whereby each choice had a corresponding numerical value in the inference engine of the tool to allow it to generate the average level of readiness. The values corresponding to the inputs were used by the system to generate representative graphs to show an overview of the readiness level. The ARAT also generates comments depending on the results of the assessment and a full report can be printed after the assessment.

### 3.11 Ethical Consideration

After sampling the public hospitals to survey, a letter requesting authorization to conduct the interviews was submitted to every hospital with a copy of a letter provided by the department of Information Technology at Moi University attesting that the research has been approved. Another letter was submitted to the ministry of Health to request an interview with the Health Information System office. Also copies of interview guides were attached to the letters. The interviews were only conducted after approval.

# CHAPTER FOUR

# AUTOMATED BDA ADOPTION READINESS ASSESSMENT WEB-BASED TOOL (ARAT)

## 4.1 Introduction

The Adoption Readiness Assessment Tool (ARAT) is a web-based assessment application that was used to assess the readiness of Burundi's public hospitals in adopting a BDA system. The tool provides the level of readiness of the country and recommendations that enabled the study to develop a detailed and tailored adoption model.

To build the ARAT, an existing online assessment tool developed by one of the biggest BDA companies in healthcare HealthCatalyst was used as a reference (HealthCatalyst, 2017) The HealthCatalyst Readiness Assessment Tool was developed to provide an assessment platform to all the potential clients in order to help them in making sure that their organizations or companies are ready to implement the HealthCatalyst system. The HealthCatalyst Readiness Assessment Tool measures 5 factors: leadership and governance, financial alignment, analytics, best practices and adoption. These factors are focused more on the organizational context and measure the implementation preparedness level of the organization vis-a-vis their organizational structures. The metrics used in the tool have multiple choices answers that are given a value of 1 to 5 and it calculates the average for each factor and the total average. At the end of the assessment a report is generated with representative graphs and comments.

## 4.2 BDA Adoption Metrics for the Automated Assessment Tool

In this study, the adoption readiness assessment tool was developed following the conceptual model described in chapter II. The adoption factors are categorized into four main contexts and each factor has one or more metrics. Table 11, 12, 13 and 14 outline

samples of the different factors with their metrics in their respective context. Tables with all the metrics are in the appendices.

**Table 11: Technological context metrics**

| Factor | Metric | Code |
|---|---|---|
| **Compatibility** | How many computers do the hospitals have? | **T4** |
| | What is the Average RAM of the computers used? | **T5** |
| | What are the existing Network devices in facilities? | **T9** |
| **Connectivity** | Are the hospitals connected to the internet? | **T10** |

**Table 12: Organizational context metrics**

| Factor | Metric | Code |
|---|---|---|
| **Awareness about the innovation** | Are the Ministry officials aware of the existence of BDA systems? | **O1** |
| | Are the hospitals aware of EHR databases? | **O2** |
| **Demographic variables** | What is the average number of patients per day in hospitals? | **O3** |

**Table 13: Environmental context metrics**

| Factors | Metrics | Code |
|---|---|---|
| **Access to information by patients and health workers** | Do the patients have access to their health records? | **E1** |
| | What are the methods used by patients to access their health records? | **E2** |
| **Communication with other organizations** | Are the hospitals interconnected with laboratories and/or other health organizations? | **E3** |

**Table 14: Political and regulatory context metrics**

| Factors | Metrics | Code |
|---|---|---|
| **Intellectual property protection** | Does the Country have a policy on health information protection? | **PR1** |
| **Procedures to enforce a contract** | Is the Procedure to enforce a contract of purchasing a Health Information system fast? | **PR2** |

### 4.3 Assessment Technique

To conduct any assessment a specific measurement technique is required. In order to standardize the measurement of all the metrics that constitute the factors of the assessment, every metric is presented as question that has 2 or 5 possible answers in form of multiple choices. These answers are given a value of 1 to 5 in the system. Table 15, 16, 17 and 18 are samples of the full tables that are presented in the appendixes with all the details.

**Table 15: Technological context metrics measurement values**

| Factor | Code | Measurement | Value |
|---|---|---|---|
| **Compatibility** | T4 | 1 | 0 computers per hospital |
| | | 2 | 1 to 10 computers per hospitals |
| | | 3 | 11 to 50 computers per hospital |
| | | 4 | 51 to 100 computers per hospital |
| | | 5 | 101 to 200 computers per hospital |
| | T5 | 1 | Less than 2gb |
| | | 2 | 2 gb |
| | | 3 | 4 gb |
| | | 4 | 8 gb |
| | | 5 | 16 gb |

**Table 16: Organizational context metrics measurement values**

| Factor | Code | Measurement | Value |
|---|---|---|---|
| **Awareness about the innovation** | O1 | 1 | Aware |
| | | 5 | Not aware |
| | O2 | 1 | 0 to 24% of the hospitals |
| | | 2 | 25 to 49% of the hospitals |
| | | 3 | 50 to 74% of the hospitals |
| | | 4 | 75 to 90% of the hospitals |
| | | 5 | 91 to 100% of the hospitals |
| **Demographic variables** | O3 | 1 | 0 to 50 patients |
| | | 2 | 51 to 100 patients |
| | | 3 | 101 to 200 patients |
| | | 4 | 201 to 400 patients |
| | | 5 | 401 to 1000 patients |

**Table 17: Environmental context metrics measurement values**

| Factor | Code | Measurement | Value |
|---|---|---|---|
| **Access to information by patients and health workers** | E1 | 1 | 0 to 24% of the hospitals said yes |
| | | 2 | 25 to 49% of the hospitals said yes |
| | | 3 | 50 to 74% of the hospitals said yes |
| | | 4 | 75 to 90% of the hospitals said yes |
| | | 5 | 91 to 100% of the hospitals said yes |

**Table 18: Political and regulatory context metrics measurement values**

| Factor | Code | Measurement | Value |
|---|---|---|---|
| **Intellectual property protection** | Pr1 | 1 | Yes |
| | | 5 | No |
| **Procedures to enforce a contract** | Pr2 | 1 | Very slow |
| | | 2 | Slow |
| | | 3 | Neutral |
| | | 4 | Fast |
| | | 5 | Very fast |

### 4.4 The Automated TOE-Based Adoption Readiness Assessment Tool (ARAT)

The ARAT was built following the waterfall development process. The programming framework used was a combination of HTML, CSS, PHP and JAVASCRIPT

programming languages to design the web-based assessment tool. The inference engine of the tool consists of the metrics from the factors studied on the first objective.

### 4.4.1 Requirements analysis

Before getting at the designing stage of any software application, requirements must be gathered depending on the type of application. In this case, the software application is an automated assessment tool.

**Programming framework**: the application software is a web-based tool that combines 4 programming languages: HTML, CSS, PHP, JAVASCRIPT and MySQL DATABASE. Since it's a web-based application we used a Colorlib Admin dashboard template that was coded in HTML and CSS. PHP and JAVASCRIPT was used to link the database written in MySQL with the dashboard.

**Input and output**: The Adoption Readiness Assessment Tool (ARAT) requires input to generate output after processing the data in its inference engine. The input is information collected previously through a survey. The input is in form of multiple choice answers and metrics are in form of questions. Each metric has 5 or 2 answers depending on the metric. Each answer has a value that is between 1 and 5 in the system to enable the system to generate numerical values.

```
1. Number of computers per hospital.
<label>0 COMPUTERS   <input type="radio" value="1" name="t4" required="required"></label>
 <label> 1 TO 10 COMPUTERS  <input type="radio" value="2" name="t4" required="required" ></label>
 <label>11 TO 50 COMPUTERS <input type="radio" value="3" name="t4" required="required" ></label>
 <label>51 TO 100 COMPUTERS  <input type="radio" value="4" name="t4" required="required" ></label>
 <label>101 TO 200 COMPUTERS   <input type="radio" value="5" name="t4" required="required"
```

As illustrated above in the example, *Number of computers per hospital* is the metric, the values in **bold** are the answers to the metric (possible values) and numerical values of each answer.

The output is generated after the inference engine calculates the average of all the answers and is presented in form of averages, visual graphs representing the final results and comments that match the results obtained from the assessment.

### 4.4.2 Application design

After establishing the requirements for the ARAT, the first step is to draw a logical diagram that describes how the application will work, then design the application itself before implementing it.

### 4.4.3 Logical diagram of the ARAT

Figure 19 is a logical representation of the automated tool and shows how it works in the backend. Inputs are saved as numbers in a database then the data is processed before the system displays the output.

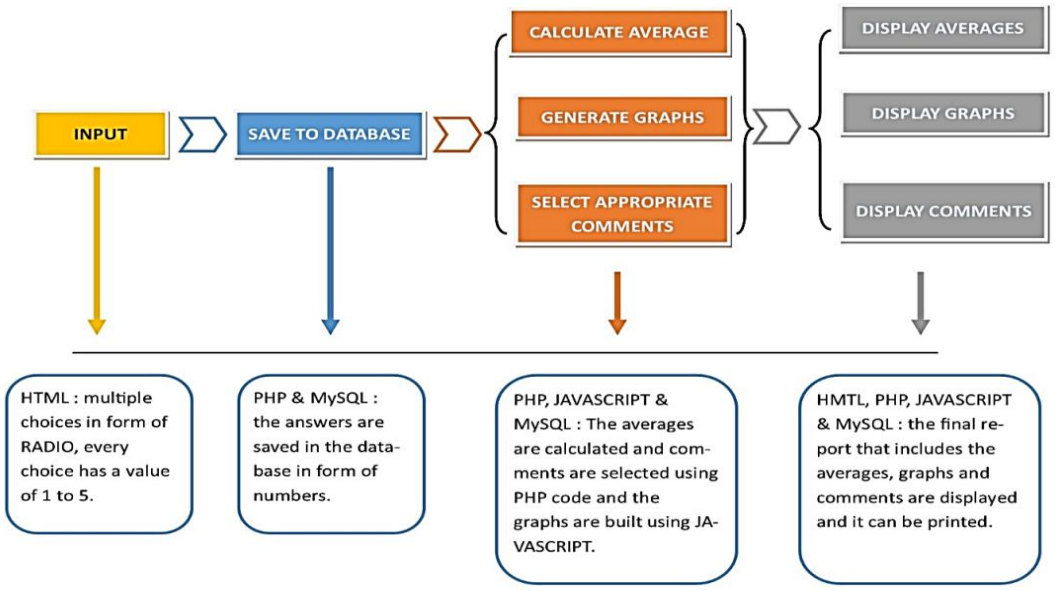



**Figure 4: Logical diagram of the ARATInput:**

```
<form id="demo-form2" method="post" action="saveRecord.php" class="form-horizontal
form-label-left">
   <div class="form-group">
                <label for="t4"><h2>1. Number of computers per hospital.</h2>
                </label><br/>
                <div  class="btn-group" data-toggle="buttons">
<label class="btn btn-default">0 COMPUTERS
<input type="radio" value="1" name="t4" required="required"></label>
<label class="btn btn-default"> 1 TO 10 COMPUTERS
<input type="radio" value="2" name="t4" required="required" ></label>
<label class="btn btn-default">11 TO 50 COMPUTERS
<input type="radio" value="3" name="t4" required="required" ></label>
<label class="btn btn-default">51 TO 100 COMPUTERS
<input type="radio" value="4" name="t4" required="required" ></label>
<label class="btn btn-default">101 TO 200 COMPUTERS
<input type="radio" value="5" name="t4" required="required" ></label>
</div>
```

**Database:** the database includes four tables whereby each table stores the input sent from the different context. The metrics are declared as *integers* and *not null*. Each metric is represented with a unique ID.

```
CREATE DATABASE `arat`;
USE `arat`;
DROP TABLE IF EXISTS `metrics`;
CREATE TABLE `metrics` (
  `t4` int(1) NOT NULL,
  `t30` int(1) NOT NULL,
  `t32` int(1) NOT NULL,
  `t33` int(1) NOT NULL,
  `t34` int(1) NOT NULL,
  `t35` int(1) NOT NULL,
  `t36` int(1) NOT NULL,
  `t37` int(1) NOT NULL
) ENGINE=InnoDB DEFAULT CHARSET=utf8 CHECKSUM=1 DELAY_KEY_WRITE=1
ROW_FORMAT=DYNAMIC;
```

**Dashboard connection to the database:** the connection is done through a PHP page *dbconnect.php*. this page allows the application to retrieve the data from the database to send them to the results page.

```
<?php
$host_name = "localhost";
$user_name = "root";
$pass = "";
$database = "arat";
$connect = mysqli_connect($host_name, $user_name, $pass) or die("Could not connect
Database!");
if($connect)
{
        mysqli_select_db( $connect, $database ) or die("Could not select <i>$database</i>!");
}
else
{
        echo "Database connection failed. Please check for errors: ".$connect;
}
?>
```

**Saving the input in the database:** the input is saved into the database through a PHP page *saveRecords.php.*

The input is first received

```
$t4 = (isset($_POST["t4"]) ? mysqli_escape_string($connect, trim(utf8_decode($_POST["t4"])))) : "" );
$t5 = (isset($_POST["t5"]) ? mysqli_escape_string($connect, trim(utf8_decode($_POST["t5"])))) : "" );
$t6 = (isset($_POST["t6"]) ? mysqli_escape_string($connect, trim(utf8_decode($_POST["t6"])))) : "" );
$t8 = (isset($_POST["t8"]) ? mysqli_escape_string($connect, trim(utf8_decode($_POST["t8"])))) : "" );
$t9 = (isset($_POST["t9"]) ? mysqli_escape_string($connect, trim(utf8_decode($_POST["t9"])))) : "" );
```

Then it is inserted into the tables

```
$sql = "INSERT INTO metrics
                    (
                        t4
                        ,t5
                        , t6
                         , t8
                         , t9
            ) VALUES(
                         '$t4'
                        , '$t5'
                        , '$t6'
                        , '$t8'
                        , '$t9'
                    )";
```

**Assessment results calculation:** the averages are calculated using PHP code in the *displayRecords.php* page.

```
$avg_comp = number_format(($sum_comp/5), 2);
```

Then it is displayed in three formats:

The readiness level,

```
<h4>1. Compatibility:  <?php echo $avg_comp;?>
```

The graph,

```
<canvas id="tech"></canvas>
```

And the comments and suggestions.

```
<?php if ($avg_comp<3){
                    echo '- Increase the number of computers in hospitals, increase the RAM capacity of computers in hospitas, upgrade the Operating Systems used up to Windows 8 or 10, implement the same software application to all the hospitals and implement LANs into all the hospitals';
}
          else{
                    echo '- The number of computers in hospitals is sufficient, they are using good Operating systems, assure that all the hospitals use the same software application and that all the hospitals have LANs.'; }
```

### 4.4.4 ARAT structure

The ARAT has a total of 6 webpages for its interface (a homepage, 4 pages one for each context coded in HTML and a last page that displays the final report coded in PHP), a MySQL database, a page for the connection of the database and the software application and a page for saving the data in the database. The two last pages are coded in PHP.

The homepage contains a brief introduction of the tool and the menu that includes all 4 context of the assessment and a display page for the final report. Figure 20 shows a brief structure of the tool.

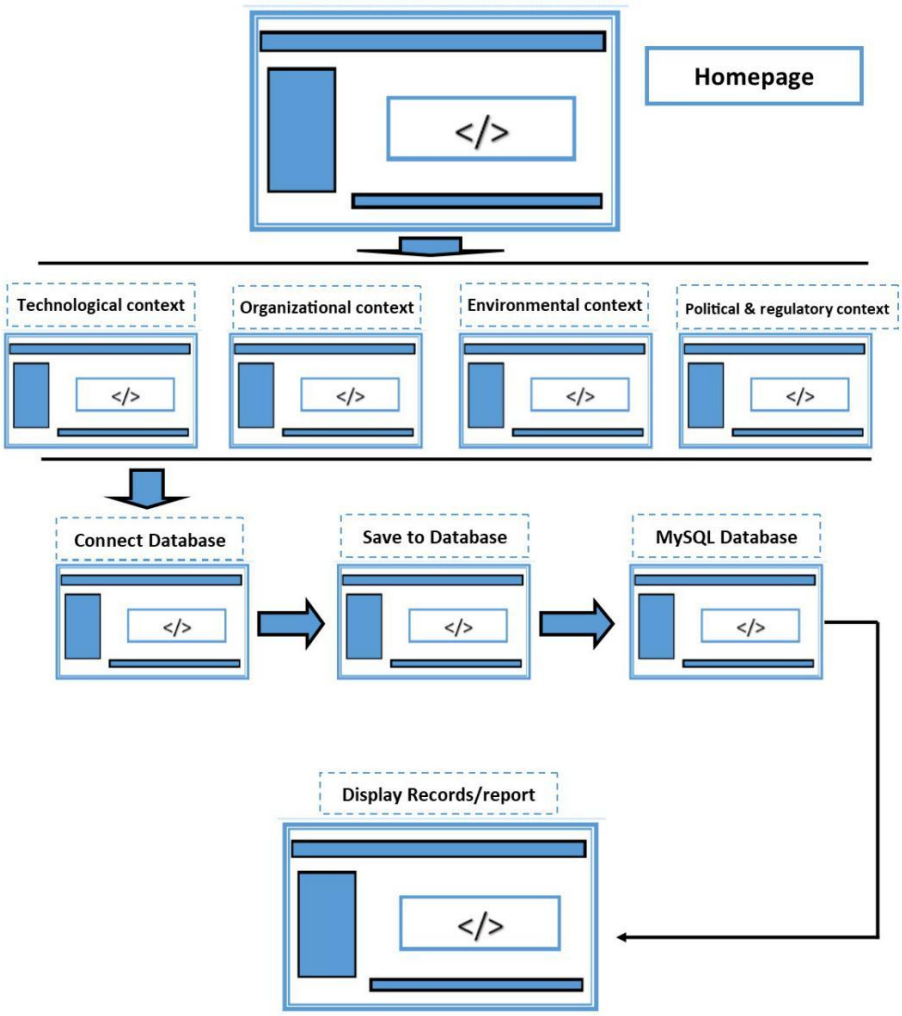



**Figure 20: ARAT web pages structure**

### 4.4.5 ARAT interface

The interface of the ARAT is a web-based admin dashboard developed using HTML and CSS. The homepage has two sections: on the left there is the menu and, in the center, and right an introduction on the tool. The dashboard was downloaded on *Colorlib* and customized to meet the requirements. Figure 21 is a screenshot of the homepage of the user interface dashboard.

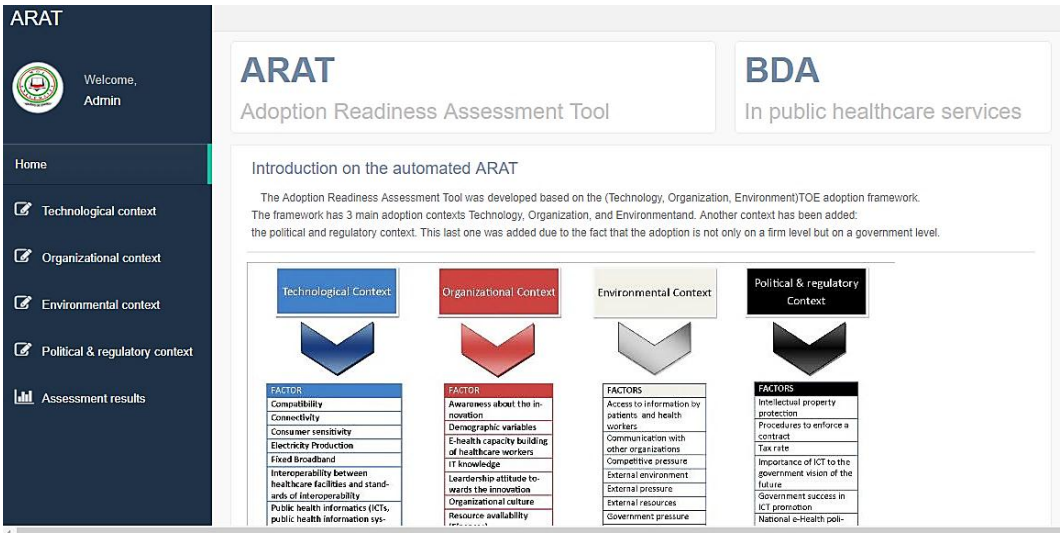



**Figure 21: ARAT Homepage screenshot**

Figure 22, 23, 24, 25, 26, 27 and 28 are screenshots of the assessment web pages. Each page represents an adoption context. The pages are in form of questionnaires with multiple answers for each question. Every question represents a metric.

```
<form id="demo-form2" method="post" action="saveRecord.php" class="form-horizontal form-label-left">
```

The code above defines the form (questionnaire). To make sure that the form works properly, the *method* has to be set to *post* to enable the form to send the input and the *action* set to *saveRecords.php* to define where the input goes.

```
<div class="form-group">
   <label for="t4"><h2>1. Number of computers per hospital.</h2> </label><br/>
      <div  class="btn-group" data-toggle="buttons">
        <label class="btn btn-default">0 COMPUTERS
                  <input type="radio" value="1" name="t4" required="required"></label>
         <label class="btn btn-default"> 1 TO 10 COMPUTERS
                  <input type="radio" value="2" name="t4" required="required" ></label>
         <label class="btn btn-default">11 TO 50 COMPUTERS
                  <input type="radio" value="3" name="t4" required="required" ></label>
         <label class="btn btn-default">51 TO 100 COMPUTERS
                  <input type="radio" value="4" name="t4" required="required" ></label>
         <label class="btn btn-default">101 TO 200 COMPUTERS
                  <input type="radio" value="5" name="t4" required="required" ></label>
</div>
```

Each question (metric) is coded as shown above. The questions all have unique codes (example *t4*). Every answer is set as *radio* to only allow the user to chose only one option instead of two or more. And they are given a *value* that is set between 1 and 5.

All four pages representing the adoption context have a section of JAVASCRIPT code. The code defines how the input submitted is saved through the *GET* method and how the data is sent to the database through the *POST* method page should react when the data is saved successfully or unsuccessfully.

```
<script type="text/javascript">
function displayRecords() {
        var http = new XMLHttpRequest();
        http.open("GET", "tec.html", true);
        http.setRequestHeader("Content-type","application/x-www-form-urlencoded");
        http.send();
        http.onload = function() {
           document.getElementById('trBody').innerHTML = http.responseText;
        }
      }
      function submitForm() {
                        alert('Sending entries');
        var http = new XMLHttpRequest();
        http.open("POST", "saveRecord.php", true);
        http.setRequestHeader("Content-type","application/x-www-form-urlencoded");
        http.onload = function() {
           if ('error' != http.responseText)
           {
              alert('Entries saved successfully!');
              document.getElementById('trBody').innerHTML = http.responseText;
           }
           else {
              alert('Entries saved successfully!');
           }
           document.getElementById("demo-form2").reset();
        }
      }
```

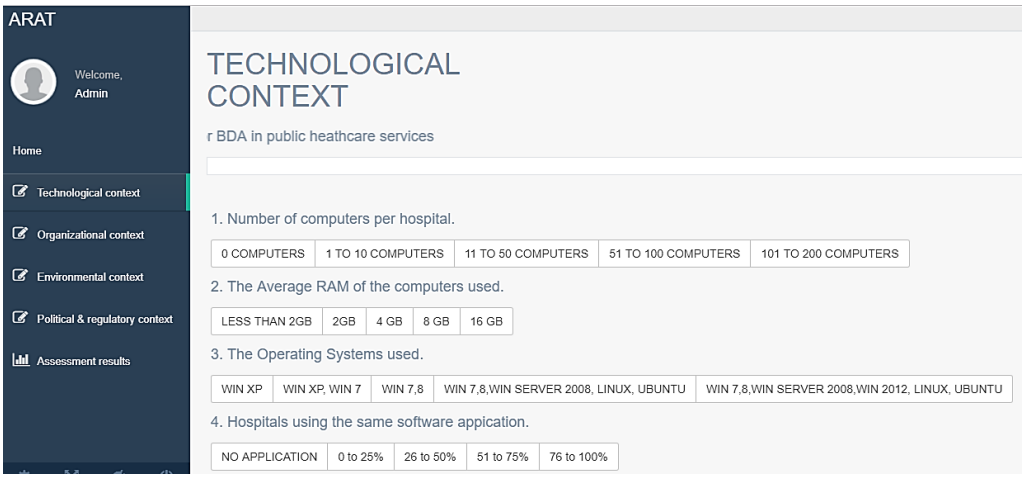



**Figure 22: ARAT Technological context page screenshot**


**Figure 23: ARAT Organizational context page screenshot**

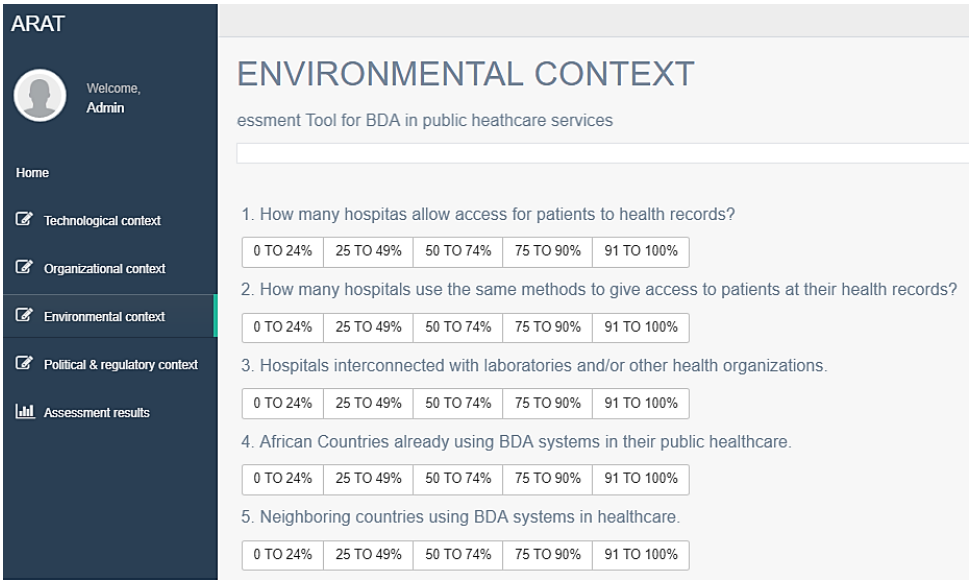



**Figure 24: ARAT environmental context screenshot**


**Figure 25: ARAT political and regulatory context screenshot**

The assessment results page is a PHP web page. The connection to the database is defined on top of the page.

```
include 'dbconnect.php';
```

The data sent to the database through the form is represented by a unique *id* and it is declared on the page as shown below.

```
$sqlString  = "SELECT t4, t5, t6, t8, t9, t10, t11, t12, t13, t15, t16, t17, t18, t22, t23, t24, t26, t27,
t28, t30, t32, t33, t34, t35, t36, t37 FROM metrics;";
```

To display the average level of readiness for each factor the *sum* and the *average* of the metrics that constitute the factor is calculated. But before, the *sum* and *average* are declared. For example, the factor of compatibility in the technological context:

```
$sum_comp = 0;
```

```
$avg_comp = 0;
```

Then the sum is calculated by adding all the metrics using their unique IDs that are declared as variables:

```
$sum_comp = $record["t4"] + $record["t5"] + $record["t6"] + $record["t8"] +
$record["t9"];
```

The average is calculated by taking the sum and dividing it by the total number of metrics of the factor, which is this case is 5 and the *2* at the end defines the number of digits in the decimal part :

```
$avg_comp = number_format(($sum_comp/5), 2);
```

The result is displayed like this:

```
<h4>1. Compatibility:  <?php echo $avg_comp;?>
```

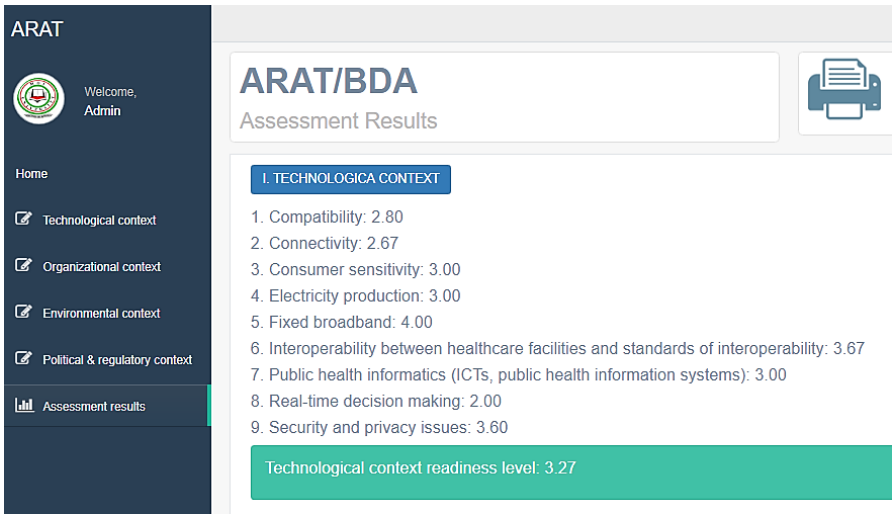



**Figure 26: ARAT assessment report page screenshot**

The comments and suggestion displayed in the assessment depend on the results. Every possible result for each factor has a specific comment and suggestion. This section is coded in PHP using the *if{}* condition.

```
<p> <?php if ($avg_comp<3){

                    echo '- Increase the number of computers in hospitals, increase the RAM capacity of computers in hospitas, upgrade the Operating Systems used up to Windows 8 or 10, implement the same software application to all the hospitals and implement LANs into all the hospitals';}

          else{

                    echo '- The number of computers in hospitals is sufficient, they are using good Operating systems, assure that all the hospitals use the same software application and that all the hospitals have LANs.';}

?></p>
```

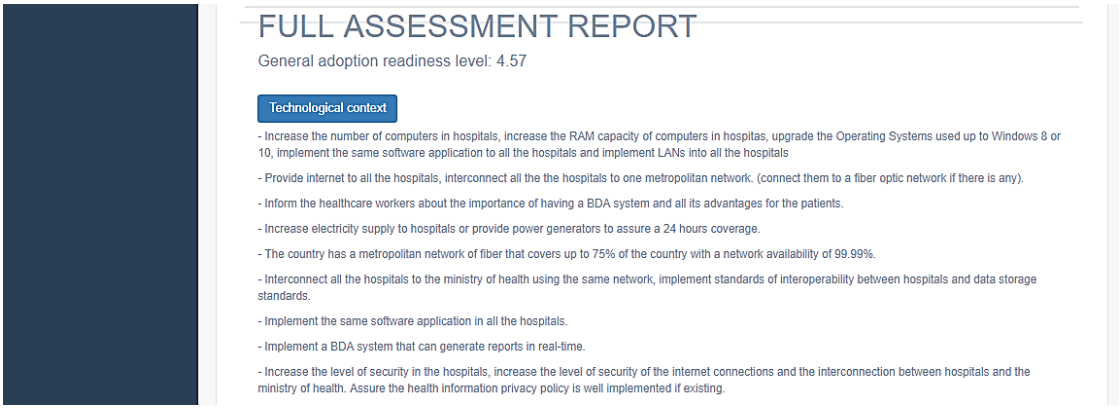



**Figure 27: ARAT assessment report page screenshot**

The graphs are generated using JAVASCRIPT. The datasets displayed in the graphs are the *averages* that were calculated previously. They are declared using PHP.

```
var config1 = {
        type: 'radar',
                data: {
        labels: ["technological", "organizational", "environmental", "political &
regulatory"],
                datasets: [{
                                        borderColor: 'rgb(255, 0, 0)',
                                        backgroundColor: "rgba(255,255,0,0.5)",
                                        pointBackgroundColor: "rgba(220,220,220,1)",
data: [<?php echo $avg_total; ?>,<?php echo $avg_total1; ?>,<?php echo $avg_total2;
?>,<?php echo $avg_total3; ?>]
                                  }, ] },
        options: {
                                 title:{
                                        display:true,
                                        text:"General assessment level"
                                  },
                                  elements: {
                                        line: {
                                                tension: 0.0,
                                        }},
                                  scale: {
                                        beginAtZero: true,
```

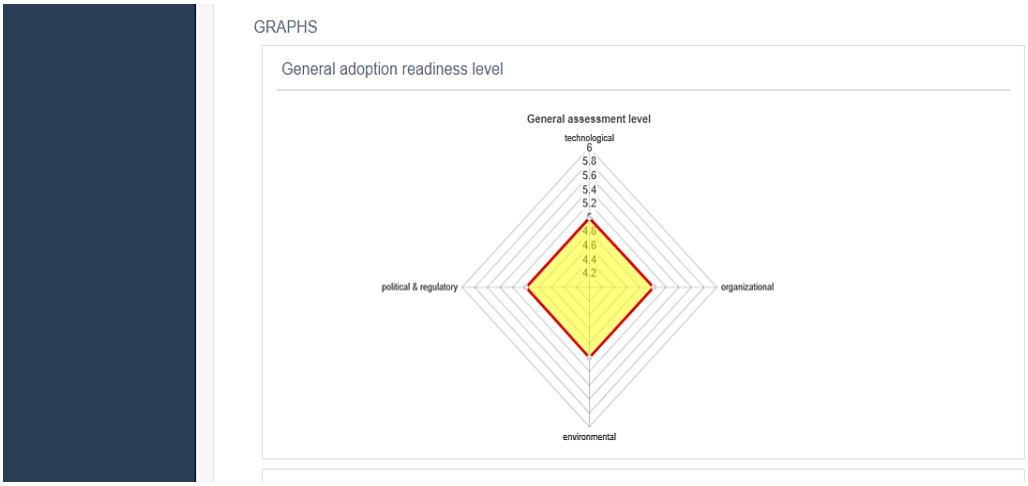



**Figure 28: ARAT assessment report page screenshot**

### 4.5 Implementation

The ARAT is an open source web-based software application and not a native software application therefore its implementation is done differently. The implementation was done as follows:

- A folder is created that contains all the HTML, CSS, PHP, SQL and images,


**Figure 29: Screenshot of the desktop with the folder containing the system files**

- Since it has a database, this requires a database management system. XAMPP was downloaded and installed,
- After installing the database management system, the ARAT folder is copied in the following location: *C:\xampp\htdocs.* This is to allow the database management system (DBMS) to access the ARAT.

- After XAMPP installation, it has to be turned on

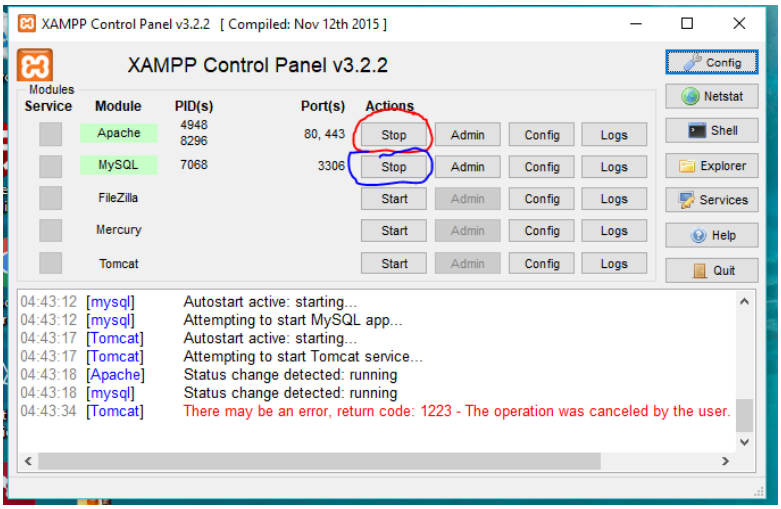
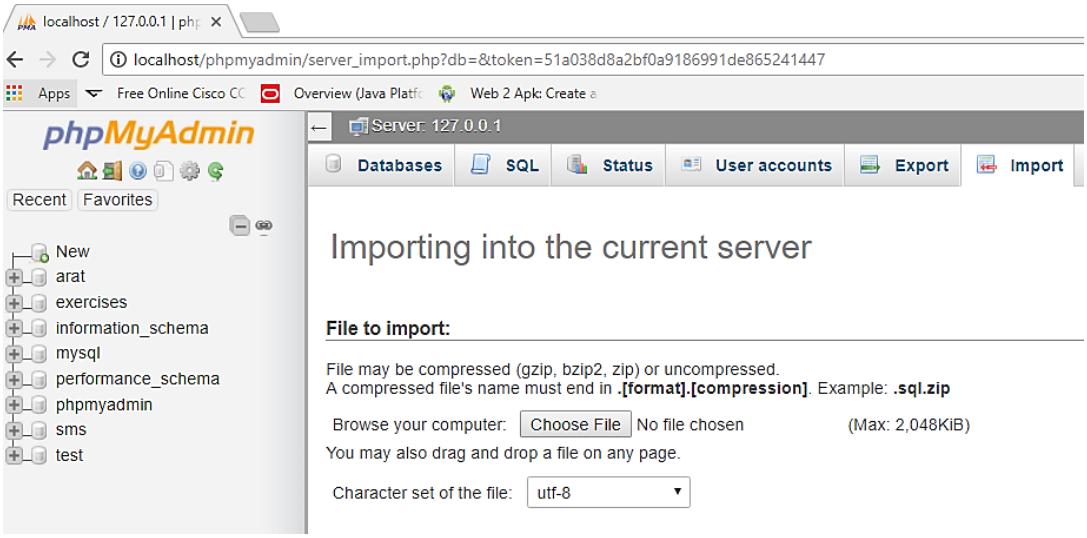



**Figure 30: screenshot of XAMPP control panel**

- After installing and launching XAMPP, the next step is to access it through a browser then upload the database in the DBMS by typing *http://localhost/phpmyadmin/* and then upload the SQL file in the ARAT folder (*arat.sql*)



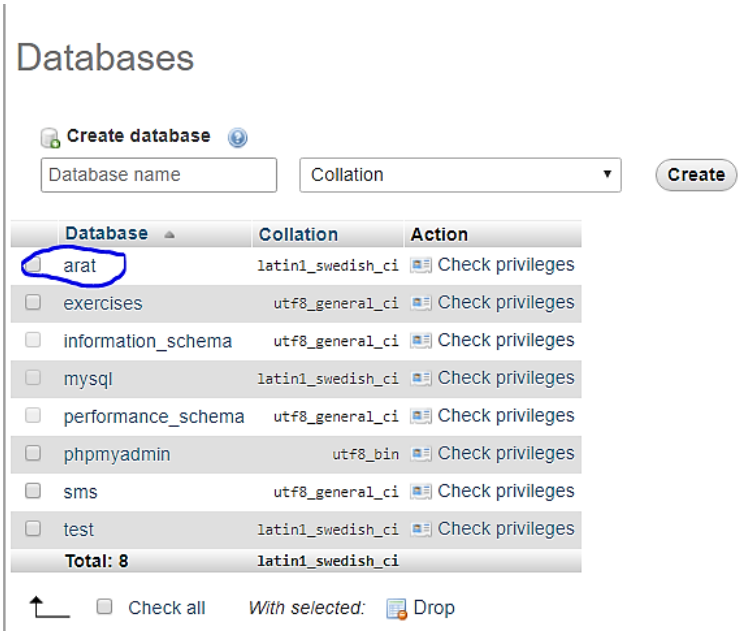



**Figure 31: Screenshot of the database manager web portal.**

- After uploading the database, the ARAT is accessed by going to the following address in the browser: *http://localhost/*. This displays the root folders of the web applications in the DBMS.


**Figure 32: Screenshot of the files location**

- By clicking on the ARAT folder it opens the index page directly.

### 4.6 Testing

To assure that our software application is working correctly, it required some tests to check if it fulfilled all the requirements. The testing was to make sure that the following tasks are completed as required:

- Entries are saved correctly in the database,
- Averages are calculated correctly,
- Visual graphs display the same values as the averages,
- Comments generated correspond to the results,
- The final report page displays only the latest entries.

The first test was conducted by entering the minimum value to all the questions which is 1, the second test used the maximum value which is 5 and the final test used random values whereby averages were calculated manually. Throughout the 3 tests the last requirement, which is to check if the report generates only the last entries was checked. All 3 tests were successful and attested that the software application is working properly and that it fulfills all the requirements.

### 4.7 Chapter Summary

In this chapter, the web based Adoption Readiness Assessment Tool (ARAT) was developed using the conceptual model established in Chapter 2. Assessment metrics were set using factors defined in the conceptual model. After completing the tool, it was tested to verify if it satisfied the requirements. The outcomes of the tests showed that the tool was successfully built. In the next chapter the adoption assessment on Burundi's public hospitals was conducted using the web based ARAT developed in this chapter.

# CHAPTER FIVE

# BDA ADOPTION MODEL FOR BURUNDI'S PUBLIC HOSPITALS

The aim of the study was to propose a tailored BDA adoption model for Burundi's public hospitals which was achieved by studying the factors that influence the adoption of BDA systems in healthcare, investigating the actual health information system in Burundi and assessing the readiness of the country in adopting a BDA system in its public hospitals.

## 5.1 Overview of the Healthcare Information System in Burundi

In this section a brief overview of the Health Information System is given before proceeding to the assessment. This overview gives a comprehensive image of how the actual healthcare information system is organized.

### 5.1.1 Ministry of Health Organizational structure

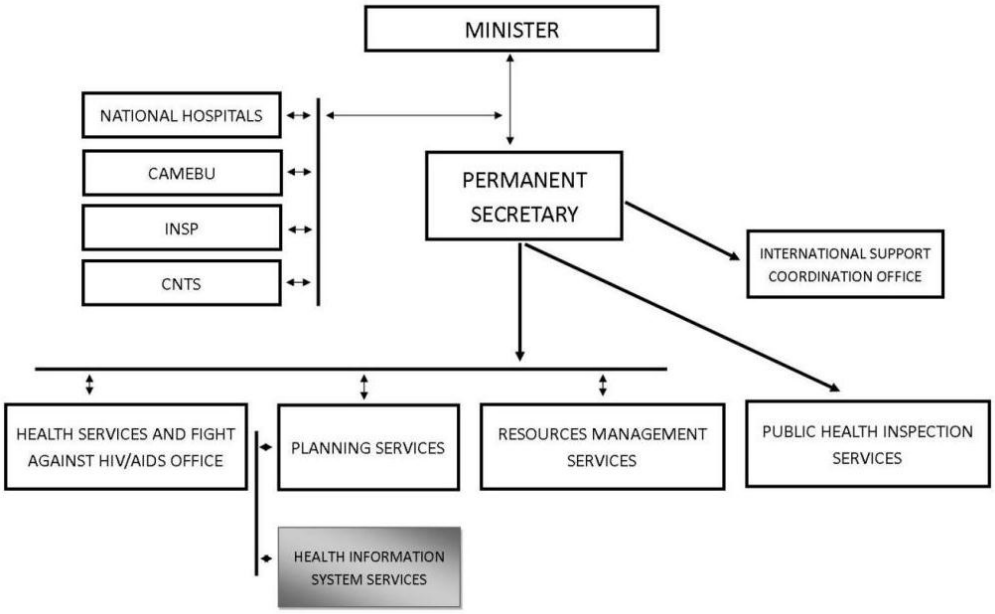



**Figure 33: Ministry of health organizational structure**

The Health Information System services, which the study is focusing on, is under the planning services that are under the direct management of the Permanent secretary of the ministry of Health as shown in Figure 33.

### 5.1.2 Public Hospitals of Burundi

According to the annual report of 2015, the country has 61 public hospitals that are in 4 categories: National Referral Hospitals, Regional Hospitals, Provincial Hospitals and District Hospitals as shown in Table 19 below.

**Table 19: Categories of public hospitals in Burundi**

| REGIONAL HOSPITALS | PROVINCIAL HOSPITALS | DISTRICT HOSPITALS | NATIONAL REFERAL HOSPITALS |
|---|---|---|---|
| **Gitega** | Bubanza | Gihanga | Hopital Roi Khaled |
| **Ngozi** | Cankuzo | Mpanda | Hopital Prince Regent Charles |
| **Ruyigi** | Cibitoke | Rushubi | Hopital Militaire De Kamenge |
| **Bururi** | Karusi | Kabezi | Clinique Prince Louis Rwagasore |
| | Kayanza | Matana | |
| | Kirundo | Rutovu | |
| | Makamba | Kibimba | |
| | Muramvya | Kibuye | |
| | Muyinga | Mutaho | |
| | Rumonge | Mutoyi | |
| | Rutana | Karusi | |
| | | Gahombo | |
| | | Musema | |
| | | Mukenke | |
| | | Nyanza-lac | |
| | | Fota | |
| | | Kibumbu | |
| | | Buye | |
| | | Kiremba | |
| | | Mivo | |
| | | Gihofi | |
| | | Musongati | |
| | | Butezi | |
| | | Gisuru | |
| | | Kinyinya | |

### 5.1.3 Data collection and reporting scheme of the Ministry of Health in Burundi

To produce an annual statistics report, the ministry of health collects information from all the healthcare facilities in the country. Figure 34 shows the structure of the data collection circuit from the healthcare facilities all the way up to the ministry.

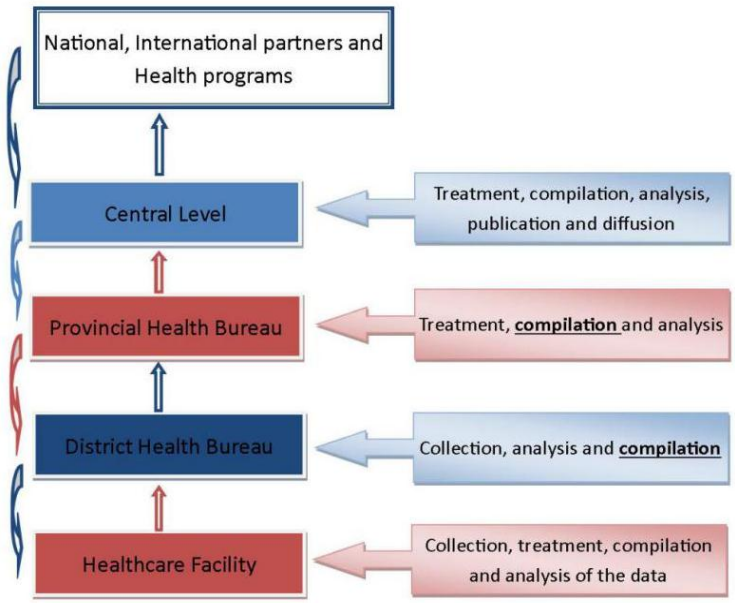



**Figure 34: Data collection and reporting scheme of the ministry of health in Burundi**

**Healthcare facilities**: at this level the data is collected and recorded using registers that are handwritten. The data is compiled and used to produce a monthly report then it's sent to the District Health Bureau before every 25$^{th}$ day of the month.

**District Health Bureau**: at this level, they organize the treatment and analysis of all the reports from the healthcare facilities then a compiled report is sent to the Provincial Health Bureau after 5 days.

**Provincial Health Bureau**: at this level all the reports from the districts health bureaus are analyzed, compiled then sent at the central level to the National Health Information System Office in the ministry of Health after 5 days.

**Central level**: at this level all the reports from the provincial health bureaus are analyzed then compiled by the National Health Information System Office in the ministry of Health to produce a national report.

The annual report on statistics in healthcare is published annually.

### 5.1.3 Standards and procedures of the National Health Information System

To coordinate the collection, analysis and publication of health statistics the National Health Information System Office uses standards and procedures to provide information to support decision making based on evidence shown in Table 20 and Figure 35. The ministry initiated a Normative Framework that constitutes the official technical tool that defines all the standards and the implementation of the Health Information System at all the levels of the Health pyramid. It defines the data to collect, the data collection tools and the information circuit. It consists of 4 main components: The operation of the National Health Information System, the information transmission Circuit, the list of indicators, and the codification of the healthcare facilities.

**Table 20: Operations of the National Health Information System**

| LEVEL | OPERATIONS | PERSONEL PROFILE | RESOURCES |
|---|---|---|---|
| **Healthcare facilities** | Collect data using handwritten registers, compile them, prepare a monthly report and transmit it to the District Health Bureau | An agent in charge of the management of health records must have a diploma or a bachelor degree. | Files, Registers, A shelf, Report forms, A computer, A printer, A telephone, Card binders |
| **District Health Bureau** | Organize the data collected from the healthcare facilities, analyze the data transmitted and insert them in the monthly reports and transmit the report to the Provincial Health Bureau. | The agent in charge of the Health Information System at this level must have knowledge in Information Technologies Management. The agent must also be able to train other health workers. | A computer dedicated to the Health Information System, A printer, A telephone, An external hard drive, A data analysis software application, Internet, A car |
| **Provincial Health Bureau** | Organize the data collected from the District Health Bureau, analyze the data and insert them in the GESIS, Transmit a monthly report to the National Health Information System Office at most at the 35$^{th}$ day. | The agent in charge of the Health Information System at this level must have knowledge in Information Technologies Management. The agent must also be able to train other health workers. | Computers, Printers, Telephone ,Internet, Cars, Papers, A data analysis software application |
| **Central Level (Ministry of Health)** | Evaluate the system on an annual basis, present the results of the National Health Information System, develop monthly tables of statistics, elaborate the needs in training and plan trainings, harmonize the data collection tools | - A managing director of the National Health Information System,<br>- A head of service in charge of the management and administration of the Health Information System,<br>- A head of service in charge of monitoring epidemics,<br>- A chief of service in charge of research and other studies,<br>- A statistician in charge of the data analysis,<br>- A computer scientist in charge of the maintenance of the database, | A operation and maintenance budget, Appropriate offices, Computers, Printers, Telephones ,Scanners, Cars |

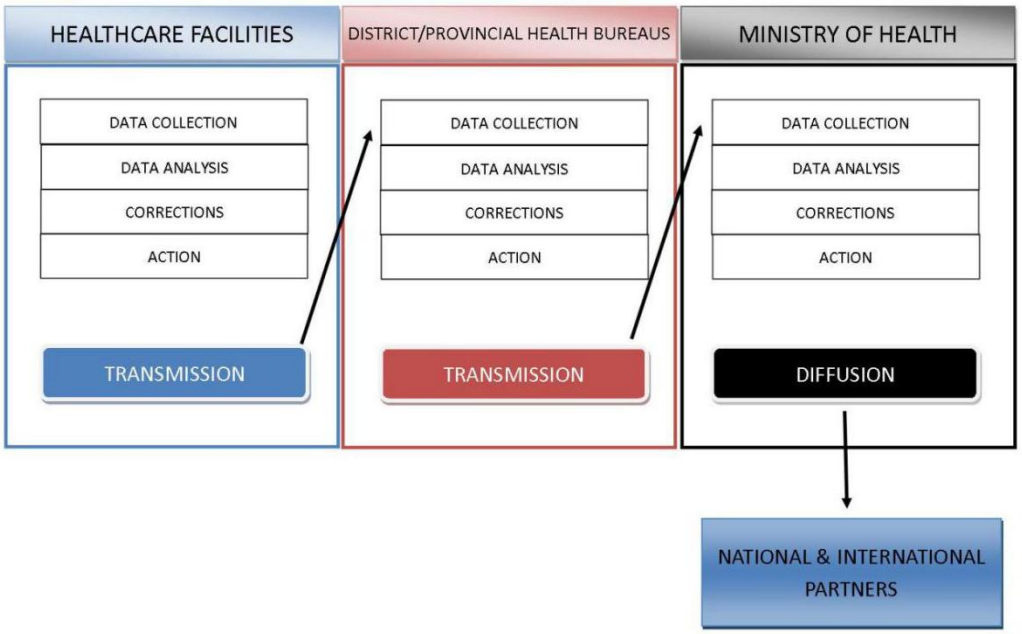



**Figure 35: Data transmission process**

### 5.1.4 National Health Information System Office structure

The office of the National Health Information System has 3 main services as shown in Figure 36: Management of health information, monitoring of epidemics, studies and research.

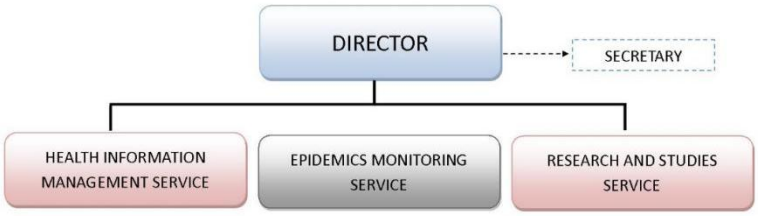



**Figure 36: National Health Information System Office structure**

## 5.2 Assessment of Burundi's readiness using ARAT

The assessment was conducted using information collected during a survey done in 9 public hospitals and at the Health Information System office of the ministry of health. The data was collected using semi-structured interviews.

### 5.2.1 Survey results

A survey was done in 9 public hospitals but only 6 responded positively to the request: 3 national referral hospitals, 1 regional hospital, 2 provincial hospitals and 1 district hospitals. At each hospital a semi-structured interview was conducted with the director of the hospital and the IT manager. Another survey was done at the Health Information System office of the ministry of health.

Table 21, 22, 23 and 24 show samples of the data collected from the hospitals and the ministry using semi-structured interviews, observations and documents. The collected data was compiled and used for the assessment with the ARAT. The tables with all the details on the data collected are in the appendix.

**Table 21: Technological context survey results**

| FACTOR | METRIC | CODE | OUTCOME |
|---|---|---|---|
| **Compatibility** | How many computers do the hospitals have? | **T4** | 346 for 6 hospitals (Average of 57 per hospital) |
| | What is the Average RAM of the computers used? | **T5** | 4GB |
| **Connectivity** | Are the hospitals connected to the internet? | **T10** | ALL (The surveyed ones ) |
| | Are the hospitals interconnected to other hospitals? | **T11** | 16.6% are interconnected other hospitals |
| **Consumer sensitivity** | Would having a Health data record in a centralized database be helpful to the patients? | **T13** | 4 out of 5 |
| **Electricity Production** | For how many hours the hospitals are provided electricity per day? | **T15** | 23 Hours per day |

**Table 22: Organizational context survey results**

| FACTOR | METRIC | CODE | OUTCOME |
|---|---|---|---|
| **Awareness about the innovation** | Are the Ministry officials aware of the existence of BDA systems? | **O1** | YES |
| | Are the hospitals aware of EHR databases? | **O2** | All the surveyed |
| **Demographic variables** | What is the average number of patients per day in hospitals? | **O3** | Average of 168.5 Total of 1180 in the |
| **E-health capacity building of healthcare workers** | Do the hospitals train workers in ICT usage? | **O4** | 83.3% surveyed train them |
| | Does the ministry have training programs in ICT for health workers? | **O5** | YES |
| | How often do the hospitals train the workers in new technology? | **O6** | 3.7 out of 5 |
| **IT knowledge** | What are the software applications known by the employees of the hospitals? | **O7** | 66.6% use OpenClinic |

**Table 23: Environmental context survey results**

| FACTORS | METRICS | CODE | OUTCOME |
|---|---|---|---|
| **Access to information by patients and health workers** | Do the patients have access to their health records? | **E1** | All said NO |
| | What are the methods used by patients to access their health records? | **E2** | NONE for all |
| **Communication with other organizations** | Are the hospitals interconnected with laboratories and/or other health organizations? | **E3** | 33.3% are interconnected with other health institutions |
| **Competitive pressure** | How many African Countries already use BDA systems? | **E4** | 11.1% of African Countries (Algeria, South Africa, Cameroun, Zambia, Ghana, Uganda) |

**Table 24: Political and regulatory context survey results**

| FACTORS | METRICS | CODE | OUTCOME |
|---|---|---|---|
| **Intellectual property protection** | Does the Country have a policy on health information protection? | **PR1** | YES |
| **Procedures to enforce a contract** | Is the Procedure to enforce a contract of purchasing a Health Information system fast? | **PR2** | FAST |
| **Tax rate** | Are the tax rates on healthcare technologies low? | **PR3** | LOW |

### 5.2.2 Assessment results

After completing the survey in the hospitals and at the ministry of health, the data collected was compiled as shown in Table 21,22,23 and 24. The compiled information was used to assess the readiness of Burundi in adopting a BDA system in its public hospitals.

In the technological context, the assessment results in Figure 37 show that public hospitals in Burundi have a sufficient number of computers and all the hospitals have LANs. Healthcare workers are aware of the benefits of using ICT and the electricity supply is sufficient although some hospitals have to use power generators to ensure a 24 hour coverage. Nevertheless, some hospitals are not using Fiber optic internet connections, some hospitals are not using Health Information Systems and there is a need of increasing the level of security at the hospitals.

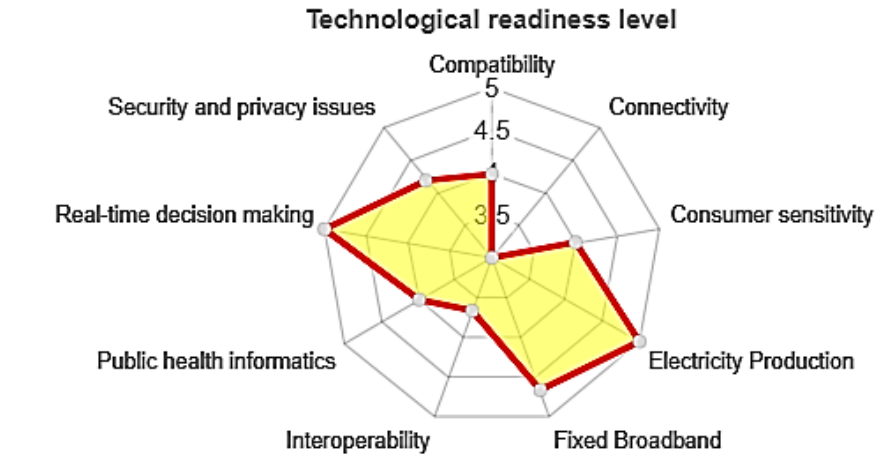



Figure 37: Technological readiness level graph

In the organizational context, the ministry of health and the hospitals are aware of BDA technologies and fully support its adoption. They also include the use of ICT in the hospital's culture. But the number of training programs in ICT provided to the workers should be increased.

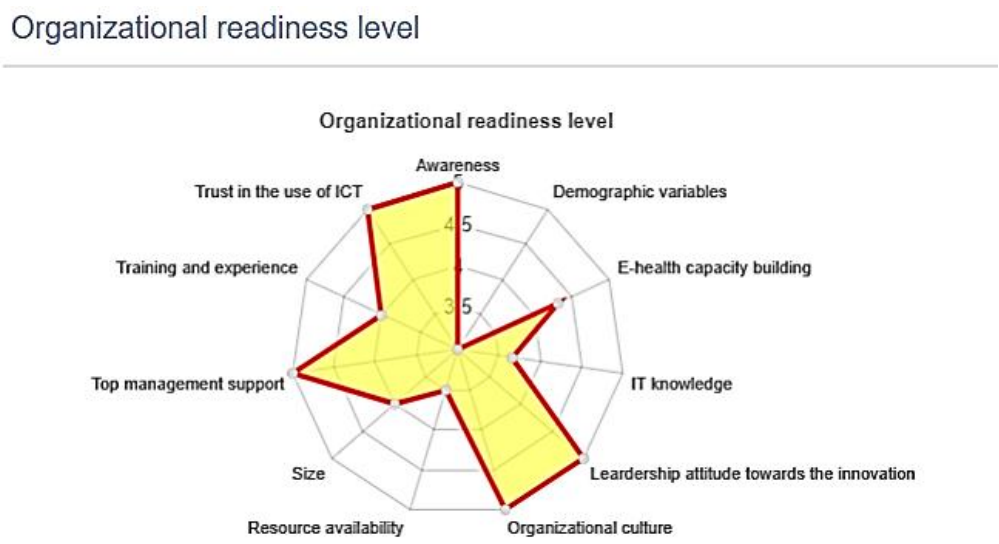



Figure 38: Organizational readiness level graph

In the environmental context, the Burundian government has the intention of adopting a BDA system in the health sector and it has external partners that are willing to offer financial and technical support. However, hospitals are not interconnected with other health institutions to facilitate collaboration and information sharing. And the number of African countries that have adopted BDA in healthcare is very low which puts on less pressure on the country.

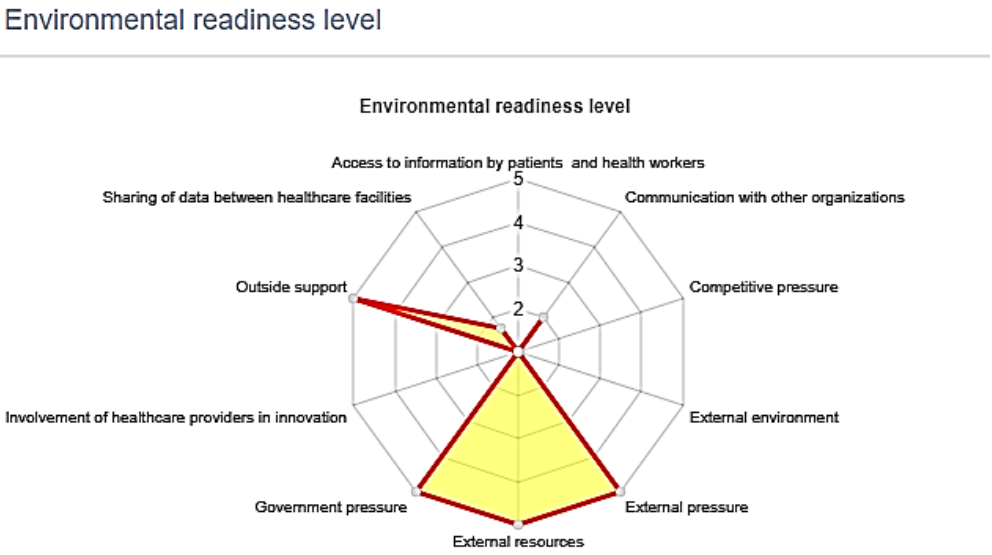



**Figure 39: Environmental readiness level graph**

Last but not least, in the political and regulatory context the government promotes the use of ICT in healthcare which is emphasized in its National Development Plan. The actual tax rates on new technologies are low and the procedure to enforce a purchasing contract are fast. Nevertheless, the government needs to adapt its e-health policy to BDA systems.

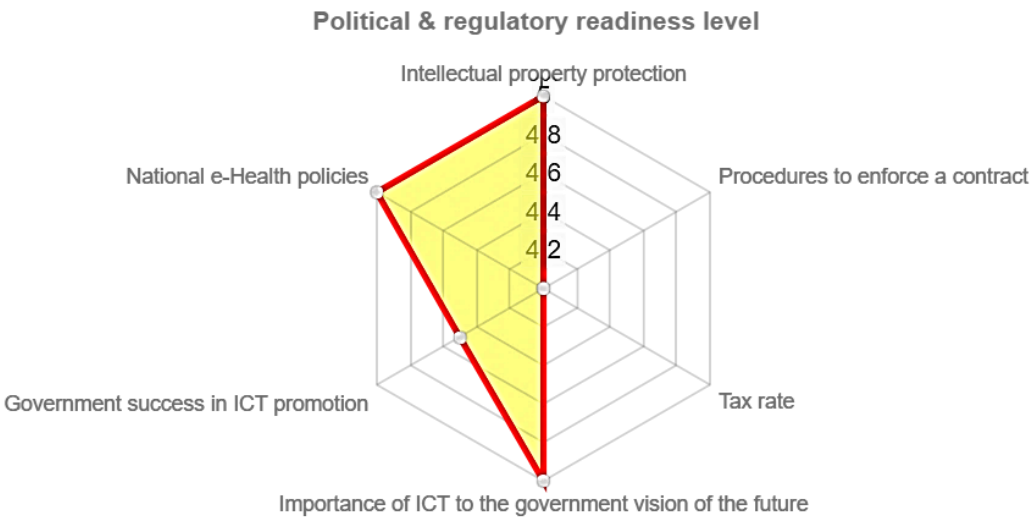



Figure 40: Political and regulatory readiness level graph

Ideally, the perfect readiness level should be 5 which means that all the requirements are fulfilled. The results of the assessment indicate that Burundi is on the right track to adopt a BDA system in its public hospitals. The graphs show that the level is the highest in the political context with 4.57 followed by the organizational context with 4.24 and the technological context with 4.0. Nonetheless, it is the lowest in the environmental context with 2.53. Overall, there are some improvements that need to be done to assure that the adoption is successful.

### 5.3 BDA system adoption model for Burundi's public hospital

After assessing the level of BDA adoption readiness in Burundi's public hospitals a tailored model is proposed based on the TOE framework and a detailed implementation process describing what needs to be done step by step in all 4 contexts.

### 5.3.1 Tailored BDA adoption model for Burundi's public hospitals

The proposed adoption model in Figure 41 resulted from a profound study of factors that influence BDA adoption in healthcare and an assessment of the adoption readiness of Burundi's public hospitals. The model briefly shows what needs to be done in every context.

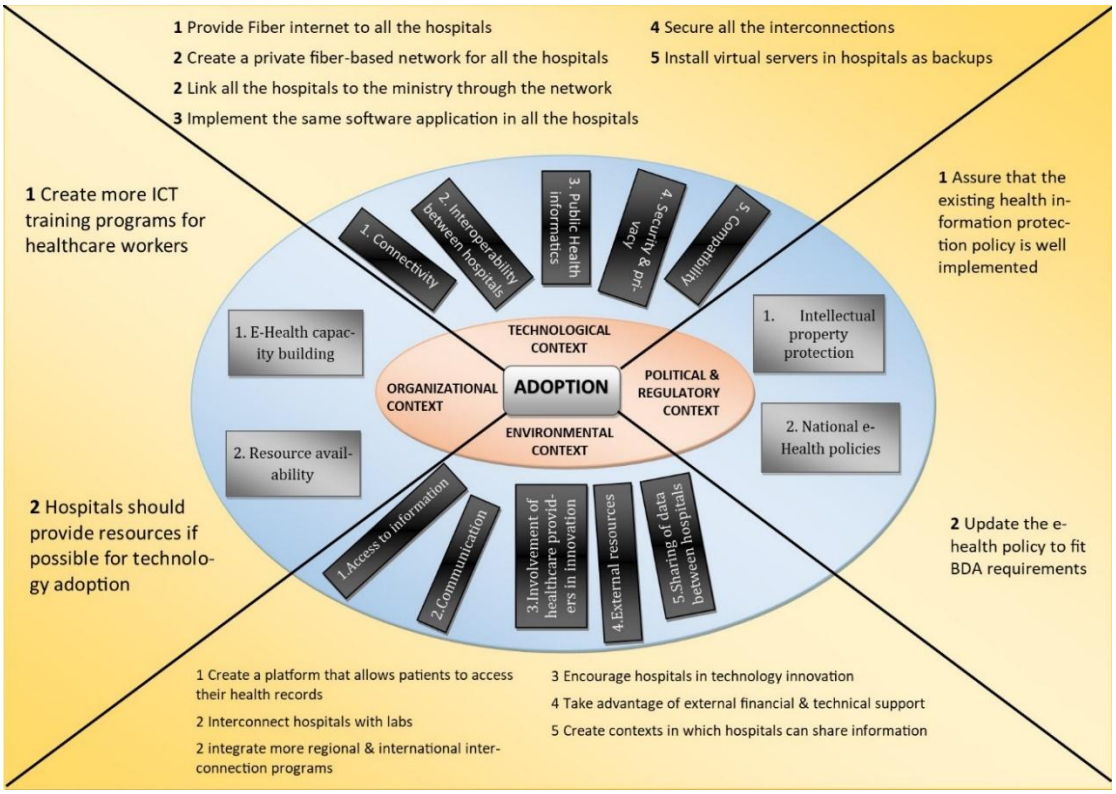



**Figure 41: Tailored BDA adoption model for Burundi's public hospitals**

### 5.3.2 Implementation process

The implementation describes in detail step by step what needs to be done by the government of Burundi to implement a BDA system in public hospitals according to the adoption model discussed in the previous point.

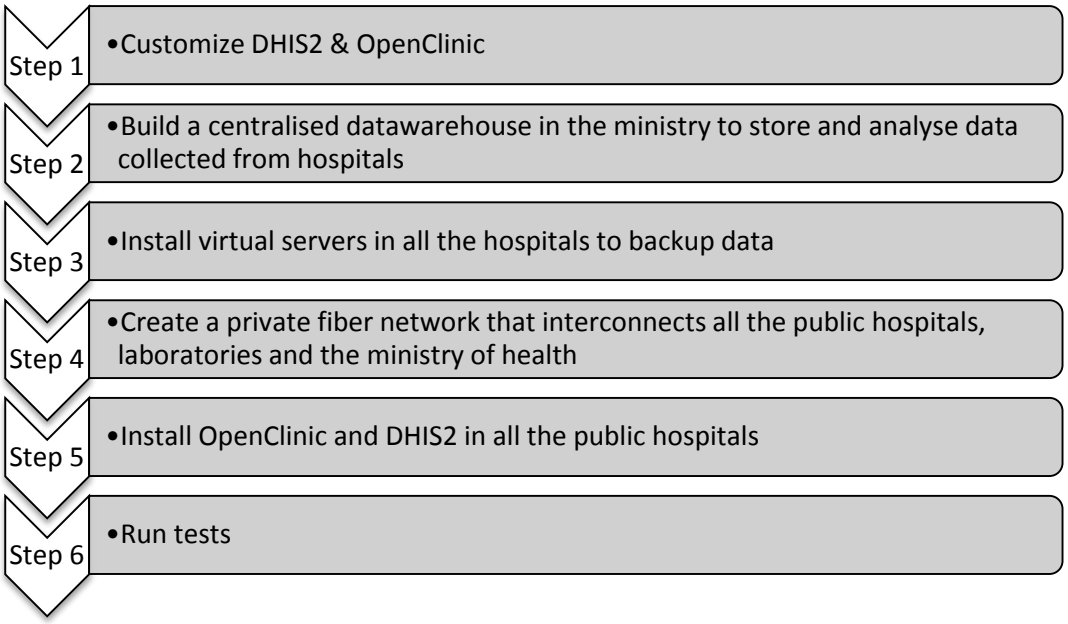



**Figure 42: Implementation process**

**Step 1**: the first step would be to buy a BDA system that combines a EHR centralized database and a BDA system. Fortunately, the ministry already uses DHIS2 that can be used as a BDA system with appropriate tools. Additionally, the ministry has implemented OpenClinic in some public hospitals to collect and store personal health data of patients. Therefore, instead of buying a new BDA system, the ministry can implement OpenClinic in all the public hospitals. OpenClinic would be storing data in a centralized database in real-time. And DHIS2 would be used to retrieve the data from the centralized database and analyze it.

> **DHIS2** is a modular web-based software package built with free and open source Java frameworks. DHIS2 is a tool for collection, validation, analysis, and presentation of aggregate and patient-based statistical data, tailored (but not limited) to integrated health information management activities. It is a generic tool rather than a pre-configured database application, with an open meta-data model and a flexible user interface that allows the user to design the contents of

a specific information system without the need for programming. DHIS2 is open source software released under the BSD license and can be obtained at no cost. It runs on any platform with a Java Runtime Environment (JRE 7 or higher) installed.

**Open Clinic** is an integrated Hospital Information System consisting of a series of modules that have been built on the OpenIT Medical Information Architecture (OpenMIA). The system automates information management for all basic functions of small to medium-sized hospitals (50-1000 hospital beds). The most important features of OpenClinic are:

- User-friendly interface,
- Low cost ownership thanks to the use of open source software,
- Unlimited number of users and devices on the system.

The system is compatible with a number of database servers: Microsoft SQL servers, Sybase, Oracle, MySQL, ProgreSQL. It's also a fully web-based interface and compatible with a variety of operating systems (Microsoft Windows NT/2000/2003 server/XP/VISTA, Linux,Sun Solaris) and the source code is available to the customer.

OpenClinic is mainly used for, among others:

- Patient demographic data
- Patient admissions, discharge and transfers management
- Patient tracking
- Electronic medical records management
- Monitoring of history health events

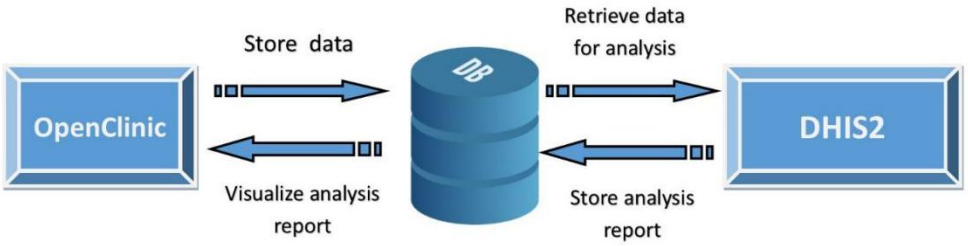



**Figure 43: Combination of OpenClinic and DHIS2**

**Step 2:** To collect and analyze data in real time from all the public hospitals in the country, a centralized Datawarehouse needs to be put in place at the ministry of health.

**Step 3:** Although the data collected in hospitals will be stored in the centralized Datawarehouse, hospitals should have a backup virtual server to store their data in case of any problem.

**Step 4:** The country already has fiber metropolitan network that covers the country. A virtual private network that interconnects all the public hospitals, laboratories and health institutions should be created and connect all the hospitals through the existing switches and only use internet for backup in case the network is down. This will allow a fast, reliable connection and secure interconnection.

BBS (Burundi Backbone System) builds and exploits telecommunication networks known as Open Access Networks. It has currently a Fiber Optic network of 1400 Km on the national level: 400Km in the capital Bujumbura (MAN BSS), 22 principal sites at every province, 6 borders with neighboring countries with a 99.9% availability to offer the best services. In Figure 44 the coverage of the network is marked in red and the grey small circles are the main switches in provinces used for the interconnection.

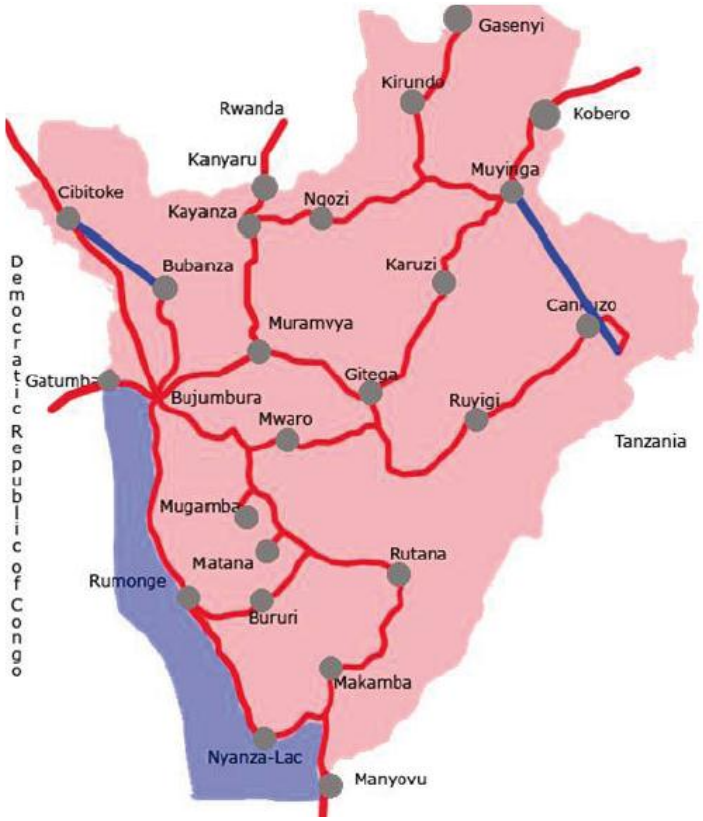



**Figure 44: BBS Open access network**

BBS has done projects like:

- BERNET (Burundi Education and Research Network) interconnecting 14 universities in the country to the internet in order to facilitate e-learning.
- COMGOV (Communication Gouvernementale) initiated in October 2013 by the government of Burundi with the support of the World Bank. The project consisted of interconnecting 46 public institutions to the fiber optic network of BBS and provides a 100Mbps internet bandwidth. Unfortunately, it's not well used due to the lack of applications. Currently 66 institutions are connected.

**Step 5:** After completing the interconnection, OpenClinic and DHIS2 should be installed in all the hospitals. OpenClinic can be used in all the services and departments of the hospitals to collect personal health information of patients. As for DHIS2 its main task will be to retrieve the data from OpenClinic and analyze it in real time. The main

administration dashboard for the virtualization of the data will be in the ministry and at the hospitals it will be a user dashboard that will allow them to get insights from the data analyzed.

**Step 6:** In order to conclude the implementation, the platform will need some tests to assure that first and foremost the network connection is well configured, OpenClinic collects and stores data in the centralized Datawarehouse as intended, DHIS2 retrieves data from the centralized Datawarehouse and runs analysis in real-time.

### 5.4 Data collection and analysis process using BDA

The current data collection and analysis system takes up to 35 days for the hospitals to submit a report to the ministry and takes a year to produce a national report. This is due to the fact that the data collection at the hospital level is not done in a standardized way. The monthly report forms are done manually then submitted through DHIS2 to the ministry. Figures 45 and 46 show the actual data collection system and what the data collection system would be like if the ministry was using a BDA system. Using a BDA system would allow the government to collect and analyze data in real-time. The proposed data collection process will help the government in saving time and resources. There will be no need to produce handwritten reports and save money on office supplies. The government will also save on fuel and transport fees whereby health district officials will no longer need to travel to every hospital to collect reports.

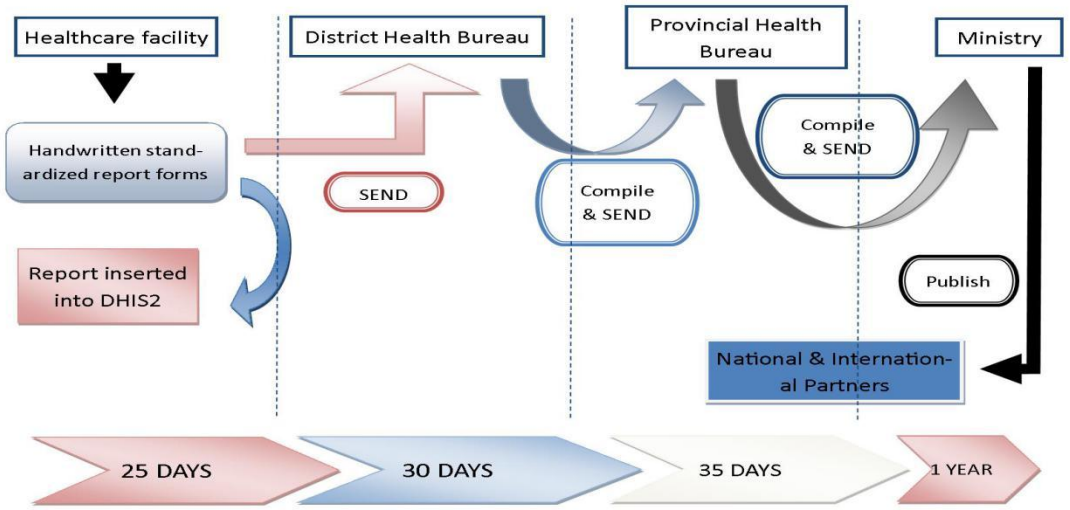



**Figure 45: The current data collection and analysis system**

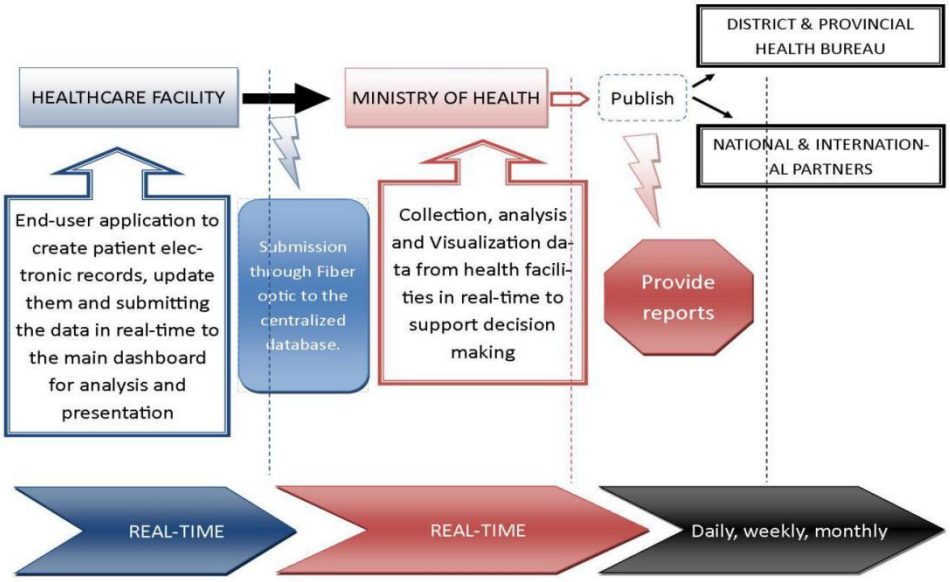



**Figure 46: Data collection and analysis system using a BDA system**

## 5.5 Chapter Summary

The assessment of Burundi's public hospitals in adopting a BDA system required information gathering. The information was collected from 6 public hospitals and the Health Information System. The findings gave a detailed overview of the existing health information system, how the information is gathered, how is analyzed at each level.

The findings revealed that it can take upto a year for the ministry of Health to produce a national report whereas a BDA would publish daily reports. The assessment results were used to propose a tailored adoption model and implementation process that fits in the Burundian context.

# CHAPTER SIX

# SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Summary

The study aim was to propose a tailored BDA adoption model for Burundi's public hospitals. This was achieved through the following objectives.

The first objective of the study was to examine the factors that influence the adoption of BDA in public healthcare services using the TOE adoption theory. Theoretical proven factors were selected from previous studies and classified into predefined adoption contexts of the TOE adoption theory using the deductive coding approach. Afterwards, an adoption assessment model was conceptualized. To emphasize on the major role that government plays in the adoption process and also the fact that the study is on the government level, an additional adoption context was added, political and regulatory context. Figure 47 displays the findings of this objective.

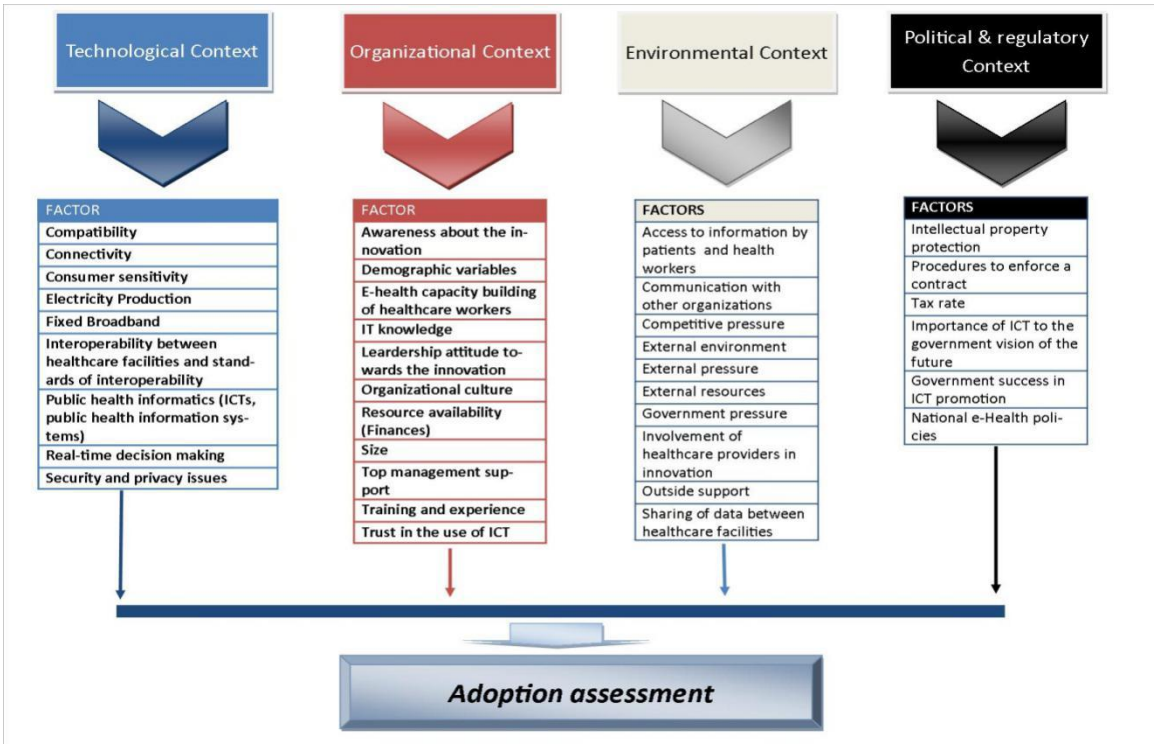



**Figure 47: TOE-Based BDA adoption model**

The second objective of the study was to develop an automated web-based assessment tool based on conceptual model developed on Objective 1. The tool was developed to assess the readiness of Burundi's public hospital. The web-based tool was developed using HTML, CSS, PHP, JAVASCRIPT, JAVA and SQL. The tool name is ARAT (Adoption Readiness Assessment Tool) and it is open source and available online on GitHub.

The third objective of this study was to investigate the methods used by the ministry of health to collect, store and analyze medical data from public hospitals of Burundi. This was achieved through semi-structured interviews, observations and document review. The findings show that the country has appropriate telecommunication infrastructures, hospitals have adequate ICT infrastructures that can facilitate the implementation of a BDA system and the government has put in place e-Health policies that emphasize on the importance of ICT in healthcare.

Although it is obvious that the country has made a lot of progress in encouraging the use of ICT in public hospitals and putting in place an environment that favors the adoption of technology in public healthcare, there are a number of challenges that are yet to be faced:

- Not all the hospitals use a health information system,
- Not all the hospitals have a fiber optic internet connection,
- There is no interconnection between hospitals thus they don't share information among them.

Objective four was to assess the readiness of Burundi in adopting a BDA system in its public hospitals using the ARAT developed on objective two and the information gathered on objective 3. The findings from the assessment show that the country is

prepared to adopt a BDA system. Overall the country has a level of 3.84 out of 5 dispersed as follow: technological context 4, organizational context 4.24, environmental context 2.53 and political and regulatory context 4.57.

The last objective of the study was to propose a tailored BDA system adoption model for improving Burundi's public healthcare services. The assessment results were combined with the requirements of a BDA system to evaluated what needs to be done by the government to secure a successful adoption. The findings of this objective were presented into two: a model describing what needs to be done in all the four contexts and an implementation process that describes step by step how the BDA system can be implemented. Figure 41 in the previous chapter briefly describes the findings of this objective.

### 6.2 Conclusions

The aim and objectives of this study were successfully achieved. Nevertheless, literature showed that there is a need of more studies on BDA adoption that deals with the African context. The majority of the studies done on BDA were focused on technical aspects. The TOE adoption framework was found appropriate for this study because of its ability to evaluate adoption not only on the technological aspect but on the organizational and environmental aspect. This was crucial to this study because the framework provides the possibility to extend adoption up to the government level. In result, an additional context was added, political and regulatory context, to emphasize on the role of the government.

The data collected during field work revealed a number of facts that attest that Burundi is on the right track in adopting BDA in public hospitals. It appeared that officials at the ministry of health, hospital directors and ICT managers are aware of the existence

of BDA and its various benefits. Furthermore, the ministry of health has started a pilot implementation of OpenClinic, a software application for hospital management, in selected hospitals. Luckily, the ministry uses a system, DHSI2, to collect monthly reports from all the hospitals. The ICT infrastructures in hospitals is good enough to support BDA adoption. As for the network infrastructure and access to internet the government needs to improve them. Unfortunately, there is no interconnection of hospitals nor a policy on information sharing. The only interconnection that is between the ministry of health and public hospitals is through DHIS2 which uses internet. The hospitals create accounts and submit reports every 30 to 35 days. Similarly, hospitals revealed that they train workers when there are new employees or new features on the software applications they use if any. As for the availability of resources, the officials at the ministry of health stated that the government has partners that are willing to support financially and technically. On the contrary, hospitals do not have budgets for new technology adoption. The few hospitals that have implemented systems were through projects funded by external partners of the government.

## 6.3 Recommendation

### 6.3.1 For the Burundian Government

One of the biggest advantages that Burundi has is that it has already some of the required tools to proceed with the use of a BDA system in public hospitals. The two existing systems that can be combined and used are: DHIS2 and OpenClinic. The other advantage is the telecommunication infrastructures. The government can proceed with the following in order to successfully adopt a BDA system:

- Implement OpenClinic in all the 61 public hospitals to use a standardized system to collect personal health records.

- A centralized data warehouse should be implemented to store health records from all the hospitals.
- DHIS2 should then be used at the ministry level to manage the centralized data warehouse and analyze the data in real-time.
- A middleware should then be implemented that links OpenClinic and the data warehouse. This middleware will allow the data warehouse to retrieve in real-time data from hospitals.
- The Burundian government also possesses another advantage, the BBS (Burundi Backbone System) that builds and exploits telecommunication networks known as Open Access Networks. BBS has currently a Fiber Optic network of 1400 Km on the national level: 400Km in the capital Bujumbura (MAN BSS), 22 principal sites at every province, 6 borders with neighboring countries with a 99.9% availability to offer the best services. The ministry of health can take advantage of its infrastructures and expertise to put up a private network that will allow it to interconnect all the hospitals. This would require less resources and time since BBS metropolitan network covers the country, the hospitals will be linked to the nearest switches that provide access to the network.

### 6.3.2 Suggestions for future studies

Big Data Analytics is a trending topic today in Information Technology. As pointed out in the first chapter, previous studies have focused more on the technical part of BDA systems and ignored studying in depth the factors that influence their adoption. This study's focus was on public healthcare services. Further research can extend their focus by:

- Conducting studies in detail how to link OpenClinic and DHIS2 to create a BDA platform.
- Due to the limited time and resources that were available for this research, a survey module could have been added to the ARAT to replace the traditional printed questionnaires that were used to collect information that was used for the assessment. Similarly, the generated comments and suggestions could have been more detailed.

Therefore, further studies can be done on how to improve these issues. The tool can be used in various adoption context since it is an open source software that can be modified and customized to fit in the desired study.

To conclude, the other focus of this study was to establish the systems used in collecting and analyzing data in public hospitals in Burundi then propose a tailored adoption model based on the TOE adoption framework. Further studies on Burundi can extend this topic up to local healthcare centers.

## REFERENCE


Analytics, E. (2017). Four Ways Governments Gain With Big Data Analytics.

Archenaa, J., & Anita, E. A. M. (2015). A survey of big data analytics in healthcare and government. *Procedia Computer Science*, *50*, 408–413. https://doi.org/10.1016/j.procs.2015.04.02

Ashwin, B., Thiagarajan, R., Soroushmehr, S. M. R., Navidi, F., Beard, D. A., & Najarian, K. (2015). Big Data Analytics in Healthcare. *Hindawi Publishing Corporation*, *2015*, 1–16. https://doi.org/10.1155/2015/370194

Aurelija, B., & Pipiriene, V. (2013). Adoption of Information Systems by Trade and Manufacturing Enterprises. *European Integration Studies*, *7*(7), 168–177.

Beyer, M. A., & and D. Laney, D.. (2012). The importance of big data: A definition. Stamford, CT: Gartner, 2012.

Bresnick Jennifer (2017). How to Choose the Right Healthcare Big Data Analytics Tools, 1–7. http://healthitanalytics.com

Chen, H., & Storey, V. C. (2012). B Usiness I Ntelligence and a Nalytics : F Rom B Ig D Ata To B Ig I Mpact. *Mis Quarterly*, *36*(4), 1165–1188. https://doi.org/10.1145/2463676.2463712

Dale, S., Burton, D., & Protti, D. (2013). The Healthcare Analytics Adoption Model (HAAM): A Framework and Roadmap, 10. Retrieved from https://www.healthcatalyst.com/white-paper/healthcare-analytics-adoption-model

Davenport H. Thomas (2014), Big Data at Work: Dispelling the myths, Uncovering the opportunities, Harvard Business Review Press, ISBN 978-1-4221-6816-5

Del Aguila- Obra, A. R., & Padilla- Meléndez, A. (2006). Organizational factors affecting Internet technology adoption. *Internet Research*, *16*(1), 94–110. https://doi.org/10.1108/10662240610642569

Dissertation, M. (2016). Assessment of Big Data Analytics Readiness in South African Governmental Parastatals, (May).

Ebrahim, Z., & Irani, Z. (2005). E- government adoption: architecture and barriers. *Business Process Management Journal*, *11*(5), 589–611. https://doi.org/10.1108/14637150510619902

Fatima B. & Kudzai C. (2016), The Evolution of Big Data in Healthcare and its uses in Africa, St. John's Colloquium – June 2016, Canadian Institute of Actuaries,

Fengyi, L., Fofanah, S. S., & Liang, D. (2011). Assessing citizen adoption of e-Government initiatives in Gambia: A validation of the technology acceptance model in information systems success. *Government Information Quarterly*, *28*(2), 271–279. https://doi.org/10.1016/j.giq.2010.09.004

Ganjir Vibha, Dr. B.K. Sarkar, Ravi Ranjan Kumar (2013). Big data analytics for healthcare. *Proc. 19th ACM SIGKDD Int. Conf. Knowl. Discov. Data Min., VI*(July), 1525. https://doi.org/10.1145/2487575.2506178

Gilani, S. (2007). *Original Research*, *13*(4), 425–432. https://doi.org/10.1089/tmj.2006.0064

Gupta, B., Dasgupta, S., & Gupta, A. (2008). Adoption of ICT in a government organization in a developing country: An empirical study. *Journal of Strategic Information Systems*, *17*(2), 140–154. https://doi.org/10.1016/j.jsis.2007.12.004

https://www.statista.com/topics/1464/big-data/, retrieved on May 10, 2018

James N. (2015) 10 of the most popular Big Data tools for developers - Computer Business Review. http://www.cbronline.com/

Jessica Long, & William Brindley. (2014). The role of big data and analytics in the developing world. Copyright © 2013 Accenture

Kambatla, K., Kollias, G., Kumar, V., & Grama, A. (2014). Trends in big data analytics. *Journal of Parallel and Distributed Computing*, *74*(7), 2561–2573. https://doi.org/10.1016/j.jpdc.2014.01.003

Karthik, K., Kollias, G., Kumar, V., & Grama, A. (2014). Trends in big data analytics. *Journal of Parallel and Distributed Computing*, *74*(7), 2561–2573. https://doi.org/10.1016/j.jpdc.2014.01.003

Kathrin, C. M., Bates, D. W., & Sheikh, A. (2013). Ten key considerations for the successful implementation and adoption of large-scale health information technology. *Journal of the American Medical Informatics Association*, *20*(e1), e9–e13. https://doi.org/10.1136/amiajnl-2013-001684

Kijsanayotin, B., Pannarunothai, S., & Speedie, S. M. (2009). Factors influencing health information technology adoption in Thailand's community health centers: Applying the UTAUT model. *International Journal of Medical Informatics*, *78*(6), 404–416. https://doi.org/10.1016/j.ijmedinf.2008.12.005

Klaus Schwab, World Economic Forum. (2015). *The Global Competitiveness Report The Global Competitiveness Report* (Vol. 5). https://doi.org/92-95044-35-5

Koppad, S. H., & Kumar, A. (2016). Application of big data analytics in healthcare system to predict COPD. *Proceedings of IEEE International Conference on Circuit, Power and Computing Technologies, ICCPCT 2016*. https://doi.org/10.1109/ICCPCT.2016.7530248

Kwon, T.H., and Zmud, R.W., "Unifying the Fragmented Models of Information Systems Implementation", in (Editor, 'ed.'^'eds.'): Book Unifying the Fragmented Models of Information Systems Implementation, John Wiley & Sons, Inc., 1987, pp. 227-251.

Louis, H. A., Mcgregor, E., & Griffith, M. (2001). Development of a Technology Readiness Assessment Measure : The Cloverleaf Model of Technology Transfer, 369–384.

Marr, B. (2015). The Incredible Ways Big Data Is Used By The US Government, 6–8.

Mathew, M & Sheppard, E. (2016). Business Value of VxRack and ScaleIO, 1–16.

Maurice, M., & Chris S. (n.d.). Country Case Study for e-Health South Africa, 1–46.

Mayer-Schönberger, K. C. (2013). A Summary of "Big Data: A Revolution That Will Transform How We Live, Work, and Think" by Viktor Mayer-Schonberger and Kenneth Cukier [blog post]. *New Books in Brief*, *7*, 242. https://doi.org/10.1089/big.2013.1513

McDonald, C. (2017). 5 Big Data Trends in Healthcare for 2017. *Mapr*, 1–6. Retrieved from https://mapr.com/blog/5-big-data-trends-healthcare-2017/

Moniruzzaman, A. B. M., & Hossain, S. A. (2013). Nosql database: New era of databases for big data analytics-classification, characteristics and comparison. *arXiv Preprint arXiv:1307.0191*, *6*(4), 1–14. https://doi.org/10.1109/ICPCA.2011.6106531

Mujawar, S., & Joshi, A. (2015). Data Analytics Type, Tools,and Their Comparison. *International Journal of Advanced Research in Computer and Communication Engineering*, *4*(2), 488–491. https://doi.org/10.17148/IJARCCE.2015.42110

Nasser, A. H., Khairalla, F. A., & Al-rashed, W. (2007). Assessing e-Readiness in the Arab Countries : Perceptions Towards ICT Environment in Public Organisations in the State of Kuwait, *5*(1), 77–86.

Nicholas, M. (2017). Smart Africa : Big-data tools transform business Venture capitalists aim to tap mobile tech wave, 1–5.

Nik Rouda & Terri McClure. (2016). Universal Storage for Data Lakes :, (November). © 2016 by The Enterprise Strategy Group, Inc.

Oliveira, T., & Martins, M. F. (2011). Literature Review of Information Technology Adoption Models at Firm Level, *14*(January), 110–121.

Omwoyo Bosire Onyancha (2007). E-governance in Africa : challenges , trends and issues, (May 2007), 1–21.

Oracle. (2006). E-governance challenges for government. Retrieved July 4, 2007, from http://www.egovcenter.in/e-governance/egov_challenges.html

Paige Goodhew (2017), 70+ companies driving the future of Healthcare technology, retrieved on 29 August 2018, https://www.redoxengine.com/blog

Paul T.C., McDonald C.J. (2006) Electronic Health Record Systems. In: Shortliffe E.H., Cimino J.J. (eds) Biomedical Informatics. Health Informatics. Springer, New York, NY, DOI: https://doi.org/10.1007/0-387-36278-9_12

Pramanick, S. (2013). 10 Big Data Implementation Best Practices. *IBM Big Data & Analytics Hub*, 5–6. Retrieved from http://www.ibmbigdatahub.com/blog/10-big-data-implementation-best-practices

Priyanka, K., & Kulennavar, N. (2014). A survey on big data analytics in health care. *IJCSIT, International Journal of …*, *5*(4), 5865–5868. https://doi.org/5: 5865-5868

Projects, D. (2017). Evolving and Improving the Requirements Approach to Big Data Projects A Roadmap to Implementing Big Data Projects, (April), 24–26.

Rahman, N. (2016). Factors Affecting Big Data Technology Adoption. *Student Research Symposium 2016*, 0–29. Retrieved from http://pdxscholar.library.pdx.edu/studentsymposium%5Cnhttp://pdxscholar.library.pdx.edu/studentsymposium/2016/Presentations/10

Ravishankar, A. R., & Clarke, D. (2016). A fully integrated open-source toolkit for mining healthcare big-data: Architecture and applications. *Proceedings - 2016 IEEE International Conference on Healthcare Informatics, ICHI 2016*, 255–261. https://doi.org/10.1109/ICHI.2016.35

Reddy, A. R., & Kumar, P. S. (2016). Predictive big data analytics in healthcare. *Proceedings - 2016 2nd International Conference on Computational Intelligence and Communication Technology, CICT 2016*, 623–626. https://doi.org/10.1109/CICT.2016.129

Ruppel Danielle (2017). Four Ways Governments Gain With Big Data Analytics. https://www.microstrategy.com

Russom, P. (2011). Big Data Analytics. TDWI Research, © 2011 by TDWI (The Data Warehousing InstituteTM ), a division of 1105 Media, Inc.

Science, C., & Publications, S. (2006). E-Government Readiness Assessment Model Ahmed Al-Omari and Hussein Al-Omari, *2*(11), 841–845.

Shankar, K. M. (2016). Application of analytics to big data in healthcare. *Proceedings - 32nd Southern Biomedical Engineering Conference, SBEC 2016*, 156–157. https://doi.org/10.1109/SBEC.2016.88

Sun, J., & Reddy, C. (2013). Big data analytics for healthcare. *Proc. 19th ACM SIGKDD Int. Conf. Knowl. Discov. Data Min.*, *VI*(July), 1525. https://doi.org/10.1145/2487575.2506178

Talia, D. (2013). Clouds for Analytics, Published by the IEEE Computer Society, 0018-9162/13/$31.00 © 2013 IEEE

Ward, J. S., & Barker, A. (2013). Undefined By Data: A Survey of Big Data Definitions. Retrieved from http://arxiv.org/abs/1309.5821

World Economic Forum. (2015). *The Global Competitiveness Report The Global Competitiveness Report* (Vol. 5). https://doi.org/92-95044-35-5

# APPENDICES

## Appendix A

### Interview Guide 1

**Interviewee category: HEALTHCARE FACILITIES DIRECTOR**

**Name of the Healthcare facility: _____**

**Location of the healthcare facility: _____**

**Date: _____**

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1. Would having a Health data record in a centralized database be helpful to the patients? T13

**Strongly disagree ◊ Disagree ◊ Neutral ◊ Agree ◊ Strongly agree ◊**

2. For how many hours is the facility provided electricity per day?T15

   _____

3. Is the facility connected to the ministry?T25

   YES ◊ NO◊

4. Does the facility use any Health information systems?T30

   YES ◊ NO◊

5. Is the facility secured?T33

**Strongly disagree ◊ Disagree ◊ Neutral ◊ Agree ◊ Strongly agree ◊**

6. Is the Healthcare facility aware of EHR databases?O2

YES ◊ NO◊

7. What is the average number of patients per day in the facility?O3

   _____

8. Does the facility train workers in ICT usage?O4

YES ◊ NO◊

9. Does the facility train the workers in new technologies enough?O6

**Strongly disagree ◊ Disagree ◊ Neutral ◊ Agree ◊ Strongly agree ◊**

10. What are the software applications known by the employees of the facility?O7

_____

_____

11. What is the academic qualification of the IT officer?O9

_____

_____

12. Is the use of ICT included in the facility's culture?O11

YES ◊ NO◊

13. Does the facility have a budget for innovation projects?O12

YES ◊ NO◊

14. What is the number of employees in the health facilities?O14

_____

15. What is the number of patients per year in the facility?O15

_____

16. What is the level of ICT training of the employees in the facility?O19

_____

17. How often are the workers trained in ICT?O20

_____

18. Do the officials and healthcare facilities managers and employees trust the use of IT?O21

YES ◊ NO◊

19. Do patients have access to their health records?E1

YES ◊ NO◊

20. What are the methods used by patients to access their health records?E2

_____

21. Is the facility interconnected with laboratories and/or other health organizations?E3

YES ◊ NO◊

22. Do healthcare providers contribute in technology innovation?E10

YES ◊ NO◊

23. Is there any technology Innovations that has been initiated by healthcare facilities/providers?E11

YES ◊ NO◊

24. Do healthcare facilities share information between them?E13

YES ◊ NO◊

25. Do facilities share information between them frequently?E14

**Strongly disagree** ◊ **Disagree** ◊ **Neutral** ◊ **Agree** ◊ **Strongly agree** ◊

26. What are the methods used to share information among facilities?E15

_____

_____

**COMMENTS**

_____

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**Interview guide 2**

**Interviewee category: HEALTHCARE FACILITIES IT MANAGERS**

**Name of the Healthcare facility: _____**

**Location of the healthcare facility: _____**

**Date: _____**

1. Is the facility connected to the internet?T10

YES ◊ NO◊

2. Is the facility connected to other facilitity(ies)?T11

YES ◊ NO◊

3. What kind of interconnection is used between the ministry and the facilities?T26

_____

_____

4. Is the internet connection secure?T34

**Strongly disagree** ◊ **Disagree** ◊ **Neutral** ◊ **Agree** ◊ **Strongly agree** ◊

5. Is the interconnection between facilities and other facilities secured?T35

**Strongly disagree** ◊ **Disagree** ◊ **Neutral** ◊ **Agree** ◊ **Strongly agree** ◊

6. Is the interconnection between the facility and the ministry secure?T36

**Strongly disagree** ◊ **Disagree** ◊ **Neutral** ◊ **Agree** ◊ **Strongly agree** ◊

7. Does the officials and healthcare facilities managers and employees trust the use of IT?O21

**Strongly disagree** ◊ **Disagree** ◊ **Neutral** ◊ **Agree** ◊ **Strongly agree** ◊

Comments

_____

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**Interview guide 3**

**Interviewee category: MINISTRY OF HEALTH OFFICIAL**

**Position: _____**

**Date: _____**

1. Are the healthcare facilities interconnected?T22

YES ◊ NO◊

2. Are healthcare facilities connected to the ministry?T23

YES ◊ NO◊

3. How many facilities are connected to the ministry?T24

_____

4. What kind of interconnection is used between the ministry and the facilities?T26

_____

5. Are they standards of interoperability between facilities?T27

YES ◊ NO◊

6. Are they Health records storage standards?T28

YES ◊ NO◊

7. Is the interconnection between facilities and the ministry secure?T36

**Strongly disagree ◊ Disagree ◊ Neutral ◊ Agree ◊ Strongly agree ◊**

8. Does the ministry have a health information privacy policy?T37

YES ◊ NO◊

9. Are the Ministry officials aware of the existence of BDA systems?O1

YES ◊ NO◊

10. Does the ministry have training programs in ICT for health workers?O5

YES ◊ NO◊

11. What are the software applications used by the ministry?O8

_____

_____

_____

_____

_____

12. Does the ministry officials support new technology adoption?O10

YES ◊ NO◊

13. Does the ministry have an available budget for innovation projects?O12

YES ◊ NO◊

14. What is the amount allocated to innovations by the government?O13

_____

15. Is the ministry willing to support financially the adoption of the system?O18

YES ◊ NO◊

16. Is there any Regional and/or international interconnectivity of healthcare institutions?E6

YES ◊ NO◊

17. Does the government have external financial support that can sponsor the adoption of a BDA system?E8

YES ◊ NO◊

18. Does the government have any intention to adopt new technologies in healthcare?E9

YES ◊ NO◊

19. Does the country have any external technical support in healthcare information system?E12

YES ◊ NO◊

20. Does the Country have a policy on health information protection?PR1

YES ◊ NO◊

21. Is the Procedure to enforce a contract of purchasing an Information System fast?PR2

**Strongly disagree** ◊ **Disagree** ◊ **Neutral** ◊ **Agree** ◊ **Strongly agree** ◊

22. Are the tax rates on healthcare technologies low?PR3

**Strongly disagree** ◊ **Disagree** ◊ **Neutral** ◊ **Agree** ◊ **Strongly agree** ◊

23. Does the government include the importance of using ICT in healthcare in its vision for the future?PR5

YES ◊ NO◊

24. How many innovations have been adopted in healthcare this year?PR6

_____

25. How many technology innovations adoptions have been successful this year?PR7

_____

26. Does the government have a e-Health policy?PR8

YES ◊ NO◊

Comments

_____

_____

_____

_____

**Observation guide**

**Name of the Healthcare facility: _____**

**Location of the healthcare facility: _____**

**Date: _____**

1. How many computers do they have?T4

_____

2. What are the Operating Systems used?T6

_____

3. What is the average year of fabrication of the computers used?T7

_____

4. What are the Software applications used by facilities?T8

_____

_____

_____

_____

5. What are the existing Network devices in facilities?T9

_____

_____

_____

_____

_____

_____

_____

6. What type of internet connection is the facility using? T12

_____

_____

7. Does the facility use any Health information systems?T30

YES ◊ NO◊

8. What is the health information system used by the facility?T31-

_____

_____

# APPENDIX B

**Table B1: Technological context metrics**

| FACTOR | METRIC | CODE |
|---|---|---|
| **Compatibility** | How many computers do the hospitals have? | **T4** |
| | What is the Average RAM of the computers used? | **T5** |
| | What are the Operating Systems used? | **T6** |
| | What are the Software applications used by hospitals? | **T8** |
| | What are the existing Network devices in facilities? | **T9** |
| **Connectivity** | Are the hospitals connected to the internet? | **T10** |
| | Are the hospitals interconnected to other hospitals? | **T11** |
| | What type of internet connection is the facility using? | **T12** |
| **Consumer sensitivity** | Would having a Health data record in a centralized database be helpful to the patients? | **T13** |
| **Electricity Production** | For how many hours the hospitals are provided electricity per day? | **T15** |
| **Fixed Broadband** | Does the country have a fiber optic network? | **T16** |
| | What is the coverage of the fiber network? (in %) | **T17** |
| | Availability of the fiber connectivity. (in%) | **T18** |
| | Is the facility connected to the ministry? | |
| **Interoperability between healthcare facilities and standards of interoperability** | Are the hospitals interconnected? | **T22** |
| | Are the hospitals connected to the ministry? | **T23** |
| | How many hospitals are connected to the ministry? | **T24** |
| | What kind of interconnection is used between the ministry and the facilities? | **T26** |
| | Are they standards of interoperability between facilities? | **T27** |
| | Are they Health records storage standards? | **T28** |
| **Public health informatics (ICTs, public health information systems)** | Do the hospitals use Health information systems? | **T30** |
| **Real-time decision making** | How fast can the BDA system generate reports? | **T32** |
| **Security and privacy issues** | What is the security level of the hospitals? | **T33** |
| | What is the security level of the internet connection? | **T34** |
| | What is the security level of the interconnection between the hospitals and other hospitals? | **T35** |
| | What is the security level of the interconnection between the hospitals and the ministry? | **T36** |
| | Does the ministry have a health information privacy policy? | **T37** |

**Table B2: Organizational context metrics**

| FACTOR | METRIC | CODE |
|---|---|---|
| **Awareness about the innovation** | Are the Ministry officials aware of the existence of BDA systems? | **O1** |
| | Are the hospitals aware of EHR databases? | **O2** |
| **Demographic variables** | What is the average number of patients per day in hospitals? | **O3** |
| **E-health capacity building of healthcare workers** | Do the hospitals train workers in ICT usage? | **O4** |
| | Does the ministry have training programs in ICT for health workers? | **O5** |
| | How often do the hospitals train the workers in new technology? | **O6** |
| **IT knowledge** | What are the software applications known by the employees of the hospitals? | **O7** |
| | What are the software applications used by the ministry? | **O8** |
| | What is the academic qualification of the IT officer in hospitals? | **O9** |
| **Leardership attitude towards the innovation** | Do the ministry officials support new technology adoption? | **O10** |
| **Organizational culture** | Is the use of ICT included in the hospital's culture? | **O11** |
| **Resource availability (Finances)** | Do the hospitals have a budget for innovation projects? | **O12** |
| | Does the ministry have a budget for innovation projects? | **O13** |
| **Size** | What is the number of employees in the hospitals? | **O14** |
| **Top management support** | Is the ministry willing to support financially the adoption of the system? | **O18** |
| **Training and experience** | How often are the workers trained in ICT? | **O20** |
| **Trust in the use of ICT** | Do the hospital's management and employees trust the use of IT? | **O21** |

**Table B3: Environmental context metrics**

| FACTORS | METRICS | CODE |
|---|---|---|
| **Access to information by patients and health workers** | Do the patients have access to their health records? | **E1** |
| | What are the methods used by patients to access their health records? | **E2** |
| **Communication with other organizations** | Are the hospitals interconnected with laboratories and/or other health organizations? | **E3** |
| **Competitive pressure** | How many African Countries already use BDA systems? | **E4** |
| **External environment** | How many neighboring countries use BDA systems? | **E5** |
| **External pressure** | Is there any Regional and/or international interconnectivity of healthcare institutions? | **E6** |
| | Does the WHO have ICT usage in its policies and requirements on improving healthcare services?E7 | **E7** |
| **External resources** | Does the government have external financial support that can sponsor the adoption of a BDA system? | **E8** |
| **Government pressure** | Does the government have any intention to adopt new technologies in healthcare? | **E9** |
| **Involvement of healthcare providers in innovation** | Do healthcare providers (hospitals) contribute in technology innovation? | **E10** |
| | Is there any technology Innovations that has been initiated by hospital | **E11** |
| **Outside support** | Does the country have any external technical support in healthcare information system? | **E12** |
| **Sharing of data between healthcare facilities** | Does the healthcare facility share information with other facilities? | **E13** |
| | How frequent does the hospitals share information? | **E14** |
| | What are the methods used to share information with other facilities? | **E15** |

**Table B4: Political and regulatory context metrics**

| FACTORS | METRICS | CODE |
|---|---|---|
| **Intellectual property protection** | Does the Country have a policy on health information protection? | **PR1** |
| **Procedures to enforce a contract** | Is the Procedure to enforce a contract of purchasing a Health Information system fast? | **PR2** |
| **Tax rate** | Are the tax rates on healthcare technologies low? | **PR3** |
| **Importance of ICT to the government vision of the future** | Does the government include the importance of using ICT in healthcare in its vision for the future? | **PR5** |
| **Government success in ICT promotion** | How many innovations have been adopted in healthcare? | **PR6** |
| | How many technology innovations adoptions have been successful? | **PR7** |
| **National e-Health policies** | Does the government have a e-Health policy? | **PR8** |

# APPENDIX C

**Table C1: Technological context**

| FACTOR | METRIC | CODE | OUTCOME |
|---|---|---|---|
| Compatibility | How many computers do the hospitals have? | **T4** | 496 for 7 hospitals (Average of 70 per hospital) |
| | What is the Average RAM of the computers used? | **T5** | 4GB |
| | What are the Operating Systems used? | **T6** | WINDOWS 7,8,10, XP, SERVER 2008 & 2012, LINUX, UBUNTU |
| | What are the Software applications used by hospitals? | **T8** | OpenClinic, OpenPharmacy, LIMS, QuickPaie, Assyst Comptabilité 100, |
| | What are the existing Network devices in facilities? | **T9** | Routers, Switches |
| Connectivity | Are the hospitals connected to the internet? | **T10** | ALL (The surveyed ones ) |
| | Are the hospitals interconnected to other hospitals? | **T11** | 2 out of 7 are interconnected other hospitals |
| | What type of internet connection is the facility using? | **T12** | Fiber Optic, Broadband, DSL |
| Consumer sensitivity | Would having a Health data record in a centralized database be helpful to the patients? | **T13** | 4.4 out of 5 |
| Electricity Production | For how many hours the hospitals are provided electricity per day? | **T15** | 24 Hours per day |
| Fixed Broadband | Does the country have a fiber optic network? | **T16** | YES |
| | What is the coverage of the fiber network? (in %) | **T17** | 100% |
| | Availability of the fiber connectivity. (in%) | **T18** | 99.99% |
| | Is the facility connected to the ministry? | | |
| Interoperability between healthcare facilities and standards of interoperability | Are the hospitals interconnected? | **T22** | NO |
| | Are the hospitals connected to the ministry? | **T23** | YES |
| | How many hospitals are connected to the ministry? | **T24** | ALL |
| | What kind of interconnection is used between the ministry and the facilities? | **T26** | DHIS2 through internet |
| | Are they standards of interoperability between facilities? | **T27** | NO |

| | | | |
|---|---|---|---|
| | Are they Health records storage standards? | **T28** | YES |
| Public health informatics (ICTs, public health information systems) | Do the hospitals use Health information systems? | **T30** | 6 out of 7 surveyed use them. |
| Real-time decision making | How fast can the BDA system generate reports? | **T32** | In real-time |
| Security and privacy issues | What is the security level of the hospitals? | **T33** | 4 out of 5 |
| | What is the security level of the internet connection? | **T34** | 3.8 out of 5 |
| | What is the security level of the interconnection between the hospitals and other hospitals? | **T35** | 4 for the 2 hospitals that are interconnected to other facilities.<br>4 out of 5 for the 2 hospitals |
| | What is the security level of the interconnection between the hospitals and the ministry? | **T36** | 4 out of 5 |
| | Does the ministry have a health information privacy policy? | **T37** | YES |

**Table C2: Organizational context**

| FACTOR | METRIC | CODE | OUTCOME |
|---|---|---|---|
| Awareness about the innovation | Are the Ministry officials aware of the existence of BDA systems? | **O1** | YES |
| | Are the hospitals aware of EHR databases? | **O2** | All the surveyed |
| Demographic variables | What is the average number of patients per day in hospitals? | **O3** | Average of 168.5<br>Total of 1180 in the |
| E-health capacity building of healthcare workers | Do the hospitals train workers in ICT usage? | **O4** | 6 out of 7 surveyed train them |
| | Does the ministry have training programs in ICT for health workers? | **O5** | YES |
| | How often do the hospitals train the workers in new technology? | **O6** | 3.7 out of 5 |
| IT knowledge | What are the software applications known by the employees of the hospitals? | **O7** | OpenClinic, OpenPharmacy, LIMS, QuickPaie, Assyst Comptabilité 100, |
| | What are the software applications used by the ministry? | **O8** | OpenClinic, DHIS2, SIDAInfo |
| | What is the academic qualification of the IT officer in hospitals? | **O9** | Bachelor Degree & Engineering degree |
| Leardership attitude towards the innovation | Do the ministry officials support new technology adoption? | **O10** | YES |
| Organizational culture | Is the use of ICT included in the hospital's culture? | **O11** | All of the surveyed said YES |
| Resource availability (Finances) | Do the hospitals have a budget for innovation projects? | **O12** | 2 out of 7 said YES |
| | Does the ministry have a budget for innovation projects? | **O13** | YES |
| Size | What is the number of employees in the hospitals? | **O14** | Total of 2182 in the 7 hospitals surveyed<br>Average of 311.7 |
| Top management support | Is the ministry willing to support financially the adoption of the system? | **O18** | YES |
| Training and experience | How often are the workers trained in ICT? | **O20** | Every new employee<br>At every update of the software applications |
| Trust in the use of ICT | Do the hospital's management and employees trust the use of IT? | **O21** | 4 out of 5 |

**Table C3: Environmental context**

| FACTORS | METRICS | CODE | OUTCOME |
|---|---|---|---|
| Access to information by patients and health workers | Do the patients have access to their health records? | **E1** | All said NO |
| | What are the methods used by patients to access their health records? | **E2** | NONE for all |
| Communication with other organizations | Are the hospitals interconnected with laboratories and/or other health organizations? | **E3** | 3 out 7 are interconnected with other health institutions |
| Competitive pressure | How many African Countries already use BDA systems? | **E4** | 6 Countries (Algeria, South Africa, Cameroun, Zambia, Ghana, Uganda) |
| External environment | How many neighboring countries use BDA systems? | **E5** | NONE |
| External pressure | Is there any Regional and/or international interconnectivity of healthcare institutions? | **E6** | YES |
| | Does the WHO have ICT usage in its policies and requirements on improving healthcare services?E7 | **E7** | YES |
| External resources | Does the government have external financial support that can sponsor the adoption of a BDA system? | **E8** | YES |
| Government pressure | Does the government have any intention to adopt new technologies in healthcare? | **E9** | YES |
| Involvement of healthcare providers in innovation | Do healthcare providers (hospitals) contribute in technology innovation? | **E10** | 1 out of 7 said YES |
| | Is there any technology Innovations that has been initiated by hospital | **E11** | 1 out of 7 said YES |
| Outside support | Does the country have any external technical support in healthcare information system? | **E12** | YES |
| Sharing of data between healthcare facilities | Does the healthcare facility share information with other facilities? | **E13** | 3 out of 7 said YES |
| | How frequent does the hospitals share information? | **E14** | 2 out of 5 |
| | What are the methods used to share information with other facilities? | **E15** | Teleconference<br>Email<br>Mail<br>Telephone<br>Discussions |

**Table C4: Political & regulatory context**

| FACTORS | METRICS | CODE | OUTCOME |
|---|---|---|---|
| Intellectual property protection | Does the Country have a policy on health information protection? | **PR1** | YES |
| Procedures to enforce a contract | Is the Procedure to enforce a contract of purchasing a Health Information system fast? | **PR2** | 4 out of 5 |
| Tax rate | Are the tax rates on healthcare technologies low? | **PR3** | 4 out of 5 |
| Importance of ICT to the government vision of the future | Does the government include the importance of using ICT in healthcare in its vision for the future? | **PR5** | YES |
| Government success in ICT promotion | How many innovations have been adopted in healthcare? | **PR6** | MANY |
| | How many technology innovations adoptions have been successful? | **PR7** | MANY |
| National e-Health policies | Does the government have a e-Health policy? | **PR8** | YES |

# APPENDIX D

**MOI UNIVERSITY**
**DEPARTMENT OF INFORMATION TECHNOLOGY**

Tel. 0721735456/0722836972
Fax No. 053-43047,43360
Telex No. MOIVERSITY 35047
Email: dit@mu.ac.ke

P.O. Box 3900
Eldoret - 30100
Kenya

22nd December, 2017

**TO WHOM IT MAY CONCERN**

Dear Sir/Madam

**RE: HABIMANA YVES (IS/MSC/IT/03/16)**

This is to confirm that the above named person is a bona fide student in this institution pursuing his Master of Science (MSc) in Information Technology. Mr. Yves who is our International student from Bujumbura-Burundi is now in his second year of study. He successfully defended his proposal on 12th October 2017 and he will be continuing with his studies during the academic year 2017/2018.

As a partial fulfillment of this degree, he will be required to conduct a research study. The title of his research is ***"An Adoption Model for a Big Data Analytics System for Improving Health Care Services in Burundi".***

We would be grateful if you could be kind enough to allow him to conduct his research study in your organization. Any assistance that you accord to him will be highly appreciated.

Please do not hesitate to contact the undersigned for any further information and/or clarification.

Thank you.

Yours faithfully,

HEAD
DEPT. OF INFORMATION TECHNOLOGY
22 DEC 2017
MOI UNIVERSITY
SCHOOL OF INFORMATION SCIENCES

**DR. IRENE MOSETI**
Head,
**DEPARTMENT OF INFORMATION TECHNOLOGY**

*IM/ej*

DELIVRE EN BREVET SOUS N° B/ 14477/17
BUJUMBURA
Le : 27 DEC 2017

**UNIVERSITE MOI**
**DEPARTEMENT DE TECHNOLOGIE INFORMATIQUE**

Tel. 0721735456/0722836972
No de Fax: 053-43047, 43360
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B.P. 3900
Eldoret -30100
Kenya

22 Décembre 2017

VU POUR LEGALISATION DE LA SIGNATURE
DE Innocent SEBITAMA
APPOSEE CI- dessous
Fait à BUJUMBURA
Le 27 DEC 2017

**A QUI DE DROIT**

Cher Monsieur /Madame

**Objet: HABIMANA YVES (IS/MSC/IT/03/16**

Ceci est pour confirmer que la personne nommée ci-dessus est un étudiant de bonne foi dans cette institution poursuivant sa Maîtrise en Sciences de Technologie informatique (MSc). Monsieur Yves qui est notre étudiant International de Bujumbura-Burundi, en est à sa deuxième année d'études. Il a défendu avec succès son projet d'études le 12 octobre 2017 et il poursuivra ses études durant l'année académique 2017/2018.

En tant qu'accomplissement partiel de son diplôme, il sera tenu de mener une étude de recherche. Le titre de sa recherche est " **Un Modèle d'Adoption pour un Important Système d'Analyses de Données pour Améliorer les Services de Soins de Santé au Burundi ".**

Nous vous serions reconnaissants de bien vouloir lui permettre de mener ses recherches dans votre organisation. Toute aide que vous lui accordez sera grandement appréciée.

S'il vous plaît, n'hésitez pas à contacter le soussigné pour toute information complémentaire et /ou clarification.

Je vous remercie.
Cordialement,

Dr. IRENE MOSETI (signée et cachetée)
Chef,
**DEPARTEMENT DE TECHNOLOGIE INFORMATIQUE.**

ENGLISH LANGUAGE CENTRE
Tel : 22 21 73 02 / 22 27 37 22

Traduit par Innocent SEBITAMA

REPUBLIQUE DU BURUNDI
OFFICE NOTARIAL
BUJUMBURA
Maître Jocelyne NIMBANGANA
NOTAIRE A BUJUMBURA

**REPUBLIQUE DU BURUNDI**

**MINISTERE DE LA SANTE PUBLIQUE**
**ET DE LA LUTTE CONTRE LE SIDA**
***CABINET DU MINISTRE***

Bujumbura, le 1er/12/2018

**A Monsieur HABIMANA Yves**
**à**
**Bujumbura**

N° 630 / 386 /CAB/2018

V/ Réf/

N/ Réf/

Objet : Votre demande d'autorisation pour enquête

**Monsieur**,

Faisant suite à votre lettre du 28/12/2017, demandant l'autorisation pour enquête dans la Direction Nationale du Système dInformation Sanitaire (DSNIS), Direction Générale de la Planification, Direction des Infrastructures Sanitaires et Equipements et des hôpitaux nationaux, j'ai l'honneur de vous informer que je marque mon accord.

Les responsables des directions sus- mentionnées qui nous lisent en copies vous donneront des directives nécessaires pour la réalisation de cette enquête.

Veuillez agréer, Monsieur , l'assurance de ma considération distinguée.

**LA MINISTRE DE LA SANTE PUBLIQUE**
**ET DE LA LUTTE CONTRE LE SIDA**

**Dr Josiane NIJIMBERE**

Cabinet du Ministre B P 1820 BUJUMBURA

**Copie pour information :**
- Monsieur le Secrétaire Permanent au MSPLS
- Monsieur le Médecin Directeur Général des Services de Santé et de la Lutte contre le Sida
- Monsieur le Directeur Général des Ressources au MSPLS
- Madame la Directrice des Ressources Humaines au MSPLS
- Madame la Directrice de la DSNIS au MSPLS
- Monsieur le Médecin Directeur de la Direction Générale de la Planification
- Monsieur le Directeur des Infrastructures Saniitaires et Equipements
- les Directeurs des Hôpitaux Nationaux

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