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An adoption model for a big data analytics system for improving healthcare services in Burundi's public hospitals

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Abstract
One of the key responsibilities of a government is to provide efficient health care services that are better and affordable. In Burundi, patients' health records are collected using handwritten forms and stored in filing cabinets. Evidence' based research and practice shows that adoption of a Big Data Analytics (BDA) system can significantly improve health care services. Unfortunately, BDA adoption models and automated assessment tools are lacking not to mention the dearth caused by researchers' predominant focus on the technical aspects. Therefore, the aim of this study was to propose a BDA system adoption model for improving health care services in Burundi's public hospitals. This was achieved through a mixed research method a large part being qualitative. The factors that influence the adoption of BDA in public healthcare services using the Technology Organization Environment (TOE) adoption theory through a desk research. Semi-structured interviews, observations and document reviews were used to investigate the methods used to collect, store and analyze data in Public hospitals of Burundi. Afterwards, a web based automated Adoption Readiness Assessment Tool (ARAT) was developed then used to assess the readiness of Burundi in adopting a BDA system in its public hospitals. The assessment results showed that the country has adequate telecommunication infrastructures and has started using information systems like OpenClinic and District Health Information Software 2 (DHIS2) in some public hospitals, the government has set up policies for e-Health and the level of awareness is high as well among health workers. But there are improvements to be made in order to assure that the adoption is successful. Lastly, a tailored adoption model was proposed describing what should be done and how in order to assure a successful adoption of a BDA in public hospitals.

Keywords: *Adoption Readiness Assessment Tool (ARAT); Big Data Analytics (BDA), Burundi; Healthcare*

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Introduction

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 and Sheppard, 2016). According to Beyer & Laney (2012) 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, 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). According to 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 United States of America (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 United States (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.

Literature review

The number of BDA systems available in healthcare has been increasing within the past few years; Explorys, Health Catalyst, and GE Healthcare are examples of some of the best systems in the market used for medical data collection, storage and analysis. Evidence based research and practice shows that adoption of a BDA systems that comprises a centralized EHR database and a real-time data analysis system that extracts useful insights from the medical data can significantly address these challenges. 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.

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, Democratic Republic of Congo, Ghana, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tanzania and Tunisia) with a total number of 53 data centers representing 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).

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) .

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 (National Health Development Plan 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.

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). The objective of the study was to **e**xamine the factors that influence the adoption of BDA in public healthcare services using the TOE adoption theory and assess the readiness of Burundi in adopting a BDA system in its public hospitals using the Adoption Readiness Assessment Tool.

Materials and Methods

The aim of this study was to propose a BDA adoption model for Burundi's healthcare services in public hospitals.

Research design

The study's objectives were achieved through three main phases using quantitative and qualitative 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 assess the readiness of Burundi in adopting a BDA system in public hospitals and the third phase was to develop a tailored adoption model both using the quantitative research method.

Sampling

Burundi 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: 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: 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.

Purposive expert sampling: 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 11.

Table 1: 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**

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.

System Development Method (SDM)

System Development Method 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.

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 CHARTOF 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, Information Technology (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 analyze 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 to in achieving the third objective of the study.

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.

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 a interview with the Health Information System office. Also copies of interview guides were attached to the letters. The interviews were only conducted after approval.

Conceptual framework

The automated adoption readiness assessment web-based tool (ARAT) was conceptualized through the Technology Organization Environment (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. Since the study is on public healthcare services it involves directly the government therefore another context was added to emphasize on its role in the adoption process. Therefore, the new TOE-based adoption model has 4 main contexts: Technological, Organizational, Environmental and Political and Regulatory. This was possible because the TOE framework is scalable and allows researchers to customize it according to the requirements and needs of the study.

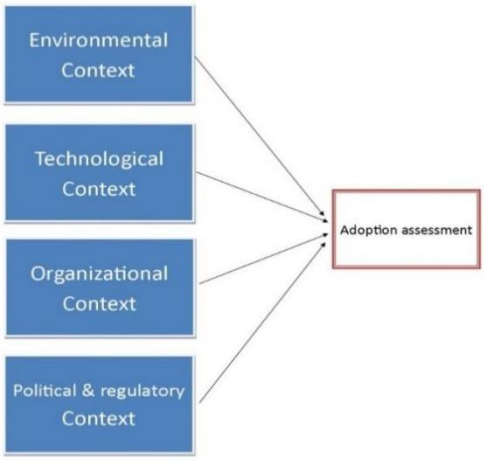

Figure 1: ARAT Conceptual model

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.

Automated BDA Adoption Readiness Assessment Web-Based Tool (ARAT)

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. Following the conceptual framework, the adoption factors were categorized into four main contexts and each factor was attributed one or more measurable metrics.

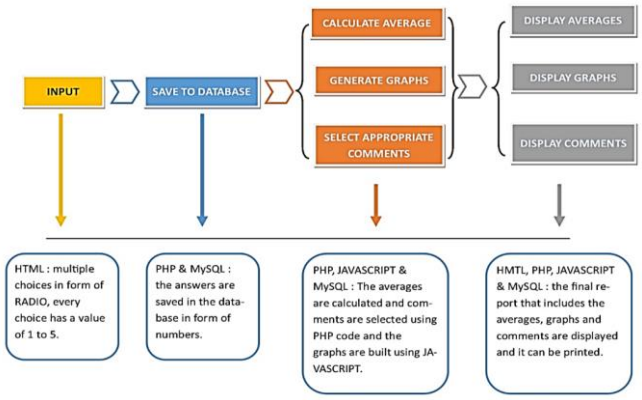

Figure **2**: Logical diagram of the ARAT

Results

The results of the assessment shown in Table 2, 3, 4 and 5 indicate that Burundi is ready to adopt a BDA system in its public hospitals. The graphs shown in Figure 5, 6, 7 and 8 indicate 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.

***Technological context*:** The assessment results illustrated in Table 2 show that public hospitals in Burundi have a sufficient number of computers and all the hospitals have Local Area Networks (LANs). Healthcare workers are aware of the benefits of using Iinformation and Communication Technologies (ICT) and the electricity supply is sufficient although some hospitals have to use power generators to ensure a 24-hour coverage. Nevertheless, graph on Figure 5 show that there are some improvements to be made. For instance, 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.

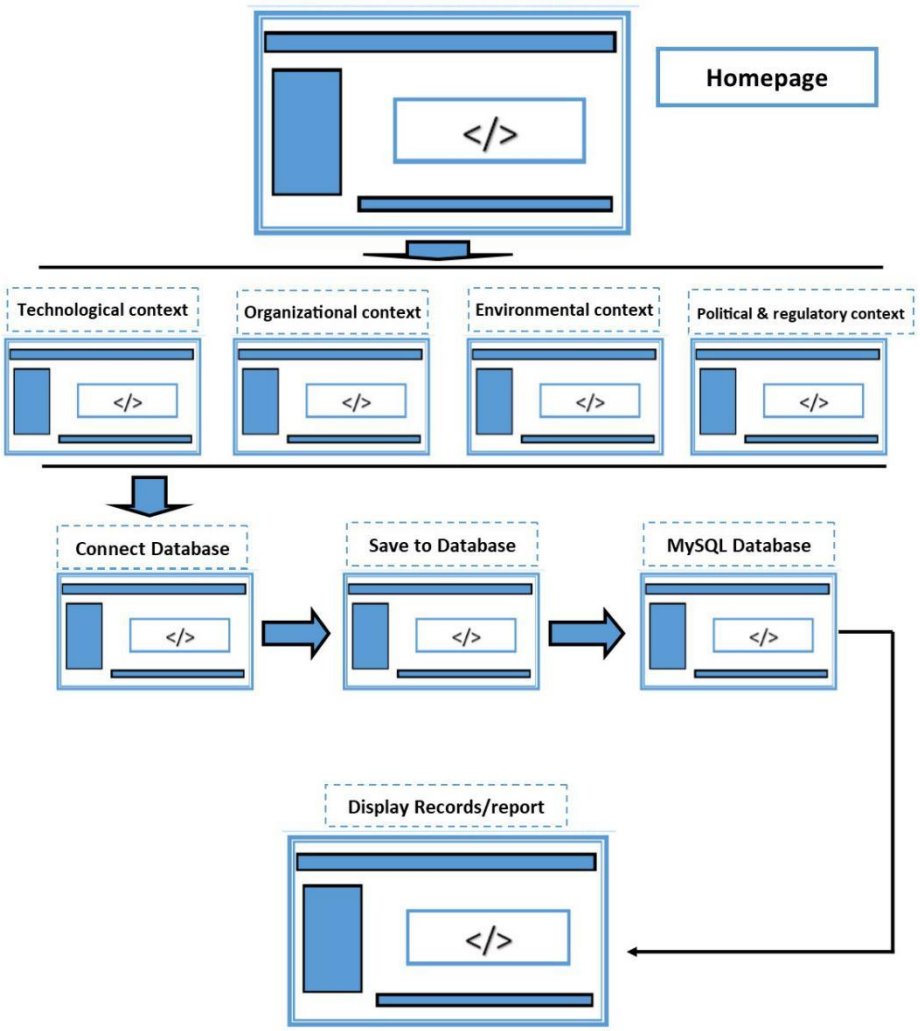

Figure 3: ARAT web pages structure

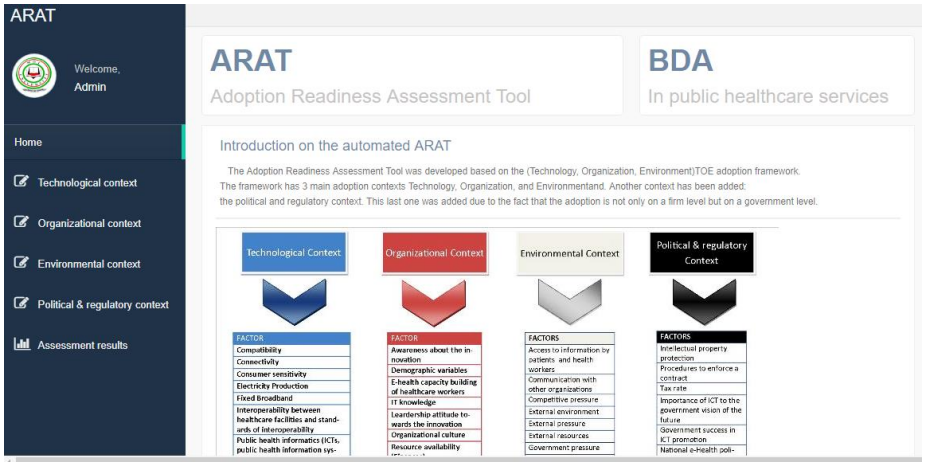

Figure 4: ARAT Homepage screenshot

Table 2: Technological context survey results

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, AssystComptabilité 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. 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

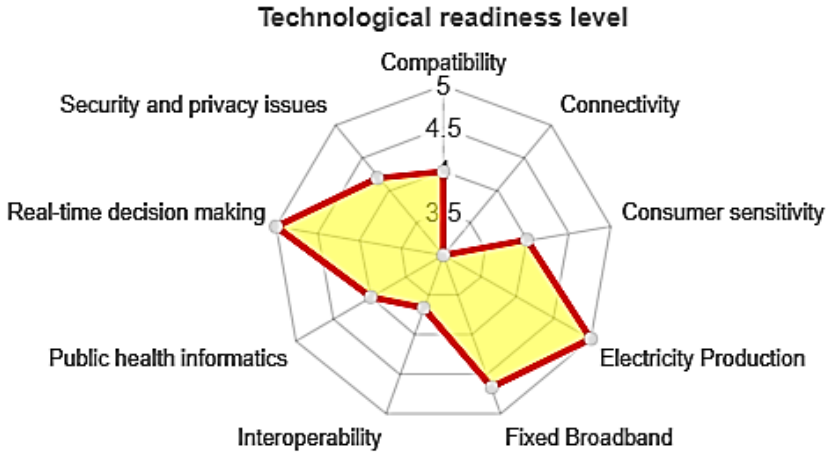

Figure 5: Technological readiness level graph

***Organizational context*:** The results in table 3 show that 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 according to the assessment results in Figure 6.

Table 3: 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**	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, AssystComptabilité 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 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 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

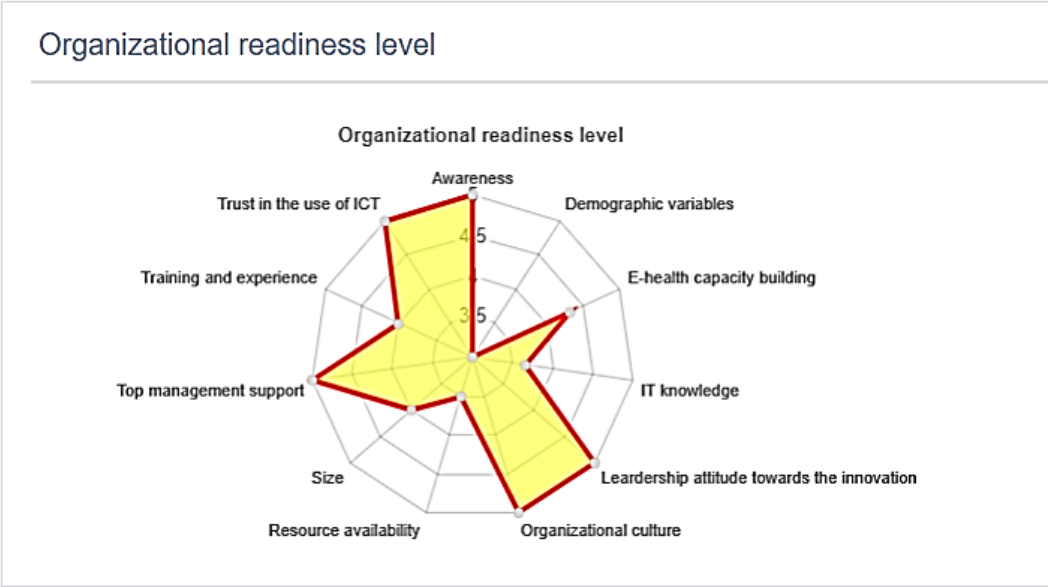

Figure 6: Organizational readiness level graph

***Environmental context*:** Results in Table 4 show that 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, the graph in Figure 7 show that 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.

Table 4: 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**	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 neighbouring 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 Email Mail Telephone Discussions

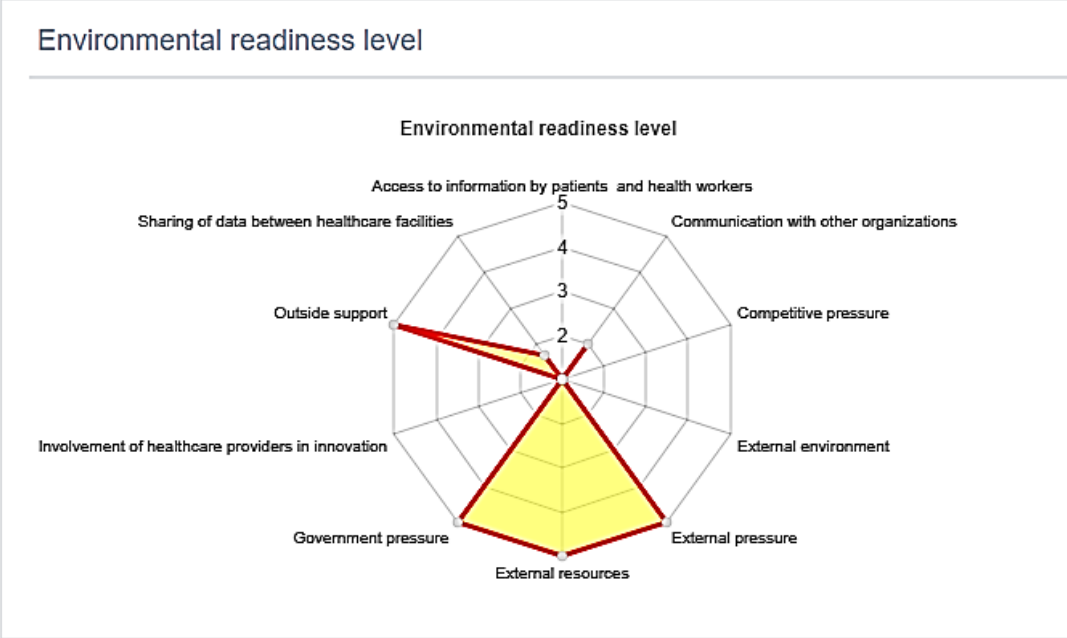

Figure 7: Environmental readiness level graph

***Political and regulatory context*:** According to the results shown in Table 5 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 graph in Figure 8 show that the government needs to adapt its e-health policy to BDA systems.

Table 5: Political & 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**	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

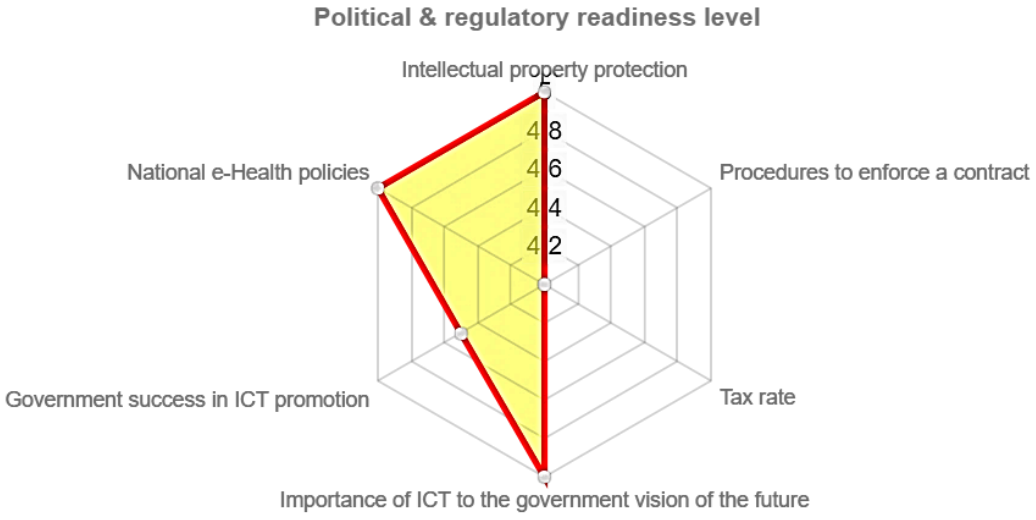

Figure 8: Political and regulatory readiness level graph

Discussion

The assessment results were combined with the requirements of a BDA system to evaluatewhat needs to be done by the government to secure a successful adoption. A tailored adoption model was proposed.

Tailored BDA adoption model for Burundi's public hospitals

The adoption model (Figure 9) describes what needs to be done by the government of Burundi at the ministry level and hospitals to successfully adopt a BDA system. To use the proposed model and adopt the BDA system, the government should follow these sequential steps described below.

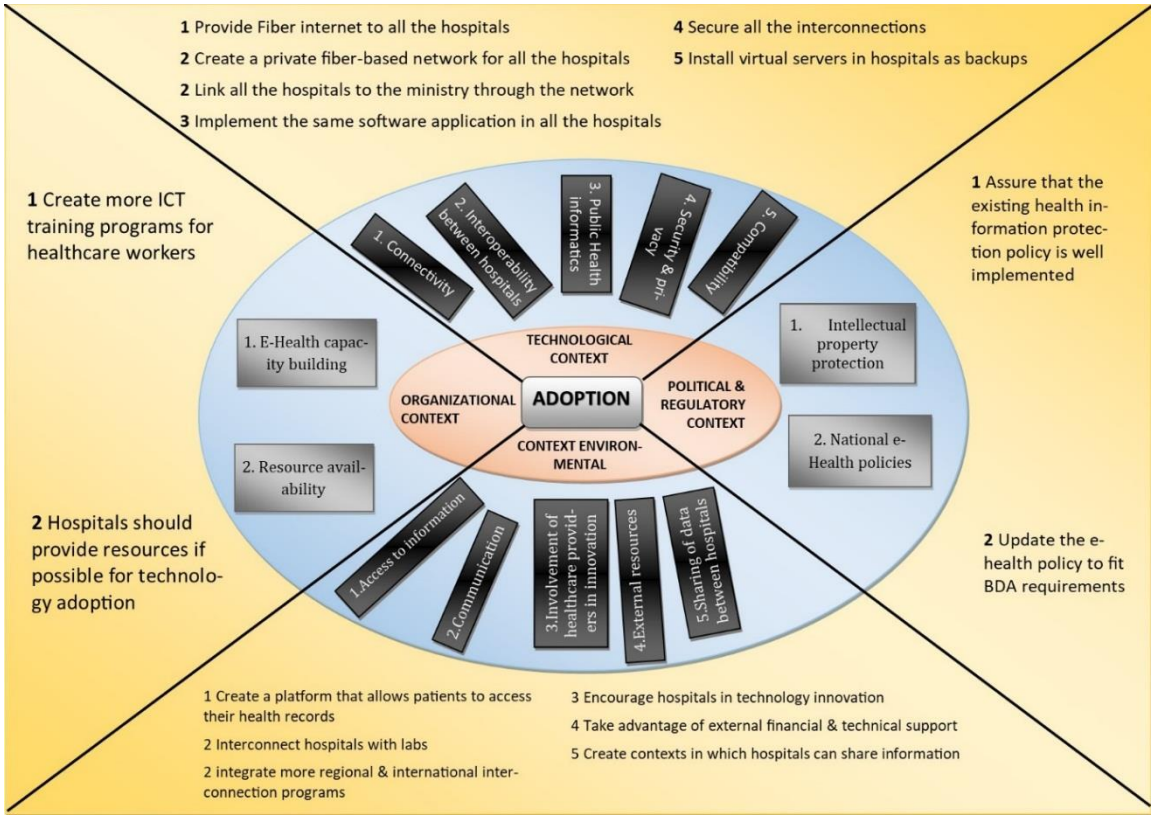

Figure 9: Tailored BDA adoption model for Burundi's public hospitals

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 servers,

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 is 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

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 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.

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.

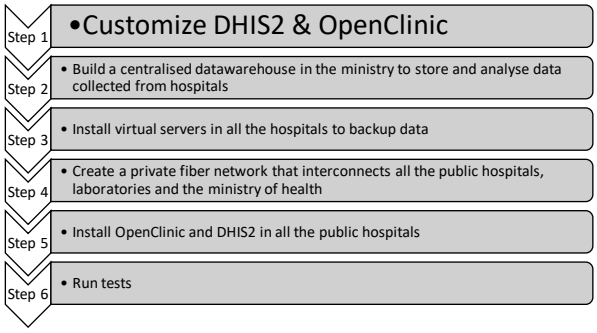

Figure10: Implementation process

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.

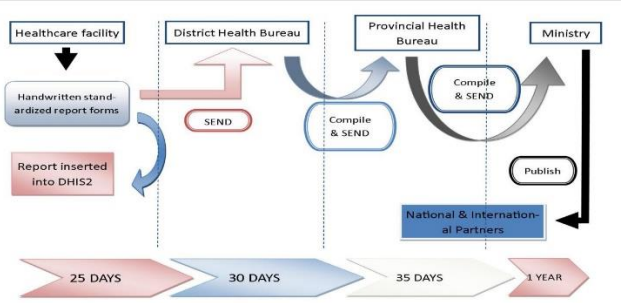

Figure**11**: Data collection and analysis system using a BDA system

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.

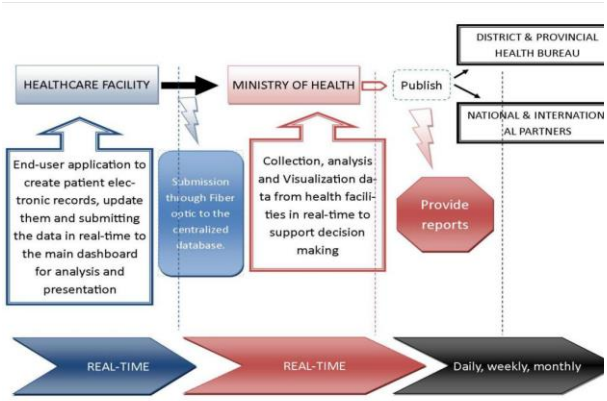

Figure**12**: Data collection and analysis system using a BDA system

Conclusion

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. The second objective 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. 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 evaluate 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.

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 go 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, DHIS2, 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.. 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.

Recommendation

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 should 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. Burundi Backbone System (BBS) has currently a Fiber Optic network of 1400 Km on the national level: 400Km in the capital Bujumbura (Metropolitan Area Network 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.

For future researchers

Big Data Analytics is the most 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 and study 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.

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