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Interoperability of Information Systems: Case of Higher Learning Institutions in Rwanda-Challenges and the way forward

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A dissertation submitted in partial fulfilment of the requirements for the degree of Masters of Science in Information Systems.

Option: e-government

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Declaration

I, Jean de Dieu Habinshuti, declare that the contents of this thesis titled “**Interoperability of Information Systems: Case of higher learning institutions in Rwanda- Challenges and the Way Forward**” has not previously been submitted for academic research and it represents findings from higher education sector that were not published in any higher institution.

I grant the University of Rwanda the right to reproduce the thesis in any manner or format for any research or learning matters.

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Dedication.

To God Almighty, my wife Aline and my children Miguel and Camilla.

Abstract

Interoperability of information systems is challenging as it is influenced by different factors contributing to the success or failure of organization data sharing, quality service delivery, communication delays, and any undesirable effects. Literature analysis shows that in developing countries, the interoperability of information systems is constrained by the following factors: ICT Infrastructure, top management support, human resources, data, and information integration, security and privacy, business process issues, IT standards, technical expertise challenges, government regulation, collaboration and coordination matters, trust issues between agencies, slow implementation of policies, lack of compliance in adopting the Minimum Interoperability Standards (MIOS), and financial constraints.

In higher education sectors, the interoperability of information systems has different constraints related to linked data strategy to connect existing multiple information, siloed data, data security, limited communications across institutions, heterogeneity of platforms with different programming languages individual applications, and IT architecture. However, there is limited knowledge about issues challenging the interoperability of Information systems from higher education institutions in Rwanda.

This research takes a case of high-learning institutions in Rwanda and investigates challenges behind information systems interoperability in those institutions. A qualitative data method is adopted whereby document analysis and interviews will be used. The findings show that the lack of a common architecture, existing of information systems designed in silos in higher learning institutions, the availability of diverse platforms for data exchange in different higher education sectors, ICT infrastructure issues, and less investment in high-quality information systems at challenges of having technical interoperability in higher learning institution. Based on challenges and suggested solutions from respondents, RHEIS (Rwanda Higher Education Information Systems) architecture was proposed to have information systems communicating with each other.

This research implies that solutions will be drawn to address issue of information systems interoperability in high learning institutions in Rwanda. This will contribute to HEC's (High Education Cancel) mission to improve the organization and functioning of high learning institutions. It will also advise the Government of Rwanda in all matters related to high education policy and strategies; to monitor the adherence to norms and standards in high learning institutions

and to follow up all activities concerning learning, teaching, and performance evaluation on high learning institutions.

Keywords: Information systems, interoperability, high leaning institutions, Rwanda.

List of Acronyms

AIMS	Africa Institute of Mathematical Sciences
ALU	Africa Leadership University
AUCA	Africa Leadership University
BRD	Development Bank of Rwanda
CIS	Central Integration Server
CMUR	Carnegie Mellon University Africa
CUR	Catholic University of Rwanda
EAUR	East African University Rwanda
EMIS	Educational Management Information Systems
HEC	Higher Education Council
ICE	Indangaburezi College of Education
ICK	Institut Catholique de Kabgayi
ICT	Information and Communications Technology
ILPD	Institute of Legal Practice and Development
INES	Institut d’Enseignement Supérieur de Ruhengeri
IPB	Institut Polytechnique de Byumba
IS	Information Systems
ISPG	Institut Supérieur Pédagogique de Gitwe
IT	Information Technology
KP	Kibogora Polytechnic
MIOS	Minimum Interoperability Standards
MIS	Management Information Systems
MKU	Mount Kenya University
NACHS	Ngoma Adventist College of Health Sciences
NUC	Ngoma Adventist College of Health Sciences
PECDTC	Premier Early Childhood Development Teachers College
PIASS	Protestant Institut of Arts & Social Science
REB	Rwanda Education Board
RHEIS	Rwanda Higher Education Information System
RHIH	Ruli Higher Institute of Health Sainte Rose De Lima
RISA	Rwanda Information Society Authority
RP	Rwanda Polytechnics
RTUC	Rwanda Tourism University College
SIF	School Interoperability Framework
SOA	Service Oriented Architecture
UGHE	University of Global Health Equity
UK	United Kingdoms
ULK	Université Libre de Kigali

UNILAK Institute of Lay Advantists of Kigali

UR University of Rwanda

USA United States of America

XML Extensible Markup Language

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Chapter 1. Introduction

This thesis explores challenges behind information systems interoperability in higher learning education and it provides the way forward to resolve interoperability challenges for the effective performance of higher education sectors in terms of efficient information systems. This chapter introduces the research by presenting the background of information systems, interoperability of information systems in higher education institutions, and challenges. This chapter provides the research motivation, problem statements, research objectives, study scope, significance of the study, organization of the study, and the chapter conclusion.

1.1 Background and Motivation

The interoperability of information systems is influenced by many factors such as clear strategy, administrative support, IT skills, IT infrastructure, security and privacy, and trust to use the services through e-government channels (Sulehat & Taib, 2016).

Before we continue with the interoperability concepts, let us understand the information systems. An information system is a work system with functions limited to processing information by performing six types of operations: capturing, transmitting, storing, retrieving, manipulating, and displaying information (Alter, 1999). An information system involves a variety of information technologies such as computers, software, communication systems, databases, the Internet, mobile devices and much more, to perform specific tasks, interact with and inform various actors in different social or and organizational contexts (Boell & Cecez-Kecmanovic, 2015). More than one information system can work together and communicate each other, which can be called systems interoperability. Interoperability is referred to a property of different systems and organizations enabling them to work together (Gottschalk & Solli-sæther, 2008). Interoperability refers to a stock of interrelated initial commitments that enable the exchange of data and functionality during the run time of interoperation whereby systems and organizations are able to communicate which result to information and services that are accepted between them (H. J. Scholl & Klischewski, 2007).

Information systems interoperability has an important role for e-government development, especially in public management information systems and ensuring the interoperability is ineffective and limited in developing countries (Thanh et al., 2018).

Information systems are embedded in the core of almost every business function in the modern organizations and higher education institutions that are the hub of today's economic, cultural and social change are part of sectors that uses information systems (BLERTA ABAZI ÇAUSHI, 2018). Higher learning institutions are among sectors that handle multitask operations with large number of students and staff members, and it is important to adopt information communication technology (ICT) to manage these information (Raymond, 2017). In higher education institutions, information systems does not only focus in increasing efficiently and efficacy for the processes but also meeting the need of students, parents, government as well as the society (BLERTA ABAZI ÇAUSHI, 2018). The fact of measuring the quality of education in a reliable and timely manner is at the core of social development of any country and the implementation of education management information systems support on that core element (Ommundsen, 2017).

Every school has its own specific needs and the value of value of management information systems was recognized during its integration stages (Shah, 2014). From a statement that every school has its own specific needs, it is possibly that each school develop its own information system. It is common to see that higher education institutions (HEIs) use different software applications for different purpose and that they spend much money towards procuring and periodical renewal of licenses (Sastry Musti, 2019). There are issues behind the use of information systems in higher educational institutions namely: architecture and functions, data security, cost, lack of well-considered concepts of realization, non-uniform and standardization for information systems, incompatible information platforms and all these results in the issues with information systems coordination in various universities (Sagitova, 2012).

As highlighted above, it is important to have interoperable systems for better quality of information and services to beneficiaries in higher education sectors. This thesis explores and helps towards interoperability in information systems from higher education sectors.

It is critical that interoperability is a challenge in developing countries including my country of Rwanda whereby there is a challenge of an architecture design that support the interoperability

between systems (Crichton et al., 2012). Particularly in Rwanda higher education , there are issues related to information systems implementation, problem related to misalignment between IT systems and educational activities, structure, policies at university, lack of clear model of IT alignment within universities are identified (Byungura, 2019) which may have negative impact for the information systems interoperability as shown in the literature. Being Rwandan and beneficiary in Rwanda education system, I have keen interest to study interoperability of information systems in Rwanda higher learning organizations. We are motivated to conduct research in that area because I believe it will contribute to the improvement of education, which is key for personal and organizational development.

1.2 Problem Statement

Information system interoperability has an important role for e-government development and each country has its own strategy in ensuring interoperability for information system. However, it is a very complex task to achieve interoperability among information systems especially in developing countries (Thanh et al., 2018) . Interoperability of information systems in that context knows various barriers. Those barriers include ICT infrastructure challenges; lack of top management support before, during and after the project management phases; lack of qualified human resource in ICT; information and data inconsistency; low or lack of information security and privacy; business duplication; financial support; cultural attitudes; technical challenges like IT infrastructure, IT security and IT standards. There is also a high dispersion in level of integration among information systems, trust issue between agencies, slow or lack of regulation and policies implementation, lack of compliance to interoperability standards, the use of different technology in different organizations, etc (Sulehat & Taib, 2016)

Higher education information systems are also involved in the current technology trends but it is a challenge to adapt and implement these technologies(Gerón-Piñón et al., 2019) and institutions have different motivations and applications design which may be an issue for high level interoperability and architecture (Griffiths et al., 2016).

In relation to Rwanda as one of the developing countries; Crichton et al.(2012) indicated that information systems interoperability in Rwanda is a challenging issue whereby syntactic, semantic,

process or heterogeneity issues are enclosed. From higher education institution in Rwanda, there are issues of existing systems that are not compatible within ICT infrastructure, ineffective top management communication, ICT policies that are not clearly inform the integrated educational management information systems (Byungura, 2019). However, we fail to understand specifically challenges constraining interoperability of information systems in Rwanda for the case of high learning institutions towards looking for a solution, that's why two questions are displayed for this study:

- What challenges behind information systems interoperability from high learning institutions in Rwanda?
- What are possible solutions that may be applied to resolve interoperability issues in high learning institutions in Rwanda?

1.3 Study Objectives

The study has general and specific objectives presented below:

1.3.1 General Objective

The aim of this research is to contribute to the implementation of information systems interoperability from high learning institutions in Rwanda.

1.3.2 Specific Objectives

The specific objectives to the status are:

- To identify constraints of information systems interoperability in high learning institutions from Rwanda
- To provide some solutions for effective interoperability in information systems from high learning institutions.

1.4 Study Scope

In this thesis, interoperability is a key requirement to support activities in heterogeneous environments effectively and efficiently whereby diversified applications and data are able to be shared and communicate despite being on different pieces of equipment and platforms (Araujo & Mackenzie, 2017). This thesis explores challenges of information systems interoperability in

higher learning institutions and provides solutions to these challenges. Some solutions could contribute to the improvement or design of information systems infrastructure, to the managerial effectiveness and other more.

1.5 Significance of the Study

The study identifies challenges of information systems interoperability in high learning information systems interoperability and these challenges are the baseline of drawing solutions towards effective implementation of interoperable information systems in high learning institutions.

The research influences the implementation of interoperable information systems in high learning institutions. It generates knowledge about challenges behind interoperability, support the government initiate and improve the quality of information system in the context of interoperable systems. The research also influences the decision-making in Higher Education Council (HEC) and partners towards policies and other technical approaches to put into effect the interoperable information systems.

1.6 Organization of the Study

The organizational viewpoint considered in this thesis focus on challenges or barriers of information systems interoperability in higher education institutions. Some solutions are provided towards addressing the identified challenges. In general, there are challenges in education sectors that are barriers of information systems interoperability namely; effective education systems management issues, standards issue for operating systems and programming languages, technical and legal issues for interoperable data, programs and content in education (Jakimoski, 2016a). This thesis specifically identifies interoperability challenges in information systems from higher education institutions in Rwanda and provides some solutions.

This thesis is divided into six chapters. Following this introductory part is chapter two, which presents the literature review about information systems interoperability in general and in educational sectors. Chapter three describes the research methodology by explaining the methods used for the study. Chapter four describes the system analysis and design. Then chapter five provides the results and analysis of findings. The thesis end with chapter six that provides the study conclusion and recommendation as well.

Chapter one introduced the background of interoperability of information systems in general and in higher education institutions and it has indicated that interoperability of information systems is a challenge issue in different sectors including education. This chapter has described the problem statement, study objectives and scope, significant of the study and how the study is organized. The following chapter two is providing the literature review about the information systems interoperability.

Chapter 2: Literature Review

This chapter presents the relevant knowledge available to the study objectives and research questions. This chapter provide an overview on interoperability of information systems in general context and highlight the level of information systems interoperability. It also reviews the status of interoperability of information systems in developing countries mostly focusing on challenges behind information systems interoperability.

2.1 Interoperability of Information Systems and Levels

2.1.1 Interoperability of information systems in general

Large organizations need to exchange information among different and separately developed systems (Sciore et al., 1994) and interoperability leads to information sharing among governmental entities (H. J. J. Scholl, 2005). Interoperability is an enabler for helping government use technology to improve government services and operations and the systems must be interoperable to effectively meet citizens' demands (Pardo et al., 2012).

Interoperability of information systems can be implemented in different sectors including e-government. The e-Government interoperability represents a set of multidimensional, complementary, and dynamic capabilities needed among these networks of organizations in order to achieve successful information sharing (Pardo et al., 2012). There are 16 dimensions for e-government interoperability from the framework of multidimensional capability for e-government interoperability (Pardo et al., 2012), and these dimensions are divided into seven categories:

- Category one is for business architecture whereby we find dimension of business architecture.
- Category two is for governance and leadership that have 3 dimensions namely governance, leaders and champions, and stakeholder engagement.
- Category three is for strategic management with dimensions of strategic planning, and performance evaluation.
- Category four is for operational management with project management, and resource management dimensions.

- Category five is for information policy with information policy and data requirement dimensions.
- Category six is about cross-organizational collaboration whereby collaboration readiness and organizational compatibility dimensions are considered.
- Category seven is for technological readiness with secure environment, technology acceptance, technology knowledge, technology compatibility dimensions

2.1.2 Interoperability processes and involved challenges

In the implementation of e-government interoperability, most projects mainly focused on the administrative and organizational sides but not emphasizing on the technological implications and they are driven from citizen-centric, one-stop service-delivery, technology-centric perspective but disregard to the non-technical challenges. E-government interoperability encounters different constraints related to constitutional/legal, jurisdictional, collaborative, organizational, informational, managerial, cost, technological, and performance interpret a high risk of failure for integration and interoperation of e-government projects (H. J. Scholl & Klischewski, 2007). However, the interoperability process might be limited by the lack of identifying needs, wants, benefits, and costs; the lack of analyzing & evaluating organizational and social impact, the lack of identifying stakeholders, pre-disposition for collaboration and critical success processes; and the lack of establishing the level of acceptance and satisfaction (H. J. J. Scholl, 2005).

Particularly in Africa, there are challenges related to interoperability like dealing with large data sets in various formats; differences in organizational cultures, behaviors and business processes; stakeholder's motivation; myriad of legacy systems based on different data formats and infrastructure, incompatible operating systems, application servers and databases, financial constraints, data privacy, security and confidentiality (Funmi et al., 2013)

2.1.3 Level of information systems interoperability

Some of the authors have displayed the level of interoperability. Technical, syntactic, semantic, and organizational levels are identified (Funmi et al., 2013). Technical interoperability is about enabling diversified systems to exchange data. Syntactic interoperability assures the exchange of

information through predefined data format and structure. Semantic Interoperability ensures the same meaning of exchanged data though predefined data format and structure. The organizational Interoperability is about business process integration beyond the boundaries of a single organization.

Technical, semantic, syntactic and organizational are levels of interoperability whereby technical interoperability is associated with hardware and software components, systems, and platforms that enable the communication of machine-to-machine. Semantic interoperability is about the common understanding between people of the meaning of the information being exchanged. Syntactical interoperability is associated with data format being transferred. Organizational interoperability is about the ability of organizations to effectively communicate and transfer information across different regions and cultures even if they may be using different information systems. (Ouardi et al., 2016)

Technical interoperability, Semantic interoperability, Organizational interoperability and Governance interoperability are the other level of interoperability (Tambouris et al., 2011). Technical interoperability covers the technical issues of linking computer systems and services while the semantic interoperability ensures the meaning of exchanged information and understandable by other application. Organizational interoperability covers business cooperation and processes of agencies. Governance of interoperability concerns political, legal and structural conditions.(Tambouris et al., 2011)

According to Zhao et al (2018), technical interoperability refers to the creation of physical connections so that data can be exchanges between systems. Syntactic interoperability covers the protocol and format so that the data can be exchanged in a standardized format and semantic interoperability realizes the meaning of the data exchanged by a common reference model so that the data context shared is understood between parties.(Zhao et al., 2018)

Four level of interoperability namely legal, organizational, semantic and technical (European Commission, 2017) have been identified. Legal interoperability is about ensuring that organizations operating under different legal frameworks, strategies, and policies are able to work together. Organizational interoperability is about public administrations align their business processes, expectations and responsibilities to achieve commonly agreed and mutually beneficial

goals. Semantic interoperability ensures that the precise format and meaning of exchanged data and information is understood and preserved throughout exchanged between parties. Technical interoperability covers the infrastructure and applications linking systems and services. The aspect of technical interoperability include interconnection services, interface specifications, data integration services, secure communication protocols and data presentation and exchange (European Commission, 2017)

Table 1.2: Summary of Interoperability levels according to authors identified in the literature

Authors	Interoperability levels					
	Technical	Syntactic	Semantic	Organizational	Governance	Legal
(Funmi et al., 2013)	✓	✓	✓	✓	-	-
(Ouardi et al., 2016)	✓	✓	✓	✓	-	-
(Tambouris et al., 2011)	✓	-	✓	✓	✓	-
(Zhao et al., 2018)	✓	✓	✓	-	-	-
(European Commission, 2017)	✓	-	✓	✓	-	✓
(Adebesin et al., 2013)	✓	✓	✓	✓	-	-

2.1.4 Description of interoperability levels: from the literature review

Technical interoperability covers the applications and infrastructure linking systems and services. Interface specifications, interconnection services, data integration services, data presentation and exchange and secure communication protocols are the aspects of technical interoperability. (European Commission - DIGIT, 2020). From the open group website, IT infrastructures are under technical interoperability and also technical interoperability includes common methods and shared services for the communication, processing, storage, and access to data primary in the application platform and communications infrastructure domains (The Open Group, 2018). IT infrastructure include the physical hardware and facilities (data centers), data storage and retrieval, network

systems, legacy interface , software to support the business goals of an enterprise, hiring, training, policy, testing, process, upgrades, and repairs in order to support the management and usability of data and information (Smartsheet, 2020)

According to Van Der Veer & Wiles (2008), technical interoperability is presented at the centre of other levels on interoperability

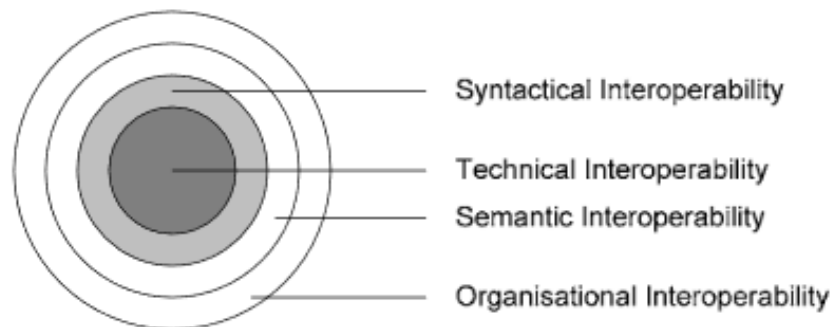


Figure 1.2: Different levels of interoperability (Van Der Veer & Wiles, 2008)

From the layers of coalition interoperability presented by Tolk (2003) , technical interoperability is at base of organization interoperability

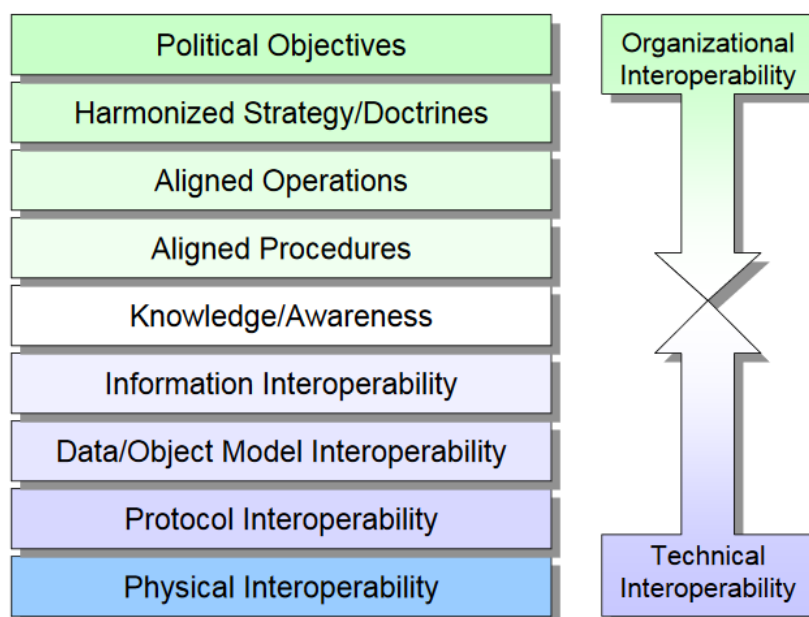


Figure 2.2: Layers of coalition interoperability (Tolk, 2003)

From the literature review, technical interoperability is about enabling diversified systems to exchange data, communication of machine-to-machine, linking computer systems and services, creation of physical connections, and covers the infrastructure and applications linking systems and services. Syntactic interoperability assures the exchange of information through predefined and standardized data format, protocol, and structure. Semantic interoperability ensures the same meaning of exchanged data through predefined data format and structure. It ensures that what (data and information exchanged) is sent is what is understood by other applications. Organizational interoperability ensures business process integration beyond the boundaries of a single organization whereby the organizations effectively communicate and transfer information among themselves. Governance interoperability concerns political, legal and structural conditions. Legal interoperability ensuring that organizations operating under different legal frameworks, policies and strategies are able to work together.

From the above interoperability levels, some authors have deeply explored these levels. According to Ouardi et al., (2016), both technical and semantic interoperability have four levels of maturity:

- Level 0 (Default level): Systems run standalone and are not prepared for interoperation.
- Level 1 (Initiating level): System is opened to interoperability whereby it is capable of performing some ad-hoc interoperations with other systems. Technical interoperability at this level deals with resource management that must be implemented for establishing interoperability that comply with standards and protocols. However, semantic interoperability deals with dynamic service creation
- Level 2 (Enabling level): System is able to make changes in its components to adhere to common reference and there are some guidelines followed about how interoperability can happen. The technical interoperability deals with data management including storing, accessing and transferring data that must be evaluated in this step. On the other hand, Semantic interoperability deals with discovery where it checks if the mechanism for searching available services as well as services specifications have been defined and determined.

- Level 3 (Integrating level): Decision-making is decentralized to improve flexibility and reactivity. At this level, technical interoperability covers items of security while semantic interoperability covers lifetime management and notification.
- Level 4 (Interoperating level): Interoperability becomes a subject of continuous improvement. At this level, technical interoperability deals with adding, changing and removing a new resource during runtime. However, semantic interoperability is about services that are managed dynamically.

Hosseini & Dixon (2016) argue that from A to B system, syntactic interoperability provides a structure and syntax that make a message be recognized by both systems.

2.2 Interoperability of information Systems in Developing Countries: Overview

The developing countries considered below are reflected from the website (World Population View) updated as of October 14, 2019 and was retrieved on 5 January 2020.

For the case of Jordan country, there are significant barriers that affect Information systems interoperability identified along with the factors that can drive its successful implementation (Sulehat & Taib, 2016). The authors have listed six main obstacles that are faced during Information Systems interoperability of e-government programs namely:

- ICT Infrastructure challenges in deploying suitable ICT infrastructure.
- Top Management Support challenge whereby focusing on real cost and benefits are the concerns faced by top management in the planning phase of any new e-government projects. The barrier is that the management support through motivating, leading, and influencing is lacking its presence during, before, and after the project management phases of e-government project implementation.
- Human Resources challenges like the lack of qualified, well-trained and skilled human resource in the ICT sector.
- Data and Information Integration issue. The information quality and data inconsistency are major challenges for data and information integration.

- Security and Privacy issues whereby there is low trust in information systems sharing at the governmental institution side.
- Business processes challenges whereby there exist business duplication toward service delivery to citizens.

In addition to these six main barriers of IS interoperability, the authors have also listed other challenges related to leadership styles, financial support, cultural attitudes, bureaucracy, and customers 'needs.

For the case of Vietnam, the lacking of interoperability has been a main challenge for the maturity of e-government and there are challenges with data loss and insufficient high quality human resources. IT infrastructure, It security, IT standards, and technical expertise challenges are also identified and they are affected in terms of management by government regulations, internet facilities, private sector attractions, and citizen's awareness. In addition to that, there are also organization factors namely: the risk management, collaboration and coordination involved. Interoperability in Vietnam is not user-friendly with a lack of inefficient information systems infrastructure and poor investment. From there, the citizens prefer traditional government procedures rather than using e-government services (Thanh et al., 2018)

In India, the portals of companies are performing better than government portals towards achieving an interoperability position and this is because there is high dispersion in the level of integration among Indian government portals and there are different reasons like legislative, administrative, technological, social barriers etc (Tripathi et al., 2012). From the authors' study, there are other issues identified like the issue of having specialized technologies for supporting metadata that are required to accomplish data integration, a lack of initiative towards implementing the message formatting languages that normally help in defining the format of data messages and documents that can be exchanged between applications. In addition, government officials are not familiar with the terminology related to data resource description that defines the language for representing metadata to a set of attributes that will capture the semantics of individual data items (Tripathi et al., 2012)

In South Africa, there is an element of trust issues between agencies. Interoperability is affected by a slow implementation of policies, weak institutional mechanisms for promoting security in e-

government, and lack of compliance in adopting the Minimum Interoperability Standards (MIOS) by some government institutions (M. Manda & Backhouse, 2016).

Most of government e-services remain in isolated silos in Philippines and there are issues of services that are not offering transaction features which have negative impact to effective service delivery (Reyes Jr & Tangkeko, 2017).

In Tunisia country, there are different technology projects managed by different organizations and regulated by different laws. This is creating a set of incompatible components of information systems (Sta, 2018).

In Egypt, the capability for networked development and management of government interoperability are still underdeveloped. This is about governance, strategic planning, business case development, resource management, project management, and business and technology architecture. In addition, the scope of the intended regulation and the future of interoperability is unclear (Klischewski & Askar, 2012).

In Pakistan, the interoperation between organizations is challenging because these organizations are different at organizational and technical levels. There are possible constraints like policies, standards, formal communication, human resources, service level agreement , political commitment, environment and ethics, and financial (Maheshwari & Janssen, 2012).

In Uganda, there are challenges hindering the development of interoperable e-government systems. These challenges are namely, lack of clear guidance to enable development of interoperable e-government systems. Some e-government projects are implemented without a clear national strategic focus and there is a liberty to operate applications on different platforms with variations in syntax and semantics. The applications are not developed with interoperability in mind and there is a lack of an operational framework and mechanisms that guide the integration of e-government systems. Another challenge is the under-developed ICT infrastructure in the country , lack of awareness on existence of national ICT standards among some managers and citizens, as well as the autonomy in making ICT investment decision across ministries, departments and agencies (Nakakawa & Namagembe, 2019).

In Thailand, there are issues of IT budget, management's mind set, complicated/dynamic business rules, lack of proficient software developer that affect the systems interoperability (Wisitpongphan & Khampachua, 2017).

In developing countries generally, there are barriers to interoperability. These barriers are namely; technological or technical barriers, human capital constraints (IT skills and expertise), social-technical/social-cultural constraints, organizational constraints, administrative culture and context, political constraints, resource constraints, strategy constraints, policy and legal constraints, leadership constraints and informational constraints (M. I. Manda & Backhouse, 2016)

In Zambia, standardization of data structure challenges, syntax and semantics across public services value chains challenges, business process challenges, and technology interface challenges are influencing negatively the implementation of interoperability (Bwalya & Mutula, 2016).

In Brazil, interoperability is affected by different challenges like technical and organizational issues, professional skills limitation, legal and privacy restrictions, information security and integrity issues, lack of clearly defined strategy for adoption, difficult in adoption of interoperability framework and standards (dos Santos & Reinhard, 2012).

In the study carried out for 26 African countries, semantic interoperability guidelines, semantic description languages, semantic assets storage, semantic assets, discovery tools or guidelines and semantic mediation are challenges faced by the process of systems interoperability (Yousif Ahmed & Twinomurinzi, 2019).

In Afghanistan, interoperability is impacted by the System and data architecture challenges (Saay & Norta, 2018)

Table 2.2: Classification of interoperability barriers in developing countries according to interoperability levels

Authors	Case study by country	Interoperability barriers	Corresponding interoperability level
(Sulehat & Taib, 2016)	Jordan	ICT Infrastructure, top management support, human resources, data and information integration, security and privacy, and business process issues.	Technical Syntactic Semantic Organizational
(Thanh et al., 2018)	Vietnam	IT infrastructure, IT security, IT standards, and technical expertise challenges. Insufficient skilled personnel, government regulation, collaboration, and coordination issues	Technical Syntactic Semantic Organizational
(Tripathi et al., 2012)	India	Data, processes, and communication integration issues.	Technical Organizational Semantic
(M. Manda & Backhouse, 2016)	South Africa	Trust issues between agencies. Slow implementation of policies, weak institutional mechanism for promoting security in e-government, lack of compliance in adopting the Minimum Interoperability Standards (MIOS) by some government institutions.	Organizational

(Reyes Jr & Tangkeko, 2017)	Philippines	Most of government e-services remain in isolated silos.	Technical Organizational
(Sta, 2018)	Tunisia	Technology projects and organizations are regulated by different laws. Incompatible components of information systems	Technology Organizational
(Klischewski & Askar, 2012)	Egypt	Governance, strategic planning, business case development, resource management, project management, business and technology architecture challenges	Technical Organizational
(Maheshwari & Janssen, 2012)	Pakistan	Organizations are different at organizational and technical levels. Policies, standards, formal communication, human resources, service level agreement, political commitment, environment and ethics, and financial constraints	Technical Syntactic Semantic Organizational Legal
(Nakakawa & Namagembe, 2019)	Uganda	Lack of an operational framework and mechanisms that guide integration of e-government systems. Under-developed ICT infrastructure in the country, lack of awareness on existence of national ICT standards among some managers and citizens.	Technical Organizational

(Wisitpongphan & Khampachua, 2017)	Thailand	IT budget, management's mindset, complicated/dynamic business rules, lack of proficient software developer	Technical Organizational
(M. I. Manda & Backhouse, 2016)	Developing Countries	Technological or technical barriers, human capital constraints (IT skills and expertise), social-technical/social-cultural constraints , organizational constraints, administrative culture and context, political constraints, resource constraints, strategy constraints, policy and legal constraints, leadership constraints, informational constraints,	Technical Syntactic Semantic Organizational Legal
(Bwalya & Mutula, 2016)	Zambia	Standardization of data structure challenges, syntax, and semantics across public services value chains challenges, business process challenges, and technology interfaces challenges.	Technical Semantic Organizational
(dos Santos & Reinhard, 2012)	Brazil	Technical and organizational issues, professional skills limitation, legal and privacy restrictions, information security and integrity issues, lack of clearly defined strategy for adoption, difficulty in adoption of interoperability framework and standards.	Technical Semantic Organizational Legal
(Yousif Ahmed &)	26 African countries	semantic interoperability guidelines, semantic description languages, semantic assets storage, semantic assets,	Semantic Technical

Twinomurinzi, 2019)		discovery tools or guidelines, semantic mediation challenges, and infrastructure	
(Saay & Norta, 2018)	Afghanistan	System and data architecture challenges	Technical Semantic

2.3 Information systems interoperability in the education sector

2.3.1 Information Systems in Education

The use of information technology in educational management has quickly increased due to its effectiveness and efficiency (Shah, 2014). Information system used in education known as EMIS (Educational Management Information Systems) is defined as the ensemble of operational processes, increasingly supported by digital technology that enable the collection, aggregation, analysis, and use of data and information in education, including for management and administration, planning, policy formulation, and monitoring and evaluation (UNESCO, 2018).

An effective EMIS provides valuable data and should improve upon four functional domains of processes namely management and administration, planning, policy formulation, and monitoring and evaluation. The important point here is that these processes are interconnected and take place at various locations in education systems from central to local within education institutions themselves (UNESCO, 2018). However, there are issues behind the EMIS effective implementation namely the unclear defined needs at technical level, data quality, robust technological infrastructure, human resources, policies, plans, and institutional arrangements, and addressing these issues directly to the successful development and implementation of EMIS (UNESCO, 2018).

In the current digital age, universities heavily depend on free flow information namely: information on course registration options, examination timetables, access to updated transcripts, bursary expenses, scholarship funds, access to payroll for salaries processes, etc (Sastry Musti, 2019).

The Management Information Systems (MIS) in universities must accomplish the following functions in a timely and reliable manner. (a) define, collect, and process educational data and

statistics, (b) consistently store and recuperate relevant data when required, (c) generate reports and statistics for all education information users, and (d) serve and support activities for analysis, enrolment, budgeting, and monitoring educational effectiveness (Karfaa et al., 2015). The MIS has a positive impact on school administration, better accessibility to information, higher utilization of school resources, reduction in workload, improvement in quality of reports, better time management, decision making and positive leadership, better human resource management, communication, responsibility and planning (Shah, 2014). The persons responsible for management in higher education institutions require real-time information systems that provide well-presented and reliable information for effective process management and decision-making (Guerrero & Sierra, 2018).

The use of information systems in high learning institutions has significantly and positively impacted the day-to-day operations of handling student and staff-related information with the higher standard level of systems security in developing countries and that level is lower in higher learning institutions from developing countries (Raymond, 2017).

2.3.2 Interoperability of information systems in higher education institutions

Data exchange between different educational systems have to be done to improve interoperability between them (Sayed et al., 2016). Interoperability is how well systems, applications, and data interact within an organization. So, when it comes to higher education institutions, interoperability of information systems enables institutions to share data seamlessly, and allows students access to a wider range of tools, enabling schools to easily manage and share data systems.

The interoperability allows the easy, integrated provision of electronic services for the academic community across multiple higher education institutions and allows efficiency and productivity gains (Ribeiro et al., 2016). Interoperability reduces technology expenses and institutions can create authentic assessments with higher rates of effectiveness from individual students at district to wide levels (Tao, 2019).

Interoperability of information systems in higher education institutions contribute to the efficiency gains in terms of staff, student data processing. It increases the value of updated data in multiple systems (Ben, 2020). In addition, stakeholders inside and outside higher education institutions are able to make queries of two or more datasets from different information systems at the same time

because of interoperability (Juanes et al., 2014). Interoperability from higher education institutions can be achieved by the use of higher education ontologies and the use of a practice that starts with the analysis of the data sources to be linked, followed by aligning of the convenient ontologies, and ends with the reproduction and publication of data in valid formats for linked data (Juanes et al., 2014). There are other benefits of educational interoperability namely: improved access to learning and teaching tools, online assessment and performance monitoring and reporting, reliable and secure transfer of educational data, access to the same service, integration of products, enhancement of the collaboration with other federal and non-federal agencies, and increased transparency towards the educational community (Ise, 2014).

Higher education information systems are also involved in the current technology trends like cloud computing, mobile technologies, artificial intelligence, big data, and virtual and augmented reality but it is a challenge to adapt and implement these technologies (Gerón-Piñón et al., 2019).

It is important to note the content, data, and interface standards for various information systems for the effective educational systems infrastructure (Jakimoski, 2016a). Standardization of common education data support effective exchange of data within and across universities (Ise, 2014). For example, there is developed framework (presented in figure 1) that support for interoperability of universities information system and that framework has been developed in reference to SOA (Service Oriented Architecture). The framework connects SOA-enabled applications such as Student, library, hostel, bursary, and human resource management systems (Ise, 2014).

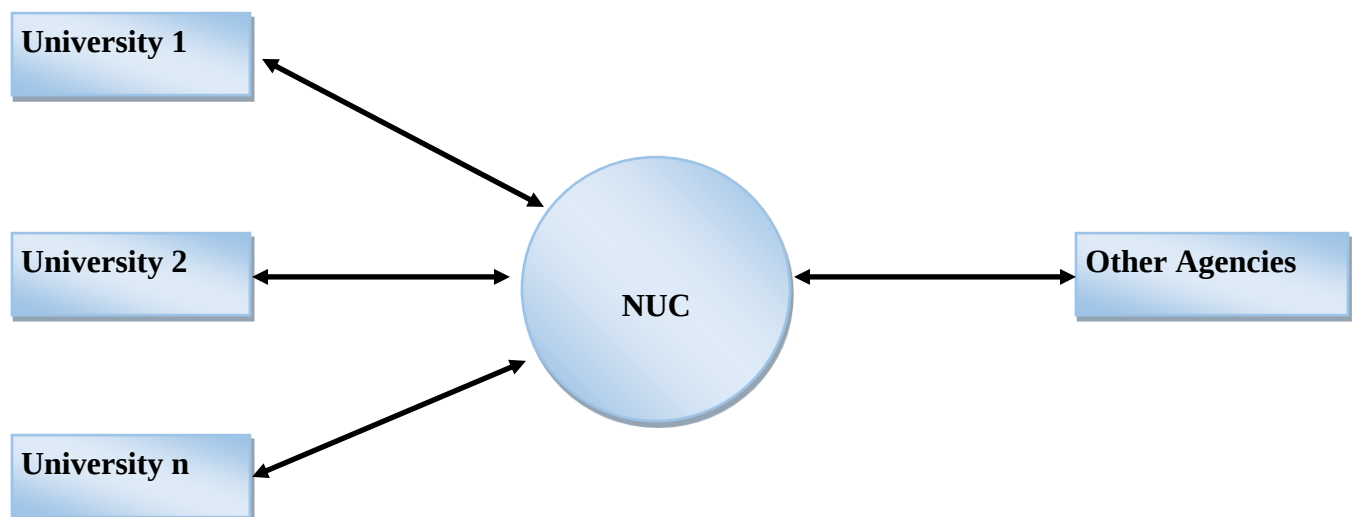


Figure 3.2: Interoperability framework for universities (Ise, 2014))

From figure 3.2, NUC stands for National University Commission, and CIS stands for Central Integration Server. It is as the National University Commission is the central of data collected from all university and the universities get access to these information as to other agencies as well.

2.3.3 Challenges related to information systems interoperability in high education institutions.

The use of a linked data strategy to connect existing multiple information systems towards interoperability is an important challenge in higher education institutions (Juanes et al., 2014) and most institutions' content is managed in silos that contributes to the interoperability challenges (Mclean, 2004). Information and e-learning management, libraries, and learning applications are affected.

Lack of interoperability leads to siloed data in education whereby data may be difficult to access, analyse and use for better outcomes. The issues with data security, limited communications across institutions are part of lack of interoperability as well (Tao, 2019) and information, e-learning management, exchange of libraries data, and learning applications are affected (Mclean, 2004). In case the systems cannot communicate with each other, there is an issue of having access to complete and updated information, and the tasks cannot be handled effectively (Ben, 2020).

It take much time for exchanging data among different educational institutions due to heterogeneity of platforms with different programming languages and different information management systems (Sayed et al., 2016). The lack of interoperability is often due to the fact that higher education institutions are not in position to identify and share their own requirements. These institutions have different motivations and design individual applications which may be an issue for high-level interoperability and architecture (Griffiths et al., 2016). There is also the issue of information systems that are usually independent from one another (Juanes et al., 2014) and it is almost impossible for education management information systems to achieve the objectives of effective information management within the education system (Jakimoski, 2016a).

As far as the interoperability of information systems in high leaning institutions is concerned, it is important that the systems communicate each other so that the student and higher institutions

benefit from the effective and timely data sharing. This research will explore more about issues behind information systems interoperability in higher learning institutions sectors from Rwanda.

As the conclusion for this chapter, the information systems play a role for the effective service delivery to citizens and it is most relevant once different systems interact each other in certain sectors towards organizational and services development and effectiveness. The interoperability is still an issue in developing countries whereby barriers like lack of infrastructure, budget, human resource, technology, legal processes, management issues and other more are involved towards success implementation of interoperable information systems. Particularly, the interoperability in the higher education sector is impacted by the heterogeneity of platforms with different programming languages and information content managed in silos. It is most important to have interoperable information systems in higher education so that students, institution management, and stakeholders benefit from the quality and timely managed information towards each beneficiary satisfaction in personal development, decision making, and other associated gains.

Chapter 3: Research Context

This research was carried out in Rwanda, one of developing country and particularly focusing on public and private higher education institutions, higher education council, and research participants drawn from technical and managerial dimensions.

3.1 Higher education sector in Rwanda: Overview

The government of Rwanda is supporting the transformation of higher education to fit international credibility and higher education institutions are required to deliver graduates, research, consultancy services, and community engagement to support the social and economic development of Rwanda (Higher Education Council (HEC), 2020). The government of Rwanda has established the Higher Education Council (HEC) as an independent government agency to support higher education transformation. HEC is a semi-autonomous institution under the Ministry of Education and is it is responsible for securing coherent quality provision of higher education in Rwanda in line with government policies and priorities, strategic planning for higher education, the modes of providing quality education within higher learning institutions (Council, 2017).

Higher education is an institution that offers programs leading to awards beyond the school leaving examination as its main or only activity (Council, 2017). As displayed on HEC website, there exist public higher institutions namely : (University of Rwanda-UR), Rwanda Polytechnics-RP, Institute of Legal Practice and Development-ILPD . There exist also private institutions namely; (Universite Libre de Kigali-ULK, Institute of Lay Adventists of Kigali-UNILAK, Catholic University of Rwanda-CUR, Adventist University of Central Africa-ACM, Institut Catholique de Kabgayi-ICK, Institut d'Enseignement Superieur de Ruhengeri-INES, Institut Polytechnique de Byumba-IPB, Rwanda Tourism University College-RTUC, Institut Superieur Pedagogique de Gitwe-ISPG, Protestant Institut of Arts & Social Science-PIASS, Mount Kenya Universty Kigali Campus-MKU-R, Kibogora Polytechnic-KP, Carnegie Mellon University Africa-CMUR, University of Kigali-UoK, Indangaburezi College of Education-ICE, Premier Early Childhood Development Teachers College-PECDTC, East African University Rwanda-EAUR, Ruli Higher Institute of Health Sainte Rose De Lima-RHIH, Ngoma Advantist College of Health Sciences-

NACHS, University of Global Health Equity-UGHE, Africa Institute of Mathematical Sciences-AIMS-Rwanda, Africa Leadership University-ALU, College of Surgeons of East, Central and Southern Africa, VATEL School Rwanda (Higher Education Council, 2020)

This research focuses on technical interoperability by exploring challenges from higher education institutions. The decision is based on different factors presented below.

Analysis of mini literature for the interoperability constraints in developing countries shows technical interoperability on top of constraints of interoperability followed by organizational constraints, then by semantic-based constraints. Syntactic based constraints follows on the list as well as the legal based constraints.

Different levels of interoperability have been discussed in the literature and technical interoperability is presented at the center of other levels of interoperability (Van Der Veer & Wiles, 2008).

3.2 Research contribution to the country strategy

This research contributes to Rwanda's ICT sector strategic plan 2018-2024 towards “government operational efficiency and citizen satisfaction”. Under output six “Satisfied citizens with service delivery” (Ministry of Information Technology and Communications, 2017), this thesis will contribute to the section of improving accessibility to digital education information and content. In addition to that, this research will also contribute to Rwanda Higher Education Council (HEC) mission of improving the organization and functioning of higher learning institutions(Higher Education Council-HEC, 2020)

Chapter 4: Research Methodology

This section describes the methodological approaches pursued in this thesis. The qualitative case study method and literature review are the two main methodological approaches for this work. A case study method was adopted for qualitative research. This section also describe the data collection and data analysis technics used in the study.

The qualitative case study method and literature review are the two main methodological approaches on this work. In order to get contextualized constraints of interoperability of information systems in higher leaning institution, the qualitative method will be used whereby interview and questionnaires will be used as data collections tools. The non-probability sampling has been adopted using the convenience/opportunity sampling technique. Therefore, one public and two private institutions are samples for the study and the personnel involved are from ICT and managerial departments.

4.1. Review of literature in research methodology

A review of literature creates a good foundation for advanced knowledge in any academic project and it facilitate theory development as well as uncovering areas where research in information systems is needed (Webster & T.Watson, 2002). Three types of literature are described namely; narrative, systematic, and meta-analytic reviews (Rhoades, 2011).

The native reviews sometimes are considered as standard/traditional reviews and it critically assesses and outlines the literature pertinent to an identified topic, collect major arguments in a field of discussion or give a compelling historical review of an important aspect, selects relevant studies based on some criteria (Rhoades, 2011). The systematic reviews of literature is sometimes known as practice-based or best-evidence research syntheses covers a profound, comprehensive, clear, unbiased review of the literature initiated based on defined study and involves processes that focus on inclusion and exclusion criteria in the review (Rhoades, 2011). As to meta-analytic review of literature, this approach is sometimes known as quantitative systematic review and it combines the data with identical properties during the review (Rhoades, 2011).

4.2 Qualitative research method

Qualitative research methods were developed to enable researchers to study social and cultural phenomena in social science, thus the method is a strategy of inquiry that step from the underlying philosophical assumptions to research design and collection of data (Myers, 1997). According to Myers (1997), four research methods namely action research, case study, ethnography and grounded theory are identified.

The action research approach is grounded in practical action while at the same time focusing on generating, informing, and building theory (Burns, 2015). This approach have eleven phases namely exploring, identifying , planning, collecting data, analysing/reflecting, hypothesising, intervening, observing, reporting, writing, and presenting.(Burns, 2015).

The case study approach can be used to describe a unit of analysis or to describe a research method and it is most common used in information systems studies (Myers, 1997). The ethnography approach is used in the discipline of social and cultural anthropology whereby a researcher spend a significant amount of time in the field for the study (Myers, 1997). As to the grounded theory, the research method seeks to develop a theory that is grounded in data gathered and analyzed systematically (Myers, 1997).

The methods discussed above can use one more technique for empirical data collection as the data source and these techniques are interviews and questionnaires, documents and texts, participant observation as well as the researcher's impressions and reaction (Myers, 1997)

This research has focused on qualitative research, the case study of higher learning institutions in Rwanda.

4.3 Data collection

There are different technics for qualitative data collection and these technics range from interviews, observation , written data sources and so forth (Myers, 1997). However interviews and focus groups are the most common methods of data collection in qualitative research (Gill et al., 2008). According to Gill et al (2008), there are three types of research interviews namely

structured, semi-structured and unstructured. Structured interviews are verbally administered questionnaires whereby a list of predetermined questions are asked, however, by their very nature, these questions are quickly processed and only allow for limited participant responses and are therefore, of little use if ‘depth’ is required. unstructured interviews do not reflect any preconceived theories or ideas and are performed with little or no organization these interviews are usually very time-consuming which means that their use is important significant ‘depth’ is required, or where virtually nothing is known about the subject area. Semi-structured interviews consist of several key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge in order to pursue an idea or response in more detail. This interview is flexible because it allows for the discovery or elaboration of information that is important to participants.

For the focus group, it is used to generate information on collective views by getting a rich understanding of participants’ views and experiences.

The data is collected from a typical category of people from higher learning institutions. ICT personnel and managers will be interviewed in the research. The questions are developed based on people category mentioned earlier and they are semi-structured interview to provide flexibility of answering questions from the respondents.

4.4 Data analysis

Data analysis is an aspect of research practice to understand the relationship, examine structure of something towards getting their meaning or interpretation (Gibson & Brown, 2009). In qualitative research, data analysis is the systematic process of arranging the interview transcripts, non-textual materials, observation notes in order to understand the phenomenon and the process involves coding or categorizing data and making sense of huge amount of data (Wong, 2008).

Qualitative data analysis can be divided into five categories (Research Methodology.net, 2019): Content analysis which is referred to the process of categorizing verbal or behavioral data to arrange, summarize, and tabulate the data. Narrative analysis refers to the reformulation of stories presented by respondents considering each case and the different experiences of each respondent. Discourse analysis refers to an analysis of naturally occurring talk and all types of written text. Framework analysis is a more advanced method that combines different stages such as familiarization, identifying a thematic framework, coding, charting, mapping, and interpretation. Grounded theory which starts with an analysis of a single case to formulate a theory.

Qualitative data analysis can be conducted through three steps (Research Methodology.net, 2019):

Step 1: Developing and applying codes. In this step, the coding is explained as categorization of data and the code can be a word or a short phrase that represent an idea or a theme. For example, we have a range of non-quantifiable elements like activities, events, meanings, and behaviors that can be coded. Open coding (the initial organization of raw data towards making a sense of it), Axial coding (interconnecting and linking the categories of codes), and Selective coding (formulating the story through connecting the categories) are three coding types from this step one.

Step 2: Identifying themes, patterns, and relationships. In this step, the research identifies common themes, patterns, and relationships within the responses of sample group members about codes that have been indicated in step one. The four most popular methods for data interpretation in this step include the following:

Word and phrase repetitions method which is about scanning primary data for words and phrases that the respondents have commonly used. Primary and secondary data comparison methods which is about comparing the findings or interviews, focus groups, observation, with the findings of literature review and discussing the differences between them. The search for missing information which is about discussing on aspects of the issue that have not been mentioned by the respondents yet they have been expected to be discussed by them. Metaphors and analogues method which is about comparing primary research findings to phenomena from a different area and discussing similarities and differences.

Step 3: Summarizing the data. In this stage, the research links research findings to hypothesis or research aim and objectives

In this thesis, the content analysis method is adopted to analysis the categories of data collected from respondents in higher leaning institutions.

According to Erlingsoon & Brysiewicz (2017), the initial step for qualitative content analysis is to read and re-read the interview to get a sense of the whole towards what participants have expressed. Then the next step is to start dividing up the text into smaller parts into meaning units. Then the next step is to label condensed meaning units by formulating codes and then grouping the codes

into categories. After these steps, the next is to report results or to go further by creating themes from the pre-selected categories (Erlingsson & Brysiewicz, 2017).

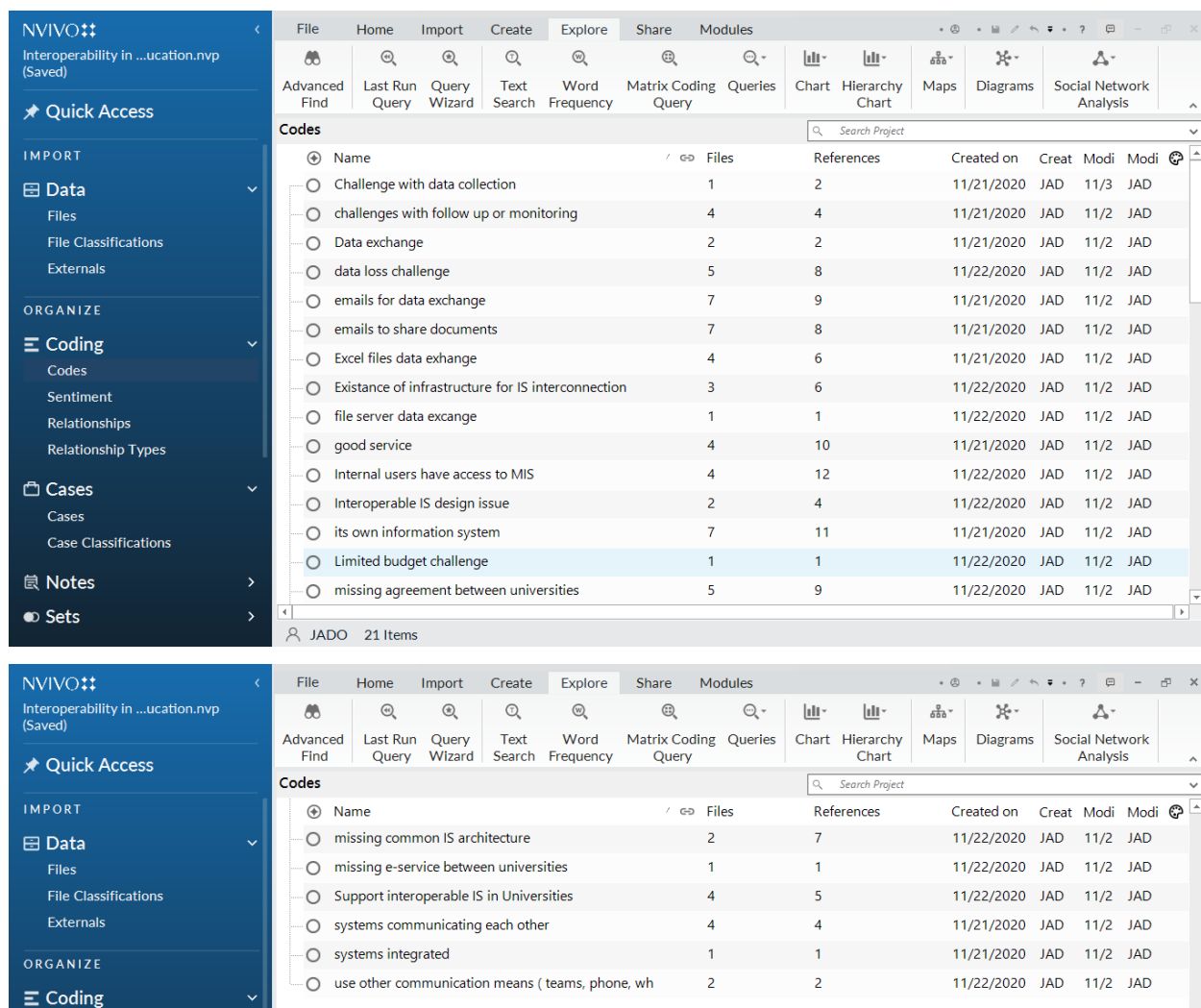
The content analysis have three different approaches namely conventional, directed and summative (Fang Hsieh & Shannon, 2005). The conventional approach is used whereby coding categories are delivered directly from the text data. For the directed approach, analysis starts with a theory or proper research findings as guidance for initial codes. The third approaches is summative that involves counting and comparisons of content or keyword followed by the interpretation of underlying context (Fang Hsieh & Shannon, 2005).

The content analysis is a systematic, rigorous approach to analysing documents obtained in the course of research and text plays a slightly different role as the researcher reads through the data and scrutinized them closely to get concepts and patterns. (White & Marsh, 2006)

Chapter 5 : Results and Analysis

This chapter focuses on the analysis of data collected through the semi-structured interview and data are presented within sections related to the research questions. Data was collected from six organizations and Nvivo was used as the data analysis tool.

Nvivo is the qualitative research software for data analysis that helps to organize, code and manage the research data (*NVivo How-To Guide - Qualitative Research and NiVivo - ULibraries Research Guides at University of Utah*, n.d.). Below is the screen shot for codes retrieved from interview data that was conducted based on the research questions. However, the codes are more than questions because they have been added to capture more data for the study. 21 codes have been identified and have supported in collecting and displaying findings that are presented in this chapter.



The screenshots show the NVivo software interface. The top screenshot displays a list of 18 codes, and the bottom screenshot displays a list of 7 codes. Both screenshots show the NVivo interface with a sidebar on the left and a main window on the right.

Top Screenshot: Codes List

Name	Files	References	Created on	Created by	Modified by	Modified on
Challenge with data collection	1	2	11/21/2020	JAD	11/3	JAD
challenges with follow up or monitoring	4	4	11/21/2020	JAD	11/2	JAD
Data exchange	2	2	11/21/2020	JAD	11/2	JAD
data loss challenge	5	8	11/22/2020	JAD	11/2	JAD
emails for data exchange	7	9	11/21/2020	JAD	11/2	JAD
emails to share documents	7	8	11/21/2020	JAD	11/2	JAD
Excel files data exchange	4	6	11/21/2020	JAD	11/2	JAD
Existence of infrastructure for IS interconnection	3	6	11/22/2020	JAD	11/2	JAD
file server data exchange	1	1	11/22/2020	JAD	11/2	JAD
good service	4	10	11/21/2020	JAD	11/2	JAD
Internal users have access to MIS	4	12	11/22/2020	JAD	11/2	JAD
Interoperable IS design issue	2	4	11/22/2020	JAD	11/2	JAD
its own information system	7	11	11/21/2020	JAD	11/2	JAD
Limited budget challenge	1	1	11/22/2020	JAD	11/2	JAD
missing agreement between universities	5	9	11/22/2020	JAD	11/2	JAD

Bottom Screenshot: Codes List

Name	Files	References	Created on	Created by	Modified by	Modified on
missing common IS architecture	2	7	11/22/2020	JAD	11/2	JAD
missing e-service between universities	1	1	11/22/2020	JAD	11/2	JAD
Support interoperable IS in Universities	4	5	11/22/2020	JAD	11/2	JAD
systems communicating each other	4	4	11/21/2020	JAD	11/2	JAD
systems integrated	1	1	11/21/2020	JAD	11/2	JAD
use other communication means (teams, phone, wh	2	2	11/22/2020	JAD	11/2	JAD

Table 3.5: Interview conducted by organization

Organization	Organization category	Number of interviews	Category of respondents	Period of data collection
UR	Higher Education Institution	4	ICT department, Registration Office, Students, Lecturers	September 18, 2020 to November 17, 2020
UNILAK	Higher Education Institution	6	ICT department, Registration Office, Students, Lecturers, Library Services	October 12, 2020 to October 22, 2020
ULK	Higher Education Institution	2	ICT department, Registration Office	November 24, 2020 to November 25, 2020
HEC	Government Institution	2	ICT department, Management	October 15, 2020 to October 21, 2020
RISA	Government Institution	1	Management	November 17, 2020

From the table 3.5, four interviews have been conducted from University of Rwanda whereby data was collected from the ICT department, registration office, students and lectures. Six interviews have been conducted from UNILAK whereby respondents from ICT department, registration office, library services, students and lectures have provided data. Two interviews were conducted from ULK whereby personnel from ICT and Registration office have provided data. Two respondents from HEC management unit and ICT department have also provided data. And one respondent from RISA has provided data towards the research questions.

The content analysis was used as data analysis technics whereby interviews have been translated into texts and then categorized into meaningful contents towards the conducted academic research.

5.1. Status of interconnected information systems in higher learning institutions

The information systems interconnection is analysed from inside the institution and between them.

Table 4.5: Availability of interconnected information system from institutions

Institution	UR	UNILAK	ULK	HEC	BRD	Interconnected with other Institutions	Total IS connected inside institutions	Total connected IS between institutions
UR	X						1	0
UNILAK		X					1	0
ULK			X				1	0
HEC				X	X		1	1
BRD					X		1	0

From the table 4.5, the sign “X” indicates the availability of communicating information systems. Respondents from UR have pointed out that they own the IS that is integrated among UR colleges. The UR owns ITS information systems that integrate student management systems, human resource management systems, and finance management systems and this is used for six colleges namely the college of Arts and Social Sciences, College of Agriculture, Animal Sciences and Veterinary Medicine, college of business and economics, college of medicine and health sciences, college of education and college of science and technology. UR students, lecturers, and staff use ITS. However, ITS does not exchange with any information systems from other higher learning institutions. ITS has not been developed by UR instead bought from developers and the current state does not exchange data with any other system outside UR.

UNILAK has developed its own MIS and it is used by students, lecturers, and staff from all three campuses namely Nyanza, Rwamagana, and Kigali. UNILAK MIS is appreciated by user and currently not sharing data with other higher learning institutions in Rwanda. However, the UNILAK ICT officer quotes” *We have designed UNILAK MIS in-house and our team can enhance*

the system any time depending on user requirements. Our MIS can be linked with other institutions systems in case it is required but this is a high-level initiative”. UNILAK MIS has been developed without considering any common agreed up on information systems architecture for higher learning institutions and this was not done by ignorance but because that very architecture does not exist in Rwanda as quoted by UNILAK ICT officer.

ULK uses ULK MIS which is accessed by users from two campuses namely Kigali and Rubavu. It is a standardized MIS in all these campuses but does not exchange data with any other system from higher learning institutions in Rwanda. As to HEC, there is one system under development that currently can communicate with BRD system for one component of study loan information for students but BRD does not shared information back with HEC currently.

From respondents' views, all this indicates that there exist information systems that are integrated within the institutions but not between them

5.2. Common and standardized Information System architecture status for higher learning institutions

The existence of a common information systems architecture for higher learning institutions is explained in table 5.5 below.

Table 5.5: Existence of common architecture for information systems in higher learning institutions

Organization/Institution	Information systems used	Common IS architecture for higher learning institutions in place and used(Yes or No)
UR	ITS	No
UNILAK	UNILAK MIS	No
ULK	ULK MIS	No
HEC	MIS under design	No

UR uses ITS systems and was developed in their preferred information systems architecture. The UR database administrator said, “*It would be better if we could have received and followed the common information systems architecture recommended by HEC or agreed upon by all higher learning institutions in Rwanda*”. UNILAK has also developed their MIS in-house and the ICT person has said that they have not followed any agreed-upon common IS architecture for higher learning institutions, not for ignorance but because this does not exist. ULK uses its own MIS developed from its preferred IS architecture. “*There is no common architecture for information systems in higher learning institutions*” quoted by a RISA person in charge of ICT facilities in the education sector. RISA is a government institution with a mandate of planning and coordinating the implementation of national ICT for development.

All this shows that information systems used by interviewed institutions have been developed without necessarily following the common and standardized information system architecture agreed upon by higher learning institutions in Rwanda. Every institution has designed or bought information systems following the preferred system architecture

5.3. Data exchange state in higher learning institutions

Data exchange status is analyzed within the institution and between them.

From the table 6.5, there are five categories of data exchange means namely file server, emails, excel file by emails, other communication means(Microsoft team, WhatsApp, phones), and Information systems.

File Server: one respondent mentioned that they use a file server as a data exchange means within the institution. They share installation files and other ICT-related data.

Emails: Seven respondents mentioned that they use emails to exchange data within and between institutions. Respondents mentioned that they share student loan information, school infrastructure standards, student and lecture status, accreditation, library status from higher learning institutions, library status information, and other electronic resources among institutions

Excel files by emails: four of the respondents pointed out that they share data in Excel templates within and between institutions. Respondents mentioned that they usually share students statistics using Excel templates

Other communication means (Microsoft Team, WhatsApp, phones): Three respondents have provided data that they also use other communication means like Microsoft Teams, WhatsApp, and phones call to exchange data within and between institutions as well.

Information systems: For data exchange through information systems, three respondents mentioned that their MIS have the features but within the institution.

Table 6.5: Data exchange state in higher learning institutions

Data exchange means	Data exchange location	Number of respondents
File server	Within institution	1
Emails	Within and between institutions	7
Excel files by emails	Within and between institutions	4
Other communication means(Microsoft team, WhatsApp, phones)	Within and between institutions	3
Information systems	Within institutions	3

The majority of respondents pointed out that emails is the most channel used to exchange data among higher learning institutions and partners. The Excel templates are used to report statistics from higher learning institutions to HEC.

Taking an example on Nvivo comparison of respondents who have mentioned that they own their information systems and data exchange means, figure 4.5 shows that respondents from HEC, UNILAK, ULK, and UR have mentioned that they use emails to exchange data. On the other hand, they own the information systems in place.

Table 7.5: Infrastructure status in interconnecting different information systems in higher learning institutions

Infrastructure	Number of respondents who pointed out the existence of infrastructure in higher learning institutions	Number of respondents who pointed out the infrastructure issue in higher learning institutions
ICT human resource	4	2
Information systems	6	0
Hardware	3	3
Network for communication service	4	2
Digital contents	4	2
Interoperable information systems	0	6
Data Storage infrastructure	4	2

ICT human resource: four respondents mentioned that there are ICT personnel that support on ICT implementation in higher learning institutions but on the other hand, two respondents articulated that there is lack of ICT personnel on the element.

Information systems: Six respondents view that there are information systems in place from higher learning institutions that can be used in data exchange

Hardware: Three respondents agree that the hardware exist while the other there respondents see that there is an issue with hardware in higher learning institutions

Network for communication services: Four respondents recognize the existence of network for communication service while two respondents mentioned that there is an issue with the network communication services

Digital contents: four respondents mentioned that the digital contents are available to be shared with others but two respondents have mentioned that digital contents in still an issues as sometimes hard copies are used to share information.

Interoperable information systems: Interoperable information systems is the common challenges in all institutions as mentioned by six respondents

Data storage infrastructure: For the case of data storage, four respondents raised the existence of that element while two respondents mentioned that there is an issue with data storage

The majority of respondents mentioned that the infrastructure to have information systems interconnected exist on the side of ICT human resource, information systems, network for communication, digital contents and data storage while less respondents have raised the issues of infrastructure in higher learning institutions. The majority of respondents have also mentioned that there are challenges with the availability of interoperable information systems in higher learning institutions. All this shows that even if the infrastructure exist in higher learning institutions, there is still an improvement towards this.

5.5. Accessibility of information service in higher learning institution

Respondents has mentioned four information services in terms of library, admission, registration, and student loan services. These services are summarized in the table number 8.5 in three evaluation criteria namely conveniently accessible, less accessible and not accessible

Table 8.5: Accessibility of information service in higher learning institutions

Service	Number of respondents on information service in higher learning institutions		
	Conveniently accessible	Less accessible	Not Accessible
Library Service	3	2	0
Admission Service	3	2	0
Registration service	3	2	0
Student loan service	2	1	1

Library services: Three respondents mentioned that the library services are conveniently accessible while two respondents said that the services are less accessible and this is due to the fact that they have experienced on and off connection to the service while they were accessing online library services.

Admission services: Three respondents mentioned that the admission services are conveniently accessible while two respondents said that the services are less accessible because they have experienced the challenges with online services navigation given the fact they have not previously oriented on how to use these services.

Registration services: Three respondents mentioned that the admission services are conveniently accessible while two respondents said that the services are less accessible because they have experienced the challenges with online services navigation given the fact they have not previously oriented on how to use these services.

Student loan services: two respondents have mentioned that the student loan services are conveniently accessible. One student has said that these services are less accessible while the other one said that these services are not accessible and this is due to the fact that they have been requested to present some hard document about their studies background and that they were not oriented previously on how to use online services for student loan request.

5.6. Challenges of having information systems that are not effectively communicate each other in higher learning institutions

From the table 9.5, six categories have been pointed by respondents for challenges of information systems that are not communicating each other among higher learning institutions in Rwanda. These categories are namely data loss, poor services, data quality issue, delays in budget planning, information storing, sharing, classification and use, as well as data collection, monitoring, and follow up.

Table 9.5: Challenges of having information systems that are not effectively communicate each other in higher learning institutions from Rwanda

Challenges of having information systems that are not effectively communicating each other	Number of respondents
Data loss	5
Poor Service	6
Data quality issue	6
Delays in budget planning	4
Storing, sharing, classification of data and use of information	5
Data collection, monitoring and follow up	3

Data loss: Five respondents have mentioned data loss as the challenge of having information systems that are not communicating each other in higher learning institutions from Rwanda.

Poor services: The majority of respondents has pointed out poor services as challenges of information systems that are not communicating each other as mentioned by six respondents in the study

Data quality issue: Data quality issue is another top challenges mentioned by six respondents in the study while talking about the challenges of having information that are not communicating each other in higher learning institutions from Rwanda.

Delays in budget planning: Four respondents said that the fact that data from institutions are not timely delivered, they may delay to plan for the yearly budget which may affect their proper planning.

Information storing, sharing, classification and use: Five respondents has pointed out information storing, sharing, classification and use of information as challenges on none interoperable information systems in higher learning institutions from Rwanda

Data collection, monitoring, and follow up: Three respondents have mentioned that they have issue of data collection, monitoring and follow up as results of having information systems that are not communicating each other.

5.7. Challenges of technical interoperability in higher learning institutions in Rwanda.

From the table 10.5, challenges of technical interoperability in higher learning institutions in Rwanda are classified into six categories namely: different platforms for data sharing, different information systems developed from different programming languages and user requirements, unavailability of standardized architecture for Information systems, less investment in high quality information systems because of budget challenges, ICT Infrastructure challenges and missing agreement between higher learning institutions about technical data exchange

Table 10.5: Challenges of technical interoperability in higher learning institutions in Rwanda

Technical interoperability challenge	Number of Institutions
Different platforms for data sharing	3
Different Information systems developed from different programming languages and user requirements	3
Unavailability of standardized architecture for Information systems	4
Less investment in high quality information systems because of budget challenges	3
ICT Infrastructure challenges	3
Missing agreement between higher learning institutions about technical data exchange	2

Different platforms for data sharing: Three respondents have mentioned that the fact that they have developed and use different platforms in their institutions, this have impact on challenges of interconnecting these different platforms

Different information systems developed from different programming languages and user requirements: Three respondents said that they might be challenges to have different information systems that been developed in silos because the user requirements are different and that the programming languages are different as well.

Unavailability of standardized architecture for Information systems: The majority of respondents have pointed out the lack of standardized architecture for information systems in higher learning institutions in Rwanda as the challenges of developing the standardised and interoperable information systems in their institutions

Less investment in high quality information systems because of budget challenges: Three respondents have mentioned that they less invest in high quality systems development because of

limited budget and this has implication in development of technical interoperability for the developed MIS

ICT Infrastructure challenges: Three respondents have mentioned that not enough ICT infrastructure have negative impact on the development of interoperable information systems

Missing agreement between higher learning institutions about technical data exchange: Two respondents have mentioned that the fact that there is no common agreement among higher learning institutions, it is difficult to have agreement about technical data exchange between their information systems. These respondents have also pointed out the issue of data privacy and security that may be part of the agreement as well.

Chapter 6: Discussion and Conclusion

This chapter focus on discussion on the study results against some theories and practices. Some recommendations are also displayed towards the way forward to address technical interoperability challenges in higher learning institution as well as the study conclusion.

6.1 Study results and theories and practices

Looking at solution taken for interoperability issues in Portuguese higher education, the standardized platform architecture was developed to enable integration and transforming information existing higher education institutions IS to support data exchange and the built of conjoint applications (Ribeiro et al., 2016).

The SIF (School Interoperability Framework) was developed to provide specification for data sharing in academic institutions and this SIF is implemented in some developing countries like USA, UK, Canada, Australia, India and other counties around the globe (Jakimoski, 2016b). The SIF has two key parts, SOA (Service-Oriented Architecture) specifications aimed for sharing information between institutions, and XML specifications with the objective for modelling educational data.

Referring to the above practices, the study results show the missing information systems architecture on top of challenges in higher education from Rwanda. Of course there are other challenges like information systems developed in silos, budget challenges, lack of guiding policies towards data exchange agreement between higher learning institutions in Rwanda and so on. With that said and in addition to some respondents suggestion, it should be better if there exist the common IS architecture in place to enable the development of interoperable information systems and that why in the next section, there is a proposed IS architecture for higher learning institutions in Rwanda.

6.2 Recommendation towards addressing technical interoperability issues

The recommendations towards addressing technical interoperability issues are based on challenges highlighted in chapter 5. The recommendations are addressed to people in the sector of higher learning institutions. The recommendations are divided into three categories. Category one is providing steps and recommendations proposed by India Interoperability Framework for e-governance as the one framework that has talked about technical interoperability. Category two is to propose the architecture for information systems in higher learning institutions as one of top challenges found in the study. Category three is displaying the recommendation provided by respondents towards addressing technical interoperability in higher learning institutions.

6.2.1. Steps for achieving technical interoperability and recommendation for technical interoperability issue

According to (India Ministry of Communications and Information Technology, 2015), there are three steps for achieving technical interoperability

Table 11.6: steps for achieving technical interoperability

Steps	Description
Step 1	Standards to Enable Technical Interoperability It is important to respect the layers or domains of technical interoperability for every designed information systems. These layers/domains are namely: presentation and archival, process, data integration, meta data, web services (data interchange), network access and application, and security.
Step 2	Integration with Legacy Application It is important to note that legacy application fulfil the e-governance requirements
Step 3	Service-Oriented Architecture SOA has been identifies as the best mechanism to enable the implementation of interoperable e-services with the appropriate access control that can used among big and different platforms with heterogeneous technology environments.

Adopting the India interoperability framework developed in 2015, here are some recommendation to address technical interoperability issue in higher learning institutions in Rwanda.

1. Technical interoperability across different information systems and storage of systems should be ensured
2. The representation of information in higher learning institutions should be on open standards and format.
3. The technology-independent frameworks or formats should be used to ensure long term preservation of information
4. Common language should be considered at all higher learning institutions from the design stage
5. Security and privacy should be ensured in universities information systems
6. The standards and technologies selected should reduce costs from all universities and for their partners
7. Compatibility with Internet and World-Wide Web specification should be ensured

6.2.2. Proposed architecture for information systems in higher learning institutions.

In consideration of respondents ideas, and given the fact that the current information systems have been designed in silos and by the fact that the common information systems architecture is missing for higher learning institutions in Rwanda, below is the proposed architecture designed for higher learning sector in Rwanda. From figure 5.6, the proposed architecture is for Rwanda higher Education Information Systems (RHEIS). The architecture shows the development of a standardised information system used by all higher learning institutions users, HEC and REB as well. RHEIS architecture enables updated data access by all partners from the standardised information system. The data is exchanged through the network and there will be the central server for RHEIS

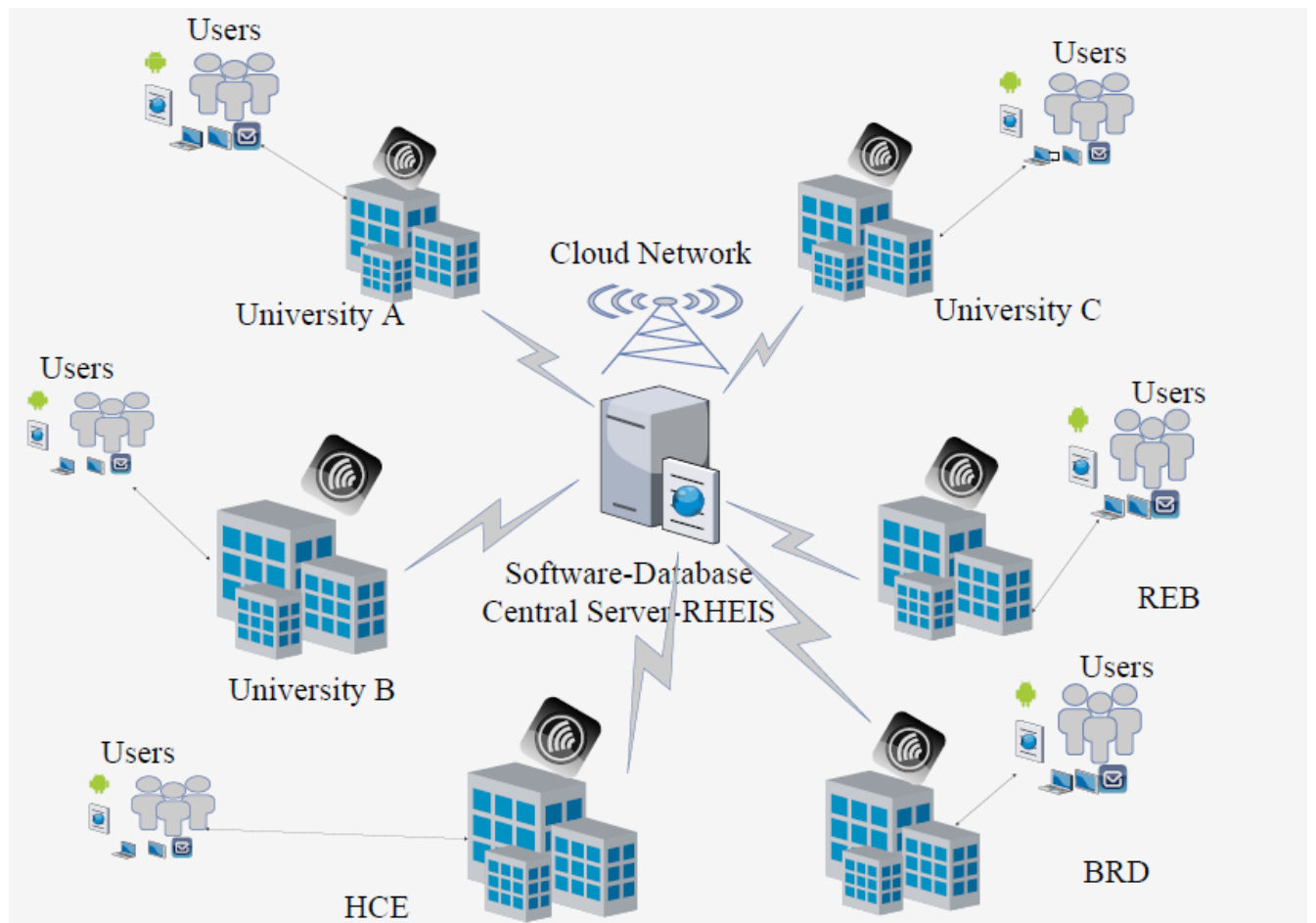


Figure 5.6: RHEIS (Rwanda Higher Education Information Systems) proposed architecture

The RHEIS should comply with the technical interoperability domains displayed in figure 5.6

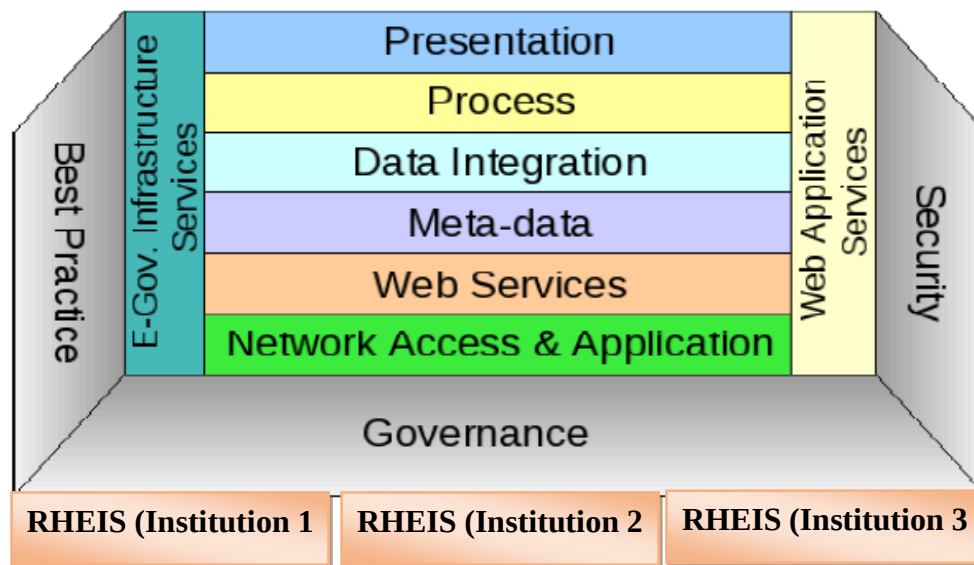


Figure 6.6: Technical interoperability domain adapted from India interoperability framework for e-governance 2015

6.2.3. Other recommendation from respondents towards interoperable information systems in higher learning institution in Rwanda

The interviewed respondents recognized the value of having the common or a standardized information systems in higher education. The other ideas are directed to the fact that it should be the accountable and lead for the initiative of having interoperable information systems in education sector whereby HEC is pointed out as the appropriate agent to coordinate all processes to make happen all the recommendations towards interoperable information systems in higher learning institutions. Enough budget was pointed out as the enabler of developing quality and interoperable information systems in Rwanda higher learning institutions. Policies and agreements towards data exchange, systems developments are also important and these should be owned by HEC and RISA as the organization that oversee all higher educations in Rwanda and ICT facilities respectively.

Conclusion

The thesis was conducted in higher learning education in Rwanda and basically to explore challenges of information systems interoperability in higher learning institutions. The study has responded to the research question by displaying challenges behind information systems interoperability from high leaning institutions in Rwanda as well providing possible solutions that may be applied to resolve interoperability issues in high leaning institutions in Rwanda.

There are various challenges discussed in chapter six and recommendation to address these challenges have been discussed in chapter six. The study has provided the proposed architecture for information systems design for higher leaning institution in Rwanda and other recommendations aligned with challenges of interoperability in higher learning institution in Rwanda.

This study has focused on technical interoperability for information systems in higher learning institutions. However, the other levels of interoperability namely organizational, semantic, syntactic, governance and legal were not studied for the case of higher learning institutions in Rwanda and this serves to recommend them for the future research.

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ANNEX: Questionnaire

The study “Interoperability of information systems: Case of higher learning institutions in Rwanda-Challenges and the way forward” is conducted by Jean de Dieu Habinshuti, a student in Masters of Science of Science in Information systems, option of e-government from University of Rwanda, department of Information Science and Technology. This research is supervised by Dr Pierre Bakunzibake and Dr Frederick Nzanywayimana from Univeristy of Rwanda.

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The objective of this survey is to identify constraints of information systems interoperability in high leaning institutions from Rwanda and recommend solutions to address the identified challenges. Interoperability is referred to a property of different systems and organizations enabling them to work together. Interoperability is a key requirement to support activities in heterogeneous environments effectively and efficiently whereby diversified applications and data are able to be shared and communicate despite being on different pieces of equipment and platforms.

The interview questions and answers serves to get results of the research and draw solution to interoperability constraints identified. The information from the interviews are for this thesis project and analysis will be shared with the interviewed organization.

Questions details: Questions are designed for people involved technically on information systems management and for people that use information systems data in higher leaning institutions

List of targeted respondents

Role or Position	Unit or organisation
ICT Manager	UR
ICT Manager	HEC
In charge of ICT	BRD
In charge of ICT	ULK
Lectures	UR
Students	UR, ULK

Executive Secretary	HEC
Manager	BRD
Academic Registrar of college	UR,ULK
In charge of library	UR,ULK
In charge of roan recovery	BRD

General questions

1. What is your role in the institution (optional)?
2. For how long have you been in this organisation?

Specific Questions for Managers

3. What are your partner organisations for your institutions?
 - a. What are your partner organisations for your institutions when it comes to exchanging digital information?
 - b. Are you satisfied with data exchange procedures with your organization partner?
4. How does your institution exchange information or data with those partner organisations?
 - a. Via which channels or systems?
 - b. What are technological systems used?
 - c. Which kind of information is exchanged?
5. How is information (or data) exchanged within units of your organisation?
 - a. Via which channels or systems?
 - b. What are technological systems used?
 - c. Which kind of information is exchanged?
6. What are the challenges faced while exchanging information (or data)
 - a. Within your units of your organisation?
 - b. With partner organisations?

7. What are plans to improve exchange of information (or data)
 - a. Within your units of your organisation?
 - b. With partner organisations?
 - c. in terms of interconnecting existing systems
 - d. in terms of developing new interconnected systems?

Specific questions for ICT personnel

8. What are the information systems used in your institutions?
 - a. Which ones are interconnected?

Architecture:

9. While designing technical information systems in your institution, to which extent do you follow some common architecture agreed up on all higher learning institutions or at national level?
 - a. Among systems used by your institution, which information systems designed and implemented having in mind the data exchange among institutions in higher education?
10. Internal content sharing: To what extent the content is exchanged among units in your organisation?
 - a. How documents are shared or accessed between units in your organisation?
 - b. How electronic records are shared or accessed between units in your organisation?
11. Cross-boundary Content Sharing: To what extent the content is exchanged among your organisation and other institutions in higher education in Rwanda?

- a. How do your institution share documents with other institutions in higher education in Rwanda?
 - b. How do your institution share electronic records with other institutions in higher education in Rwanda?

- 12. ICT infrastructure (including network and data storage infrastructure: How ICT infrastructure is used for interconnecting different technical systems
 - a. How internal ICT infrastructure is used to interconnect different technical information systems in your organisation?
 - b. How public ICT infrastructure is used to interconnect different technical information systems in institutions in higher education?

- 13. What are challenges of having information systems that effectively communicate to each other
 - a. Within units in your organisation?
 - b. Among higher learning institution?

- 14. What are existing plans having information systems that are effectively communicate to each other
 - a. Within units in your organisation?
 - b. Among higher learning institution?

Specific questions for users (officers and students)

Core Services

- 15. To what extent information related to student admission is readily available and conveniently accessible and via a technical information system?

16. To what extent information related to student registration is readily available and conveniently accessible and via a technical information system?
17. To what extent information related to library service account of a student is readily available and conveniently accessible and via a technical information system?
18. To what extent information related to student loan is readily available and conveniently accessible and via a technical information system?
19. Services: How service information (e.g. related admission, registration, library, student loan) are conveniently accessible by managers?