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Adoption of Free and Open-Source Software in the Angolan Public Sector

Domingos Garcia da Silva

PhD in Information Science and Technology

Supervisors:
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To my parents,

Mateus Domingos da Silva and Maria Garcia Simão

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To everyone, my deepest thanks,

So be it!

"It is finished"
John 19:30

Resumo

A procura crescente de serviços inovadores tem pressionado os governos a adaptarem-se rapidamente. A transformação digital, embora seja uma resposta adequada, enfrenta desafios significativos, nomeadamente nos países em desenvolvimento, tais como os custos elevados e a dependência dos fornecedores de tecnologia. Vários estudos têm sugerido a adoção de software livre e de código aberto (FOSS – Free and Open-Source Software) como estratégia para promover a transformação digital. O FOSS tem vários benefícios, que incluem, mas não estão limitados a sua relação custo-benefício, flexibilidade e segurança. O principal objetivo deste trabalho estudo é investigar a adoção do FOSS no setor público, com ênfase na área de saúde em países em desenvolvimento, como Angola. Esta tese é motivada pela crença de que a busca pelo FOSS não é apenas por uma alternativa de custo reduzido às soluções proprietárias, mas uma forma de promover independência tecnológica e flexibilidade para personalizar sistemas de acordo com necessidades específicas. Seguindo uma abordagem metodológica mista, de "Natural Sciences" e "Design Science", a pesquisa oferece uma visão abrangente da literatura de FOSS, identifica fatores-chave que influenciam a aceitação/adoção de FOSS. Além disso, fornece uma análise detalhada sobre o papel crucial do FOSS na superação de desafios de interoperabilidade. Como resultado, foram obtidos clusters bibliométricos, um modelo teórico de adoção do FOSS e uma arquitetura para melhorar a acessibilidade dos cuidados de saúde em áreas remotas. Estes resultados sugerem aos decisores, especialmente nos países em desenvolvimento, que o FOSS promove a autossuficiência e a inclusão digital, desempenha um papel fundamental na transição digital.

Palavras-Chave: Software Livre e de Código Aberto, Transformação Digital no Setor Público, Adoção de FOSS em Países em Desenvolvimento, Interoperabilidade, Segurança, Modelos Teóricos de Adoção de FOSS.

Abstract

The growing demand for innovative services has put pressure on governments to adapt quickly. Digital transformation, while an appropriate response, faces significant challenges, particularly in developing countries, such as high costs and dependence on technology providers. Several studies have suggested the adoption of Free and Open-Source Software (FOSS) as a strategy to promote digital transformation. FOSS has several benefits, which include, but are not limited to, its cost-effectiveness, flexibility, and security. The main objective of this research is to investigate the adoption of FOSS in the public sector, with an emphasis on health in developing countries, such as Angola. This thesis is motivated by the belief that the search for FOSS is not only a low-cost alternative to proprietary solutions, but a way to promote technological independence and flexibility to customize systems according to specific needs. Following a mixed methodological approach, from "Natural Sciences" and "Design Science", the research offers a comprehensive overview of the FOSS literature and identifies the key factors influencing the acceptance/adoption of FOSS. In addition, it provides a detailed analysis on the crucial role of FOSS in overcoming interoperability challenges. It obtained as results bibliometric clusters, a theoretical model of FOSS adoption, and an architecture to improve the accessibility of health care in remote areas. These results suggest to decision-makers, especially in developing countries, that FOSS promotes self-sufficiency and digital inclusion, and plays a key role in the digital transition.

Keywords: Free and Open Source Software, Digital Transformation in the Public Sector, FOSS Adoption in Developing Countries, Interoperability, Security, Theoretical Models of FOSS Adoption.

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List of Acronyms

AI: *Artificial Intelligence*

AVE: *Average Variance Extracted*

APIs: *Application Programming Interfaces*

BI: Behavioural Intentions

COVID-19: *Coronavirus Disease 2019*

CR: *Composite Reliability*

CSV: *Comma-Separated Values*

CPU: *Central Processing Unit*

SRM: *Design Science Research Methodology*

DTMF: *Dual-Tone Multi-Frequency*

DS: *Design Science*

EExp: *Effort Expectation*

EHR: *Electronic Health Record*

FOSS: *Free and Open-Source Software*

GoF: *Goodness-of-Fit*

HL7 FHIR: *Health Level Seven Fast Healthcare Interoperability Resources*

HIS: *Hospital Information System*

HTMT: *Heterotrait-Monotrait Ratio of Correlations*

ICT: *Information and Communication Technologies*

Intero: Interoperability

IoT: *Internet of Things*

IP: *Internet Protocol*

IVR: *Interactive Voice Response*

LV: *Latent Variables*

mHealth: *Mobile Health*

NLP: *Natural Language Processing*

NS: *Natural Sciences*

OSPO: *Open-Source Program Office*

PExp: *Performance Expectation*

RAM: *Random Access Memory*

REST: *Representational State Transfer*

Sec: *Security*

SEM-PLS: *Structural Equation Modeling - Partial Least Squares*

SI: *Social Influence*

SIP: *Session Initiation Protocol*

SO: *Specific Objectives*

SysQual: *System Quality*

TCO: *Total Cost of Ownership*

UML: *Unified Modeling Language*

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

Usab: *Usability*

VIF: *Variance Inflation Factor*

VoIP: *Voice over Internet Protocol*

Chapter 1

Introduction

This chapter introduces the context and motivation underpinning the research, outlining the main underlying objectives, and detailing the methodological approach chosen, as well as presenting the organizational structure of the thesis. This chapter plays an essential role and provides a broad view of the scenario in which the research is inserted and in the justification of its relevance.

1.1. Motivation and Scope

In the context of evolving societies, as countries have grown and developed, their citizens have become increasingly hungry for new services. This desire has been amplified by the advent of the information society, an era in which information and communication technologies (ICT) have come to play an increasingly central role in the social, cultural and political life of citizens (Adam & Dzang Alhassan, 2021; Haider et al., 2021; Ziemba, 2013).

However, as the information society consolidated, new demands emerged, which posed a substantial challenge for governments. This has considerably increased the pressure on them, forcing them to look for ways to reinvent themselves to meet the growing demand for innovative services that meet standards of quality, simplicity and transparency, making accessibility imperative regardless of geographical location or socio-economic status (Damanpour & Schneider, 2009; Dawson et al., 2016; Guadagnoli, 2022). Faced with these challenges and in order to meet these requirements, digital transformation in the public sector emerged as a pressing need, becoming a key piece in the strategic positioning to respond to this demand and ensure that new services were aligned with the expectations of a more culturally integrated society (Khisro, 2020; Milenkova & Manov, 2022).

The underlying premise is that digital transformation has the potential to effectively address these challenges, stimulating innovative dynamics that not only simplify and optimize various aspects of citizens' lives, but also play a key role in promoting the sustainable development of these governments. This digital transition is reflected in improved performance and operational efficiency of the public sector, faster access and democratization of public services, as well as cost reduction and prevention of adverse incidents, many of which are related to human error (Angst et al., 2012; Buckman et al., 2022; McCullough et al., 2016). In addition, the digital transformation increases the accessibility of essential public services in remote and economically disadvantaged communities, thereby driving new modes of operation by the public sector and providing an overall improvement in the citizen experience (Shaltynov et al., 2022; Zain Rashid et al., 2019).

However, the digital transformation process is not linear and brings with it several challenges. These include the high cost associated with software licensing, vendor lock-in, the pressing need to ensure security, transparency, and interoperability between systems, as well as the complexity involved in customizing and adapting these systems to meet the specific needs of the public sector. These challenges end up limiting the autonomy and hindering the public sector's ability to innovate. Therefore, the choice between different ICT categories, ranging from proprietary, free or open source ICT – hereinafter referred to as FOSS, represents a strategic decision of great importance and, therefore, fundamental to enhance the transition from a paper government to a more digital government (Anand et al., 2018; Dhir & Dhir, 2017a).

FOSS represents a type of computer program that can be obtained free of charge, with no associated financial costs, whose source code is made publicly available, allowing anyone to view, modify and distribute freely (Kilamo et al., 2020) resulting in low dependence on suppliers and cost reduction related to technological licensing and maintenance (Umm-e-Laila et al., 2021). These changing characteristics of FOSS make it an alternative of great potential value, capable of efficiently and cost-effectively leading the public sector towards a more digital, sustainable and people-centred future (Katsamakas & Xin, 2019; Muwanguzi & Musambira, 2019; Sowinska et al., 2021). However, FOSS goes beyond being just a cost-effective alternative to proprietary ICT (Jokonya, 2015; Patino-Toro et al., 2022). It also stands out for its remarkable feature of open standards, which tend to provide greater security, transparency, flexibility, and the freedom to customize and adapt it according to the needs of the context (Bundit, 2016; Silva et al., 2023; um-e-Laila et al., 2021).

This disruptive and promising approach to FOSS has aroused growing interest, especially from various governments, especially in developed economies countries, evidencing a growing acceptance of FOSS as a viable technological alternative to drive digital transformation in the public sector (Koloniaris et al., 2019; Linaker & Runeson, 2020; Shaikh, 2016a; Sowinska et al., 2021) As a result, many organizations have begun to adopt open technologies in a wide variety of critical contexts (Patino-Toro et al., 2022; Rito, 2019; St. Amant & Flammia, 2016; Umm-e-Laila et al., 2021), spanning from governments (AlMheiri et al., 2018; Shaikh, 2016b) business (Correia et al., 2018), agriculture (Cestari et al., 2020; Jean-Daniel et al., 2019; Kassim, 2020), education (C. Mota & I. Seruca, 2015; Laugasson et al., 2016; M. Pezer et al., 2017) and health (Frade et al., 2022; Paton et al., 2022; Poba-Nzaou et al., 2020; Verma et al., 2021; Wanger et al., 2023).

In Europe, for example, FOSS has played a key role in the modernization of the public sector, and this recognition is tangibly reflected in the creation of the Open-Source Program Office (OSPO) by the European Commission. This body was created with the explicit mission of promoting and facilitating the use and collaboration around FOSS. The industry-inspired approach, which prioritizes the adoption of FOSS, is gaining acceptance in several European countries, where governments and public institutions realize the benefits of utilizing open-source solutions to modernize and optimize their services. At the same time, on the Asian continent, nations such as South Korea and China have a long history of incorporating FOSS into their industrial policies. These countries have long recognized the potential of FOSS to drive innovation, technological independence, and efficiency in crucial sectors, including the public. The promotion of FOSS is a strategy that these countries have used successfully. Similarly, in the United States, the federal government has also recognized the value of FOSS in pursuing greater transparency, efficiency, and innovation in the public sector. Policies have been established to encourage the use of and contribution to FOSS in various government agencies. This has resulted in a growing adoption of FOSS at different levels of the U.S. government.

However, despite all this attention and recognition of FOSS in more developed contexts, such as Europe, Asia, and the United States (European Commission, 2020; Guadagnoli, 2022; Linåker et al., 2023; Scanlon, 2019; Sowinska et al., 2021), there is a notable lack of studies exploring how FOSS is applied and its implications in developing countries. Most of the available research and evidence focuses on more developed settings, and the study gap in developing countries is evident. Therefore, it is imperative to address this lack of research and understand how FOSS can be effectively utilized to address the limitations, obstacles, and challenges of promoting digital transformation in developing contexts. This gap represents a crucial need for research, as developing countries canes also benefit enormously from the advantages offered by FOSS in their search for more efficient and accessible public services.

The problem of FOSS adoption in developing countries remains a slow and often unsustainable path. In most cases, adoption initiatives fail to scale during the implementation phase. Several studies have shown that this persistent difficulty is a significant challenge. This resistance to FOSS adoption is often attributed to a few factors, such as technological and organizational barriers, as well as reliance on proprietary vendors. This problem is not new and has already been addressed, from different perspectives, and needs to be overcome for FOSS to reach its full potential in these nations.

From a technological point of view, for example, compatibility and interoperability play a critical role and often hinder the smooth transition to FOSS. Because many organizations already have legacy systems in production, integrating FOSS with existing infrastructures can be necessary, complex, and costly (Gurusamy & Campbell, 2011; M. Silic & A. Back, 2017). Several studies have shown that the lack of FOSS experts and resources for adequate training poses a significant challenge to the successful adoption of FOSS (Glynn et al., 2005; Msiska, 2017), as it contributes to the difficulty of maintenance and problem solving, generating fear in adoption and perpetuating dependence on proprietary suppliers.

On the other hand, the issue of acceptance of FOSS at the organizational level has also been a problem. Top management assumes a visible relevance in the process and the impact it has on the acceptance of FOSS by employees. Therefore, resistance to change and a lack of understanding of the benefits of FOSS on the part of leadership and employees are common challenges that can create significant obstacles in the successful adoption of FOSS. In addition, government policies and regulations often do not favor the adoption of FOSS, making it less attractive to public organizations (Hauge et al., 2010; Kasaine & Khamadi, 2018).

Another high-impact challenge is the reliance on technology vendors that promote proprietary solutions, often offering financial incentives to stay in that model, which perpetuates a culture of resistance to transitioning to FOSS. This limits the autonomy of organizations and holds them hostage to suppliers, preventing the flexibility and customization that FOSS can offer (Umm-e-Laila et al., 2021). Additionally, the lack of clear standards and guidelines for implementing FOSS adds uncertainty to the process, discouraging many organizations from considering this approach (Sanchez et al., 2020; Wang et al., 2020).

As far as motivations are concerned, this research is therefore driven by the relevance of FOSS in the public sector, especially in developing and low-income countries. The motivations behind this research are multifaceted. Firstly, there is an academic motivation to explore this area of investigation, supported by the authors' professional experience in the context of systems adoption in digital transformation processes through the implementation of FOSS in various contexts. In addition, there is the motivation that, after the research, it is possible to extract recommendations from the results obtained, which can become essential for decision-makers who shape future policies and strategies aimed at modernizing public services and promoting digital transformation.

In this sense, the research seeks to be an added value for the public sector in Angola, a valuable contribution to the understanding of the relevance of FOSS for technological development and a starting point for future investigations, considering the scarcity of studies in this area in the context of developing countries, as revealed by the bibliographic research carried out as part of this investigation.

1.2. Research Questions and Objectives

The adoption of FOSS in the public sector is a topic of growing interest and relevance, especially in developing countries. Overcoming barriers to FOSS adoption in these countries requires an integrated approach tailored to each context.

Therefore, the central aim of this research is to investigate and promote the adoption of FOSS in the public sector of developing countries and its implications for digital transformation. It is recognized that there is no single solution to the challenges that these nations face, but we believe that a great goal is achieved step by step, and this study represents only one step in that journey, which for this the following specific objectives (SO) have been defined:

SO1: Conduct a literature review related to FOSS to identify prevalent issues, highlight emerging trends, outline key areas of interest, and point out substantial gaps in this field of knowledge.

SO2: Identify the factors influencing the adoption of FOSS in the context of developing countries.

SO3: Develop a conceptual model to empirically validate and explain the factors influencing the adoption of FOSS.

SO4: Present practical solutions to modernize public health and improve accessibility to health care in remote areas.

Thus, the research carried out within the scope of this research aims to answer the following research questions (RQ):

RQ1: What factors influence the adoption of FOSS in the public sector, especially in developing countries such as Angola?

RQ2: How can FOSS adoption drive digital transformation, promote sustainability, and improve the quality of public services in developing countries such as Angola?

As already mentioned, the present research focuses on the adoption of FOSS, especially in developing countries and other less industrialized contexts. As such, the authors chose Angola as the main setting for this research (Silva et al., 2023), a country that is facing a generalized crisis, with urgent needs for improvements in public services, especially in the area of health.

The underlying hypothesis guiding this research suggests that the adoption of FOSS is a promising prospect for driving innovation and promoting development by facilitating the delivery of quality, integrated, and sustainable public services, similar to what is observed in developed countries (Bai et al., 2021; Katsamakas & Xin, 2019; Marsan & Paré, 2013; Syzdykova et al., 2017).

By adopting FOSS, the goal is not only to modernize the technological infrastructure, but also to create a sustainable and long-term technological foundation. FOSS offers a cost-effective and flexible alternative that allows developing and low-income nations to build their own technological capacity, reduce dependence on technology providers, and invest in local skills and digital literacy. In addition, by adopting FOSS, governments can allocate financial resources to critical areas such as education and healthcare, driving economic growth and improving the quality of life for their citizens.

1.3. Methodological Approach

Scientific inquiry is a journey that often encompasses the exploration of theoretical concepts and the development of practical solutions. In this context, the choice of an appropriate methodological approach plays a fundamental role in conducting the research (Adebowale, 2011) - and in line with what is intended with this research, the choice of the scientific method falls on a mixed approach between two paradigms of scientific approach, namely "Natural Science" and "Design Science" . The integration of these two methodological models is justified by the multifaceted nature of our research. As suggested by the guidelines of (March & Smith, 1995) these approaches can converge effectively, enriching the quality and relevance of research, contributing not only to the advancement of academic knowledge, but also to the solution of real-world problems, providing solid practical and theoretical results.

Thus, therefore, this multifaceted methodological approach allowed for a comprehensive investigation into various aspects of FOSS, from the analysis of the existing literature as well as the factors influencing its adoption to the development of practical solutions. The methodology was divided into several distinct steps, each tailored to the specific nature of its research, but all sharing the overall methodological approach to ensure the rigor and consistency of the investigation.

Figure 1.1 summarizes the methodological approach used in this investigation, highlighting the harmonious integration of the "Natural Science" and "Design Science" paradigms.

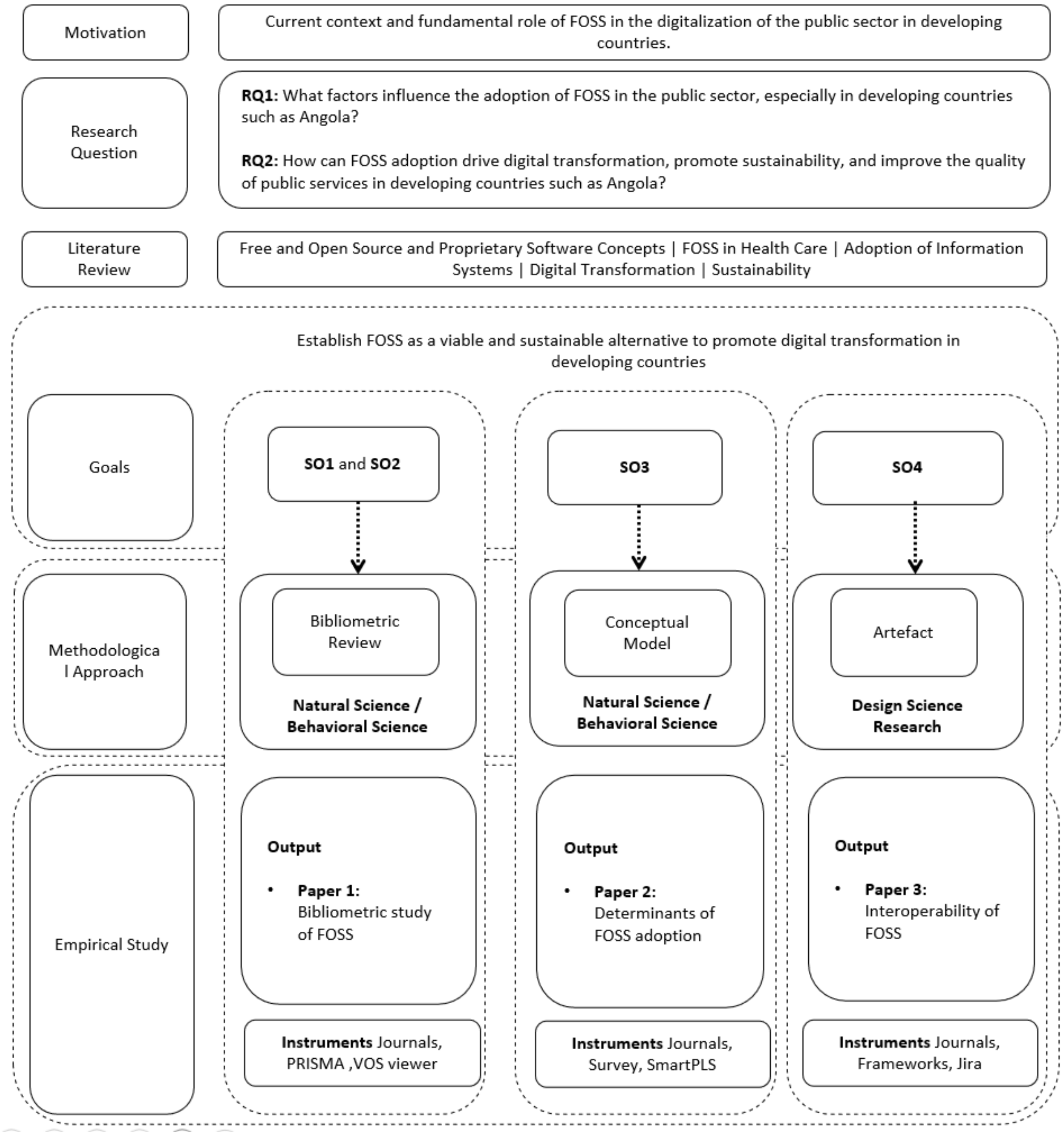


Figure 1.1: Methodological approach

The first component of our methodological approach is intrinsically linked to the paradigm of "Natural Science". This paradigm is essentially deductive, is guided by the exploration and validation of theories, and is often applied in exploratory research to explain or predict organizational and human phenomena (Hevner et al., 2004). Our "Natural Science" approach is applied in the initial phase of the research, in which we conduct a bibliometric and critical review of the literature related to FOSS. This review followed rigorous scientific principles, seeking to identify trends, patterns, and gaps in existing research. During this phase, we examine previous theories and results to inform our research objectives. In addition, the approach was used to theorize, justify, and empirically validate the theoretical conceptual model, with the aim of explaining the trend of FOSS adoption.

The second component of our methodological approach aligns with the "Design Science" paradigm. Unlike "Natural Science", this paradigm is constructivist and oriented towards the creation of practical and innovative solutions (Aparicio et al., 2023). It is particularly relevant when seeking to develop artifacts that address real-world problems. Our "Design Science" approach comes into play after literature review and the development of a theoretical conceptual model. At this stage, our primary goal is to design and develop a practical artifact. This artifact represents an original contribution to the solution of a real problem and is therefore inserted in the domain of "Design Science".

1.4. Results and Contributions

The conduction of this research involved the application of a hybrid methodological approach that united elements of the "Natural Science" and "Design Science" paradigms. During this investigative process, three distinct studies resulted, each of which contributed substantially to the understanding and promotion of the adoption of FOSS in the public sector, with special attention focused on developing nations, among which Angola stands out.

The first study consisted of a comprehensive bibliometric analysis, allowing an assessment of the current state of FOSS adoption. This analysis revealed predominant trends, prominent themes, and regions with the highest scientific production in this area, offering a holistic view of the research field. The results obtained reveal an exponential growth of literary production related to FOSS over time. The United States leads this scenario, followed by India, South Africa, and Brazil, emphasizing the relevance of developing economies in this context. In addition, four distinct thematic themes emerged from the analyses, addressing topics such as open systems, health, information systems, costs, and human implications. By examining the patterns identified, it became evident that pertinent discussions of "IoT," "machine learning," "deep learning," and other technical innovations on the rise were emerging. The authors also emphasize the need to develop a future agenda of studies in emerging areas. This study provides rich and valuable insight into understanding the FOSS landscape, its implications for sustainability, and the potential impact on the trajectories of developing countries. However, this article is in the process of revision at the time of submission of the thesis.

The second study resulted in the creation of a new theoretical model for the adoption of FOSS in developing countries. Through an in-depth empirical analysis, the main factors influencing the decision to adopt FOSS solutions in the public sector of these countries were identified. Factors such as cost, performance, social influence, system quality, security, interoperability, and usability were identified as determinants in this choice. The results show a significant relationship between FOSS adoption and variables such as reduced cost, performance expectations, social influence, and system quality. Notably, aspects such as security, interoperability and usability stand out as crucial elements in decision-making related to adoption, explaining a substantial portion of the observed variability.

In essence, Study 2 contributes to the proposition of a new model for the adoption of FOSS, especially in countries with significant growth prospects. The objective is to enrich the knowledge of the scientific community, providing a deeper understanding of the reality of organizations that adopt FOSS in developing country contexts. This article was accepted in a high-impact journal, classified as Quartile 1 (Silva et al., 2023).

The third empirical study resulted in the development of an innovative artifact. This artifact combines artificial intelligence (AI) and interoperability standards to improve accessibility to healthcare in remote areas. The results show that the implementation of the proposed design can bring considerable benefits in terms of accessibility and interoperability in the health sector. This article was submitted to a high-impact journal, classified as Quartile 1 and is under review.

The results demonstrated the considerable benefits of this implementation in terms of accessibility and interoperability in the healthcare sector. In addition to the specific contributions, this research fills a crucial gap in knowledge by addressing the adoption of FOSS in developing countries. It also provides valuable insights for government policymakers, spurs innovation and technological development, and promotes digital inclusion and universal access to essential services. This thesis contributes not only to the advancement of academic knowledge but also to the resolution of practical real-world challenges in the public sector in developing countries.

1.5. Thesis Structure

To discuss the above issues in more detail and provide an overview of the work done in this thesis, we have divided it into five chapters, in which, each addressing specific aspects of the theme investigated.

Chapter 1: This chapter presents the introduction of the research, providing the context, the problematic and the relevance of the theme of the adoption of FOSS in the public sector in developing countries. This chapter also describes the general and operational objectives of the research, as well as the methodological approach adopted to achieve the proposed objectives.

Chapter 2: This chapter presents the bibliometric review on FOSS. This review covers a survey of the relevant scientific literature, identifying the main research trends, themes explored, most influential authors and institutions, as well as knowledge gaps in the area, providing a comprehensive overview of the evolution of research on the topic over time.

Chapter 3: This chapter presents the empirical study conducted to understand the factors that influence the adoption of FOSS in the public sector in developing countries. This chapter describes the methods of data collection, data analysis and the proposal of the new theoretical model of FOSS adoption. The results of the empirical study are presented and discussed, providing valuable insights into the perceptions and experiences of public sector professionals regarding the adoption of FOSS.

Chapter 4: This chapter describes the second empirical study, which presents our digital health artifact proposal designed to improve health care accessibility.

Chapter 5: This chapter presents an integrated analysis of the results obtained in the bibliometric review, in the empirical studies. The overall results of the research are discussed, highlighting the main findings and contributions to knowledge about the adoption of FOSS in the public sector in developing countries. Suggestions for future research and the practical relevance of the results obtained are also presented.

Chapter 2

Literature Review

This chapter analyses the state of the art of FOSS. The study contained in this chapter of the thesis was published in (D. Silva et al., 2019). FOSS plays an important role in promoting sustainability by providing customized and inexpensive software solutions that empower local communities. The aim of this study was to examine the literature on FOSS and identify the main trends in the scientific body in this field. The study is based on a search that included 897 publications published between 2001 and 2023 and indexed in the Scopus database. This research reveals the nations that are most active in the production of knowledge, as well as the documents and writers that have the biggest effect on the literature. Furthermore, the approach of detecting keywords is used to uncover noteworthy trends and bring up new research areas. The results reveal an exponential development in FOSS literary creation through time, with the United States leading the way, followed by India, South Africa, and Brazil, underscoring the importance of developing and rising economies. Furthermore, the research reveals four thematic themes that address topics such as open systems, healthcare, information systems, costs, and human implications. Considering the observed patterns, pertinent conversations concerning "IoT," "machine learning," "deep learning," and other emerging technical advancements emerge, in which the authors advocate the development of a future study agenda. This report provides useful information for understanding the FOSS area, its implications for sustainability, and its potential to impact the trajectory of developing countries.

2.1. Introduction

In an increasingly digitized world, where technology plays a key role in almost every aspect of modern life, the choice of software solutions has significant implications for organizations, both public and private. In this case, the decision on what type of software to adopt goes beyond simply finding a functional solution, as it directly impacts operational efficiency, security, cost, and even the issue of integration and interoperability with other systems involved. Among the many options available, FOSS is increasingly standing out as an attractive alternative capable of driving technological innovation. As such, its adoption has become a topic of great interest in both developed and emerging economies. Evidence of this technological disruption is widely documented in a variety of studies (Fukawa et al., 2021; Rudmark et al., 2023). In emerging economies, for example, FOSS can offer many benefits, such as cost savings and freedom to innovate, thus creating a favourable environment for the development of agile solutions on an unprecedented scale (*Why You Need an Open Source Software Strategy*, 2021). Its guiding principles, such as collaboration, transparency, and community participation, make it stand out as a key driving force in this era of digitalization (Barcomb et al., 2022; Mockus et al., 2002; Nakakoji et al., 2002).

FOSS refers to the type of software that can be freely used, modified, and distributed (Chopra & Dexter, 2009). This approach contrasts significantly with the strategy of proprietary, closed-source software, access to which is often subject to restrictions and payment for its use (Kilamo et al., 2020) As a result, their adoption fosters an autonomous ecosystem capable of reducing dependence on proprietary solutions (Katsamakas & Xin, 2019), and boosts the development of technical skills in local communities. This facilitates the creation of innovative products and services, allowing these communities to overcome their barriers to digitalization by developing customized software solutions in an innovative, cost-effective, and efficient way. In addition, it boosts self-sufficiency and digital inclusion, becoming a strategic ally in achieving long-term sustainability and development, especially in emerging economies (Goel & Vishnoi, 2022; Omer et al., 2023).

The influence of FOSS spans several areas. Previous studies report its impact on various segments, such as education (Chernogorova & Dimova, 2019), companies (Correia et al., 2018), governments (AlMheiri et al., 2018) and health . In addition, several dimensions such as cost reduction, system quality, security, usability and interoperability of FOSS (D. G. Silva et al., 2023), are also identified as benefits resulting from their adoption.

However, despite the widespread recognition of FOSS, the existing literature reveals a significant theoretical gap in the discussion of FOSS from different geographical perspectives. Most studies focus on developed economies, while emerging regions face challenges in widely adopting FOSS. This gap highlights the need for additional research in different geographical contexts, especially in emerging economies where their potential is not being fully exploited.

This lack of geographic diversity in academic production on FOSS tends to distort and limit the understanding of the challenges and opportunities of this model in the face of different cultures, economic and social contexts.

Therefore, to fill this gap, the study presented in this chapter aims to analyse the state of the art of the FOSS literature in developing countries and indicate new avenues for future research.

To this end, the research answers the following questions (RQ):

RQ1: What is the status of FOSS research?

RQ2: What are the prominent research themes among current FOSS publications?

RQ3: What are the directions for future research related to FOSS?

To this end, the study adopts a combined approach, which integrates bibliometric analysis and systematic review. The research adopts the bibliometric approach to analyse parameters, such as analysis of publications by year, identification of predominant countries, co-occurrence of keywords, and emerging topics. In addition, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach (Page et al., 2021) is used to analyse and synthesize bibliographic information more objectively. It is therefore hoped that the results of this study can serve as a guideline, with the aim of encouraging and furthering new research into FOSS.

The contributions of this study are varied. Firstly, this study provides a new perspective and understanding of the research trend on FOSS; secondly, this study adds a methodological contribution by incorporating the PRISMA framework; finally, the study sheds light on valuable insights that can guide future research directions.

2.2. Material and Methods

2.2.1. Search Strategy

The research followed an exploratory and documentary approach of FOSS. To achieve these objectives, the study adopts a methodology that combines a bibliometric analysis and a systematic review of the literature. In this way, the research quantifies and highlights the trends of studies on FOSS, while performing the qualitative analysis of the identified studies.

To identify indexed publications related to FOSS, the authors obtained metadata from the Scopus database. The choice of Scopus is supported by its comprehensiveness and multidisciplinary nature, encompassing summaries and citations of articles from highly relevant academic journals. The search does not impose restrictions on the period or type of documents searched. The following keywords/terms were used in the advanced search: (TITLE-ABS-KEY ("Open source") OR TITLE-ABS-KEY ("Free Software") AND TITLE-ABS-KEY ("Developing Countries") OR TITLE-ABS-KEY ("low-income countries")). The research resulted in a total of 897 documents published between 2001 and 2023.

2.2.2. Bibliometric Review

After identifying the relevant documents for analysis, the metadata was extracted in CSV format and imported into VOSviewer, a tool for analysing and visualizing bibliometric networks (McAllister et al., 2022). These networks can encompass journals, researchers, or individual publications and are built based on citations, bibliographic coupling, co-citation, or co-authorship relationships. VOSviewer also offers text mining functionality, which allows you to build and visualize co-occurrence networks of important terms drawn from the scientific literature.

Initially, a thesaurus was created to standardize vocabulary and optimize keyword analysis. Similar terms have been grouped into a single term to simplify analysis, such as "internet of things", "internet of things (iot)", "iot" and "internet of things", which have been combined into a single term "internet of things". In addition, words such as "oss", "foss" and "open source", as well as "developing country" and "low-income countries", were excluded from the analysis because they refer to the same central concept. Then, analyses of bibliometric indicators were carried out, including the temporal production of documents, analysis of citations and identification of the main research flows.

2.2.3. Systematic Review

After the bibliometric analysis, a systematic review of the literature was carried out, following the guidelines of PRISMA. The inclusion and exclusion criteria for each publication are presented in detail in **Error! Reference source not found.**. This rigorous method enabled a c omprehensive and structured analysis of the available literature, ensuring accuracy and transparency at every stage of the review process.

Table 2.1: Characteristics of selected data

Criterion	Observation
Duplicate studies	Exc. of duplicate articles, keeping only one instance of each study
DOI availability	Exc. of articles that did not have a Digital Object Identifier (DOI)
Citations	Exc. of articles without citations
Author Info; Keywords	Exc. of articles that do not provide basic information, such as author names and keywords
Relevance	Exc. of articles whose keywords is not related to the scope of the study
Language	Exc. of full articles not written in English
Doc. Type	Exc. of documents whose type is not "Article" in "Article final" and "in press" status
Open Access	Exc. of articles not classified as opens access

As mentioned earlier, the research followed the PRISMA guidelines as a basis for the preparation of reports of systematic reviews and meta-analyses. Figure 2.1 illustrates the steps in the document selection process. The first stage consisted of the "identification" of 897 documents, of which 616 were excluded during the "screening" phase, based on the criteria established in the Table above Figure 2.1. This process resulted in 269 "eligible" documents, which were reviewed based on the title and abstract. In the end, 154 documents were excluded, and 115 were considered "included" for the final analysis.

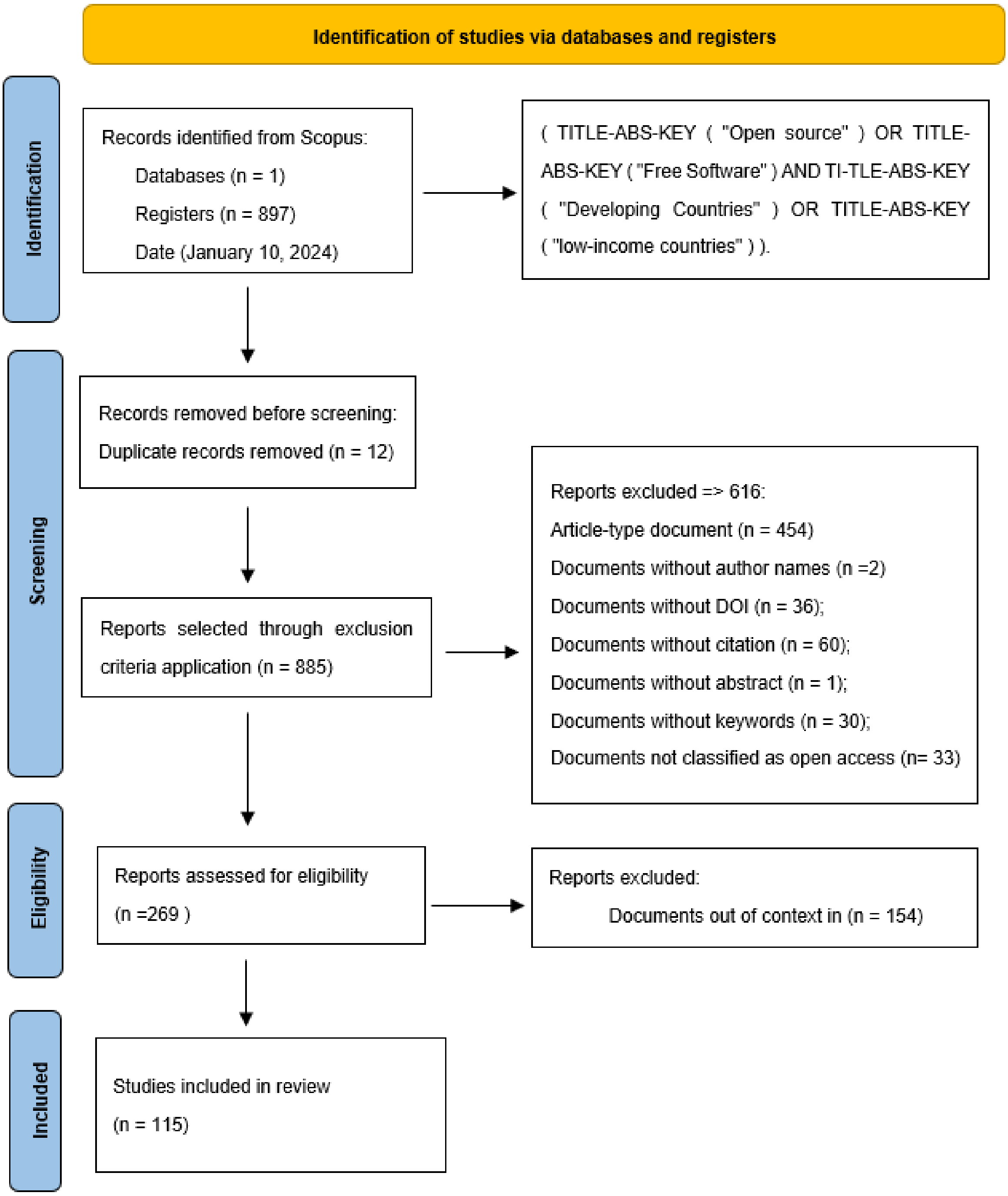


Figure 2.1: PRISMA flow diagram

2.3. Results and Analysis

In this section, the results of the bibliometric analysis and the systematic review of the literature are presented and discussed separately. First, the results of the bibliometric analysis are discussed, followed by the discussion of the systematic review.

2.3.1. Results of the Bibliometric Analysis

The results of the bibliometric analysis provided significant insights into the trends in scientific production related to FOSS. To this end, an in-depth analysis was carried out using bibliometric techniques of citation of "document" and "author". In practice, this technique quantifies the number of citations that the items, which can be (e.g., documents, author, country, institution, or keyword), receive to estimate their degree of relevance and impact on scientific production. In addition, the authors analysed the co-occurrence of keywords to explore the main search streams of FOSS literature in developing and low-income countries (Donthu et al., 2021).

From this analysis, the items are represented in network graphs composed of a set of clusters. Typically, clusters consist of several items/nodes of interconnected networks, which may present variable sizes proportional to the number of times they are cited in the analyzed literature, allowing inferring the relative importance of each identified thematic area. Some of them are close or even connected in a cluster, while others are more distant and even have small clusters of their own, so the shorter the distance between nodes, the stronger the strength ratio of this link will be (McAllister et al., 2022). Total Link Strength (T.L. strength) offered insight into the strength of connections between keywords and clusters (Shen & Wang, 2020).

2.3.1.1. Research Trend and Literature Evolution by Year

To analyse the evolution of FOSS research, Figure 2.2 presents the trend over the years. There was a steady increase in the number of publications from 2001 to 2023, reflecting the growing interest and relevance of the area. However, between 2013 and 2015, there was a drop in production, followed by a slight decrease between 2019 and 2020. In contrast, 2021 saw a significant increase, with 88 articles published, but 2022 and 2023 showed a decrease, with 71 and 84 articles, respectively. These variations can be attributed to a variety of factors, such as changes in research priorities and external influences. Additional studies are needed for a deeper understanding of these trends.

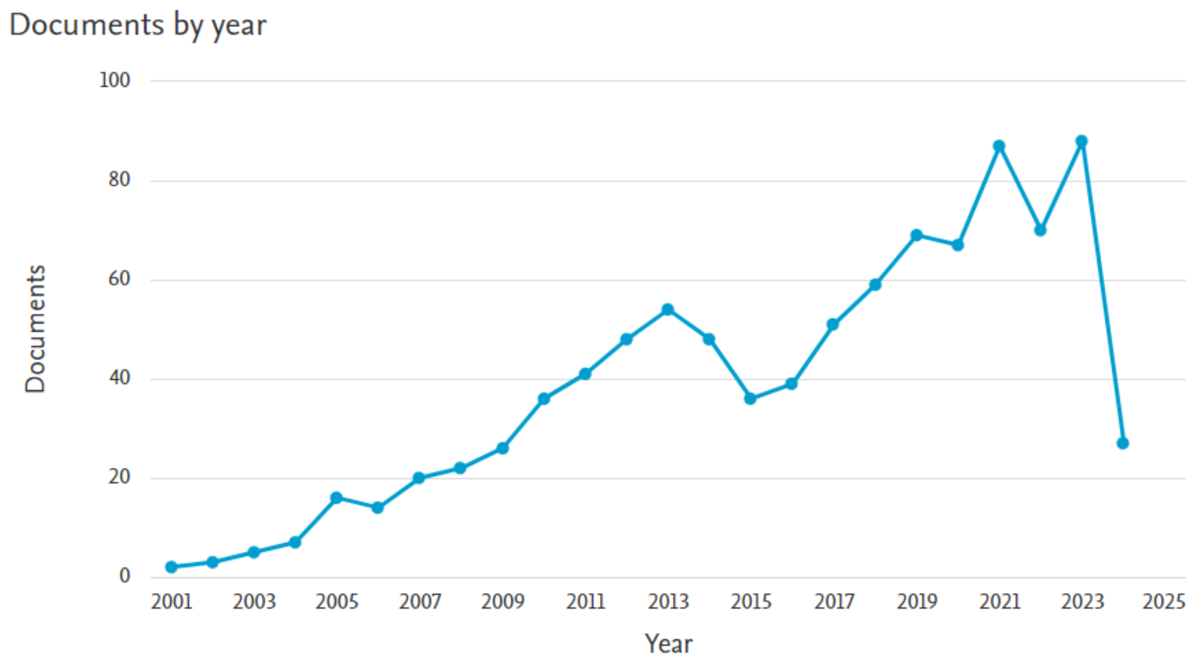


Figure 2.2: Number of publications on FOSS by year (2001-2023)

2.3.1.2. Distribution of Publications by Country

The results of the geographic distribution analysis of this literature are presented in Figure 2.3, revealing the main countries involved in FOSS research. It is noteworthy that the United States leads in volume, with an impressive total of 216 publications and 5126 citations received. Next comes India, with 95 publications and 1395 citations, demonstrating significant involvement in this field. Surprisingly, despite having fewer publications than India, the UK received a relatively higher number of citations, totalling 1457.

This suggests that the research carried out in the UK has a considerable impact and is widely recognized by the academic community. In addition to these countries, others such as Italy, Germany, South Africa, Canada, Spain, Australia, and Brazil also contributed with a considerable representation, ranging from 29 to 42 articles published in the period analysed. Notably, when examining the ten most productive countries in this field, we note that India stands out as the most active developing and low-income country in FOSS research, followed closely by South Africa and Brazil. This geographical distribution underscores the global and collaborative nature of FOSS research and highlights the significant impact these countries are having in this area of study.

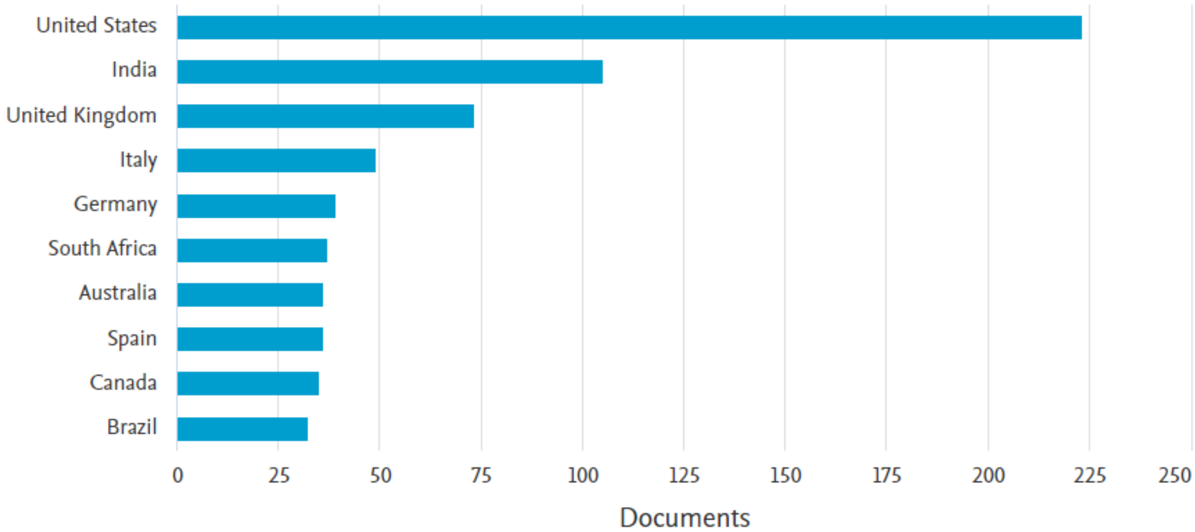


Figure 2.3: Distribution of publications by country

2.3.1.3. Main Research Areas

Scientific production on FOSS from the perspective of developing countries, including low-income countries, has expanded across several areas of knowledge, reflecting the broad impact and versatility of FOSS. The results show that Computer Science continues to be the most representative area, covering 23.2% of research, which highlights the importance of FOSS in technological advancement and innovation in these countries. Engineering also stands out, with 13.6% of the studies, evidencing the strong interest of researchers in exploring the practical and technical applications of FOSS. In addition to traditional areas, the results indicate that FOSS has spread to interdisciplinary fields, such as the Social Sciences, which correspond to 12.5% of publications. This suggests a growing interest in investigating the social, economic, and cultural impacts of FOSS, especially in development contexts.

Medicine, representing 9.6% of the studies, underlines the relevance of FOSS in health, both for the development of accessible tools and for addressing specific challenges in low-income countries. These data, illustrated in Figure 2.4, reveal the diversification of FOSS in emerging domains, expanding its influence and applicability in different sectors.

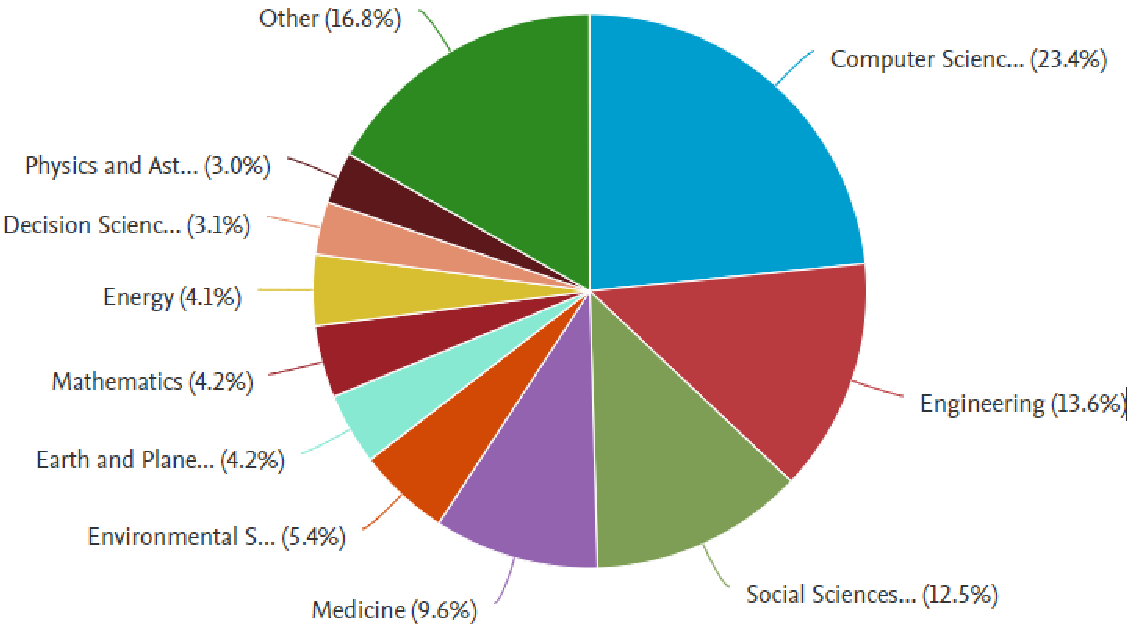


Figure 2.4: Documents by subject area

2.3.1.4. Analysis of Citations by Documents

Table 2.2 briefly presents the ranking of the ten most influential articles/documents in the literature under Analysis. The result reveals a higher number of citations to the article (Dewan et al., 2019), published in the year (2019), making it the most influential article, with 827 citations over time. Other essential articles were (H. Wang et al., 2016) and (Koh & Wich, 2012), which also received a significant number of citations, with 444 and 437, respectively. In addition, articles such as those by (Stoet, 2010) and (Kogut, 2001) received a relatively low number of citations, with 388 and 308, respectively.

Table 2.2: Top 10 influential articles in FOSS literature

Items	Citations	Year	DOI
Documents	827	2019	10.3171/2017.10.JNS17352
	444	2016	10.1016/S2352-3018(16)30087-X
	437	2012	10.1177/194008291200500202
	388	2010	10.3758/BRM.42.4.1096
	308	2001	10.1093/oxrep/17.2.248
	216	2017	10.1016/j.rse.2017.03.015
	206	2011	10.1371/journal.pone.0023783
	205	2014	10.1016/j.jclepro.2014.02.009
	137	2015	10.1002/aur.1575
	130	2014	10.1016/j.solmat.2014.08.008

2.3.1.5. Analysis of Citations by Author

Table 2.3 lists the ten authors who stood out the most regarding publications. According to the results, Ghosh R.A. leads the list of the most influential authors with three published documents and 34 citations. Next, we have Igira F.T., Rafiq M., and Doctor G.; Ramachandran S., each with two published documents and 31, 23, and 19 citations, respectively. However, there are other authors with two published documents but with a very limited number of citations, such as Amrollahi A., Khansari M., and Manian A., but they stand out for having a T.L. strength of 2.

Table 2.3: Top 10 influential authors in FOSS literature

Authors	Doc.	Citations	TL Strength	DOI
Ghosh R.A.	3	34	0	10.5210/fm.v8i12.1103
Igira F.T.	2	31	0	10.1057/palgrave.jit.2000132
Rafiq M.	2	23	0	10.1016/j.iilr.2009.07.001
Doctor G.; Ramachandran S.	2	19	0	10.1109/ICALT.2007.138
Sipitakiat A.; Blikstein P.	2	8	0	10.1145/1709886.1709931
Ridwan S.B.; Ferdous H.S.; Ahmed S.I.	2	7	0	10.1007/978-3-642-33944-8_12
Meetoo-Appavoo A.; Chutoo A.; Appavoo P.; Durgahee B.	2	5	0	10.1109/MTS.2013.2276671
Parry D.; Parry E.; Dorji P.; Stone P.	2	4	0	10.4018/jhisi.2008070101
amrollahi a.; khansari m.; manian a.	2	3	2	10.4018/978-1-5225-2262-1.ch003
chavez a.; kovarik c.	2	3	0	10.4018/ijossp.2014010103

2.3.1.6. Co-occurrence of Keywords

Continuing the analysis, we sought to identify patterns and trends in the area using citation indicators. These tools allow you to measure the thematic similarity between documents, offering a more in-depth understanding of the structure and themes prevalent in this ever-evolving field. The minimum number of citations was set at 20 citations to focus essentially on the most influential words, which resulted in the identification of 30 keywords grouped into four clusters. cluster 1 (represented by red) is the largest, containing 14 keywords. Cluster 2 (green) includes nine keywords, cluster 3 (blue) contains four keywords, and cluster 4 (yellow) contains three keywords. The clusters are related through the thematic similarity of their items, as shown in Figure 2.5.

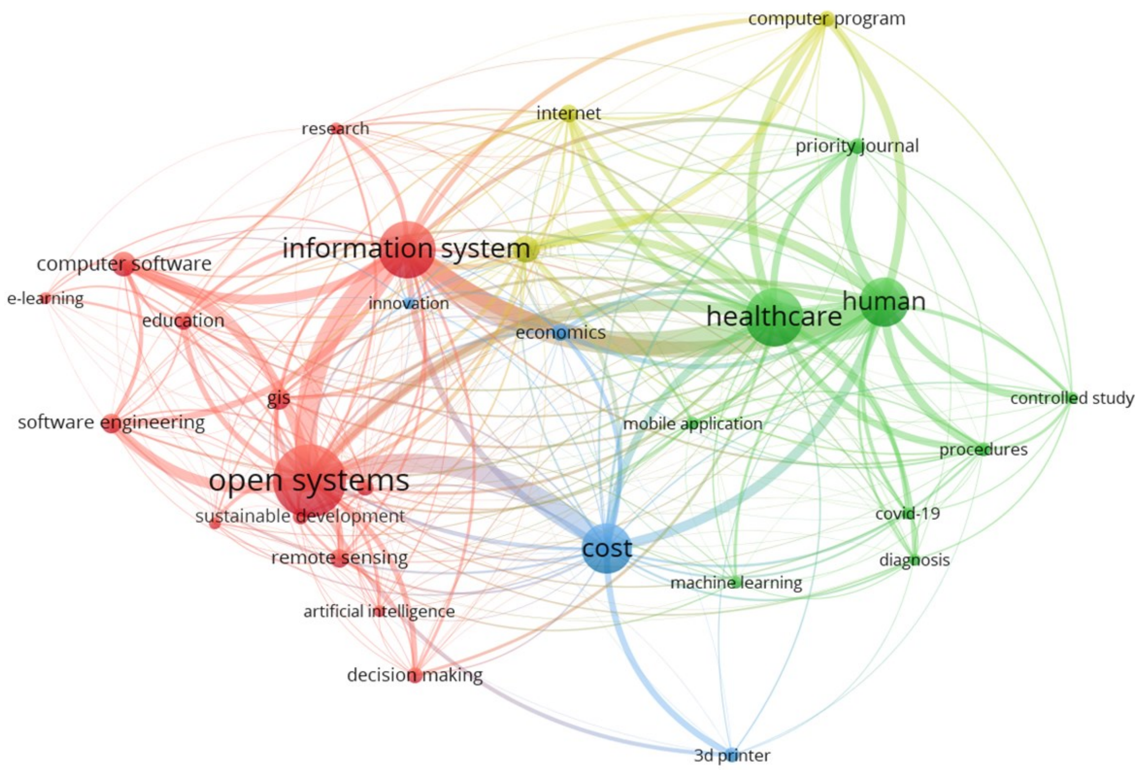


Figure 2.5: Analysis of co-occurrence of keywords

The results revealed that the keyword "open systems" was the most recurrent, with 216 occurrences and a total binding force of 380, indicating that it is widely used and has great importance around the FOSS. This suggests that the study and development of open systems are central and relevant themes in this field. Secondly, the keyword "health" stood out, with 160 occurrences and a total binding force 424. This indicates that the healthcare sector is a prominent research topic, significantly focusing on health-related studies. The cost had 134 citations and a total binding strength of 256. This indicates that the topic of costs, especially concerning FOSS, is relevant and addressed in the research. Other words like "information system" and "human" are also an area of interest and investigation, each with 156 and 129 occurrences, respectively.

Figure 2.6 shows, which details the items that make up the previously identified clusters. This is intended to provide a thorough overview of the most prominent topic areas, highlighting the keywords and their frequency in each cluster. This in-depth analysis allows us to better understand the trends and patterns emerging in the field, providing valuable insights to guide future research and practice on the topic.

cluster	*items*	*TLS*	*Occurrences*	*Main areas of research*
1	cost	45	127**	Low-cost technology and applied engineering
	internet of things	8	16	
	robotics	11	16	
	engineering education	11	15	
	agricultural technology	7	13	
	hardware	11	13	
	manufacture	6	11	
2	information system	74	125***	Information Science and Digital Technology
	digital libraries	10	15	
	digital storage	8	13	
	digital divide	6	11	
	mobile devices	8	11	
3	teaching	17	18	Information Technology Education
	computer operating systems	9	14	
	societies and institutions	10	13	
4	healthcare	66	143*	health technology and interoperability of information systems
	interoperability	6	10	

Figure 2.6: Key words in the clusters

Figure 2.6, highlights the most frequent keywords in each of the clusters, indicating the number of citations of each and the T.L. Strength. The results suggest that the keywords of Cluster 1 fit into searches related to areas such as low-cost technology, applied engineering, and the Internet of Things (IoT) play significant roles in the context of FOSS. This is due to the continuous search for accessible and open-source solutions that promote accessibility and digital inclusion, in line with FOSS principles. In addition, the second cluster, focused on information systems and digital technology, further reinforces the relevance of FOSS. In this sphere, FOSS plays a key role in building digital infrastructure, including digital libraries and storage systems, while contributing to bridging the digital divide by increasing accessibility and inclusion for marginalized communities.

Similarly, the third cluster, related to information technology education, highlights the importance of FOSS in the training of IT professionals. Utilizing open-source operating systems and engaging with open-source communities not only empowers students with practical skills, but also fosters values of collaboration and knowledge sharing, which are fundamental in the FOSS universe.

Similarly, the fourth cluster, focused on technological health and interoperability of information systems, highlights the potential of FOSS in healthcare. Thus, therefore, open-source solutions not only reduce the costs associated with medical technology but also facilitate interoperability between different systems, enabling the efficient exchange of information and improving the quality of healthcare.

2.3.1.7. Thematic Evolution

Subsequently, the next step was to analyse the thematic evolution. The color of the nodes on the map indicates the average year of publication of the articles in which the term occurs, with the most recent ones displayed in yellow. In this way, the map offers a clear view of the areas of research in FOSS that have gained prominence in recent years. Notably, terms such as "IoT", "machine learning" and "deep learning" appear in yellow, indicating that these emerging technologies have been increasingly explored in the context of FOSS, as well as growing concern about sustainability and the adoption of renewable energy. This suggests that these areas have been a source of innovation and opportunity for the development of innovative and sustainable solutions, with the potential to drive progress in different sectors and promote digital inclusion in low-income countries. In addition, the term "covid-19" also appears in yellow, indicating the importance of FOSS in contexts of collaboration and response to the global crisis.

It is interesting to note that these emerging terms are portrayed exactly in the FOSS literature, within developing countries, in the period of 2021, during which there was a significant increase in the number of publications on the FOSS theme, as identified in Figure 2.7. This observation suggests a link between the growth of interest in FOSS and the emergence of these new technology-related research topics. Therefore, these results may be useful to direct future research on FOSS and identify promising application areas.

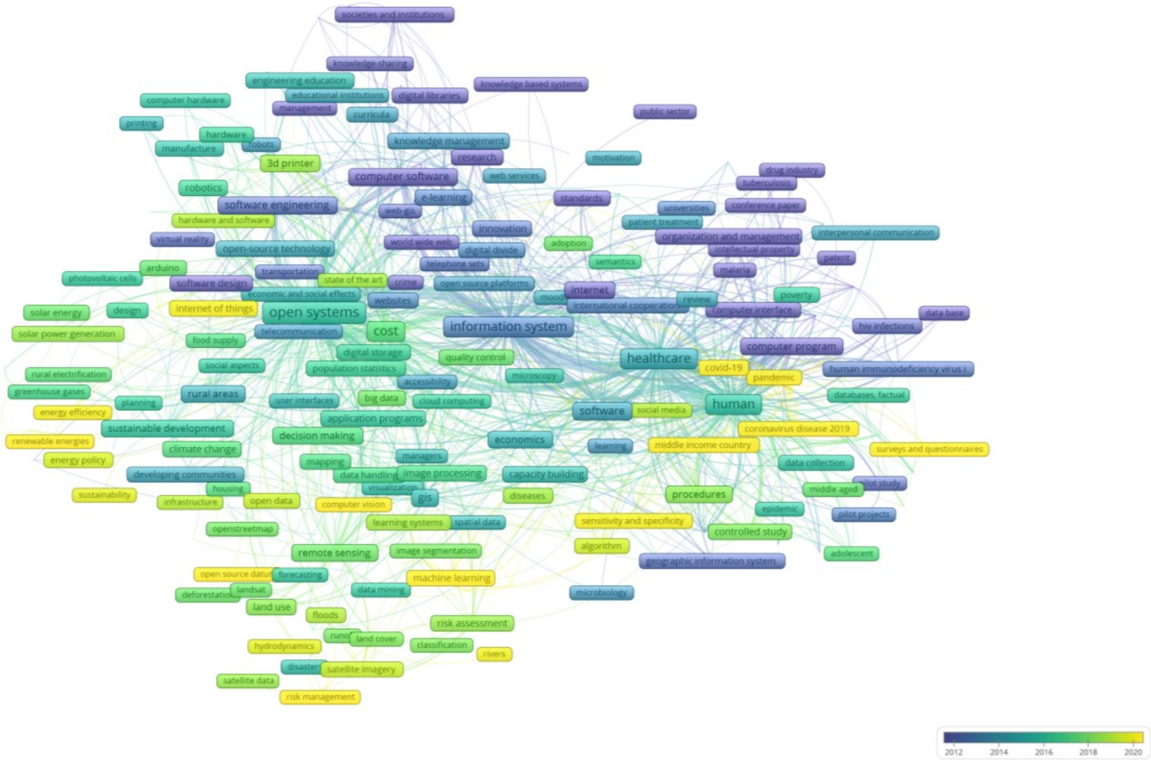


Figure 2.7: Thematic evolution based on keyword co-occurrences

2.3.2. Results of the literature Review

This section presents the results of the literature review, conducted in accordance with the PRISMA guidelines. Of a total of 17 keywords identified in the literature, "Health" stood out as the most recurrent, registering 143* occurrences and a total binding strength of 66. This finding highlights the relevance of FOSS in this crucial area, highlighting the value placed on open systems research and development for health. This trend is confirmed in several studies emphasizing the effectiveness and adaptability of FOSS in healthcare settings. For instance, in a study conducted by (Nsaghurwe et al., 2021), the successful integration of Tanzania's vertical health information system with the aid of an interoperability layer, involving both proprietary and open-source tools, was described. The authors highlighted the importance of interoperability and the use of open technologies to improve data exchange and the efficiency of health systems. In other research, (Bonnet et al., 2017) addressed the development of electronic disease surveillance systems in low-income countries, highlighting the crucial role of open-source systems in the collection and transmission of real-time health data, especially in resource-constrained settings.

Similarly, in (Spencer, 2013), open-source data on avian influenza were explored to understand the transition and spread of infectious diseases in developing countries, using the Kuznets curve as an analytical tool. Another relevant contribution was presented by (Tsala-Mbala et al., 2022), who proposed an open-source methodology to transform plastic waste into paving blocks, highlighting the importance of open innovation and low-cost solutions to solve public health problems such as waste management. In addition, (Vivas Fernández et al., 2020) described the development of a low-cost, multifunctional lung ventilator, called ResUHUrge, utilizing open-source hardware and software, underscoring the importance of collaboration and resource sharing in creating affordable solutions to address health challenges.

Another significant presence was the keyword "cost", mentioned 127** times, with a total binding force of 45, reflecting the considerable attention given to FOSS, especially in relation to financial aspects. This indicates their substantial relevance to the economic and financial viability of software projects, highlighting their critical influence on strategic decision-making and their role in the sustainability and success of technology-related initiatives. Studies such as those by (Buitenhuis & Pearce, 2012; Wittbrodt & Pearce, 2017) illustrate how FOSS can facilitate access to technological solutions in resource-constrained contexts, such as developing countries, through its ability to reduce costs. (Wittbrodt & Pearce, 2017) assessed the value of RepRap as an entry-level 3D printer in developing countries, proposing a low-cost photovoltaic (PV) support solution for these regions. In turn, (Buitenhuis & Pearce, 2012) examined how the development of FOSS could catalyze rapid innovation in the photovoltaic (PV) industry by identifying business models that would enable accelerating access to solar energy worldwide.

In addition, the analysis also revealed the importance of the information systems component related to FOSS. The keyword "information system" was mentioned 82*** times, with a total binding strength of 36. Studies such as those by (Sheikhtaheri et al., 2022) have highlighted the implementation of a technical and architectural infrastructure for a real-time surveillance system based on electronic health records for COVID-19, demonstrating the relevance of FOSS in this context. (Schweik et al., 2009) also contributed to the understanding of the importance of FOSS by offering introductory online courses on geographic information systems (GIS) using FOSS, evidencing its applicability in different areas, including health. These studies, along with those mentioned earlier, demonstrate the variety of ways in which FOSS is being utilized and its relevance in promoting innovative and affordable solutions to various challenges in this industry.

2.4. Discussion and Future Work

The purpose of this analysis was to conduct a comprehensive review of the literature on FOSS, with a specific focus on developing countries, to guide future research and offer crucial insights for the continued understanding of this ever-evolving domain. In this section, we cover the results and key findings identified in the survey, highlighting significant trends and implications related to FOSS and its role in promoting digitalization.

The corresponding results are in line with previous research that has observed a notable growth in the output of FOSS-related research over time (Piotrowski & Marzec, 2023) albeit with a slight decrease observed in 2020, possibly due to the impacts of the COVID-19 pandemic, as evidenced in studies from other disciplines (Alkan & Şahinoğlu, 2023; M. Xiao et al., 2023) Therefore, it is plausible that this temporary interruption in research production can be attributed to the restrictions and challenges faced during the pandemic, temporarily affecting the pace of academic and research activities.

In addition, convergence was also evidenced in the analysis of the distribution of scientific production among countries (Ariza & Pearce, 2022) where developing nations also emerged, in a very limited way in terms of scientific production compared to industrialized countries, a trend commonly observed in the scientific literature (Garcia et al., 2021; D. Silva et al., 2019) These findings corroborate the response to **RQ1**, highlighting the United States as an important contributor to the body of knowledge on FOSS, leading in terms of a significant number of publications.

The analysis of trends over the study period also revealed an increase in discussions related to areas such as healthcare, cost, and information systems. This thematic diversification reflects the growing relevance of FOSS in different domains, indicating the potential to develop innovative and sustainable solutions that can improve the quality of life and drive development in low-income countries. Previous research, such as the study conducted by (Ariza & Pearce, 2022) corroborates this importance by reporting how FOSS can reduce costs and promote accessibility and inclusion, especially in healthcare, where the eHealth approach of FOSS is considered a viable solution for underserved areas (Syzdykova et al., 2017).

All this intersection with FOSS offers significant opportunities to expand access to technology and promote digital inclusion in diverse contexts. However, this trend is likely to grow further, as FOSS continues to play a central role in the search for affordable and adaptable technology solutions. Although we observed limitations, such as the predominance of research in industrialized countries, the results contribute significantly to the understanding of the impact of FOSS in promoting digitalization as a catalyst for social change in emerging countries.

Thus, it is hoped that these results will stimulate collaborative efforts and future research in the field of FOSS, the authors suggest further research in various areas to advance the understanding and maximize the potential of FOSS. These emerging directions can guide researchers and practitioners interested in exploring new opportunities and solving challenges related to FOSS may include integration with emerging technologies, enhancement of information systems, technology education, governance and sustainability, security and privacy, and interoperability.

1. Integration with Emerging Technologies: As emerging technologies continue to shape the digital landscape; it is essential to explore how FOSS can integrate and interact with these technologies. Future research may investigate how FOSS can harness the potential of artificial intelligence, blockchain, augmented reality, and other emerging technologies to drive innovation in a variety of industries.
2. Information Systems Enhancement: FOSS-based information systems play a crucial role in many contexts, from education to healthcare to e-government. Therefore, future research may focus on improving the efficiency, security, and usability of these systems by developing new tools, practices, and governance models.
3. Technology Education: Empowering individuals with FOSS skills are critical to promoting its adoption and effective use. Therefore, future research can explore innovative technology education strategies that encourage knowledge and utilization of FOSS in educational, professional, and community settings.
4. Governance and Sustainability: FOSS projects rely on active community participation and effective governance models to ensure their long-term viability. Thus, future research can focus on the development and analysis of governance and sustainability models for FOSS projects, with a view to ensuring their continuity and success.
5. Security and Privacy: Security and privacy issues are crucial to user trust and data protection in FOSS systems. Therefore, future research can explore strategies and tools to ensure the security and privacy of FOSS systems, addressing concerns related to data integrity, security vulnerabilities, and regulatory compliance.
6. Interoperability: Interoperability between different systems and platforms is essential to ensure the effectiveness and usefulness of FOSS-based solutions in increasingly interconnected digital environments. Therefore, future research may focus on the development of standards, protocols, and tools to facilitate interoperability between FOSS systems and other proprietary or disparate standards-based systems.

2.5. Conclusions

The goal of this study was to assess the literature on FOSS to identify the key trends in scientific research in this topic and to propose new research directions. The Scopus database was used to choose 897 papers published between 2001 and 2023 for this study. This study offers light on an understudied subject by concentrating on low-income countries, enhancing understanding of the influence of FOSS in difficult situations. According to the findings of this study, FOSS plays an important role in encouraging sustainability. FOSS software solutions could empower local communities by lowering dependency on proprietary solutions and fostering technological self-sufficiency. At the highest concentration of research, the United States was one of the nations that contributed the most in terms of publications, while India, followed by South Africa and Brazil, led in emerging and low-cost countries. Authors like Ghosh R.A., Igira F.T., and Rafiq M. were among the most cited, with 34, 31, and 23 citations, respectively Table 2.3.

Furthermore, keyword co-occurrence analysis revealed the existence of thematic clusters such as "TechSolutions for Rural Development", "HealthTech Advancements to Empower Diagnosis and Care", "Innovative Cost Economics and 3D Printing Revolution" and "Infrastructure Technology", demonstrating that FOSS contributes to significant advances in vital areas such as health, economics, and rural development.

The findings also indicate an increasing synergy between FOSS and new technologies. Terms like "IoT," "machine learning," and "deep learning" have gained importance, implying that these developments should be investigated in the context of FOSS. This confluence could provide new and sustainable solutions that have the potential to improve quality of life and accelerate development in low-income countries.

Despite its own limitations, this research underscores the importance of expanding the research to a more complete understanding of the impact of FOSS, particularly in emerging and low-cost countries. This expansion can contribute to a better understanding of the impact of FOSS, legitimizing it as a driving factor for good changes and making new methodological and theoretical contributions.

In conclusion, this research provided useful insights to academics by showing the importance and potential of FOSS in improving sustainability in low-income countries. In doing so, the research pointed to previously undiscovered areas, providing the groundwork for future research. We expect that our findings will considerably contribute to the current body of knowledge in the FOSS sector and stimulate collaborative efforts for sustainable and innovative solutions.

Chapter 3

Factors Influencing Free and Open-Source Software Adoption in Developing Countries - An Empirical Study

This chapter describes a study in which the determinants of FOSS adoption are analysed. The study contained in this chapter of the thesis was published in a scientific journal (Silva et al., 2023). FOSS is essentially seen by many organizations as a key pillar for accelerating technological innovation. This study aims to evaluate the extent to which factors such as cost and quality of the system, as well as usability, interoperability, and security, influence the intention to use FOSS. Based on the data obtained from the survey, we propose a new theoretical model that we test and evaluate using the SEM-PLS method. The results suggest a significant relationship between FOSS adoption and factors such as low cost, performance expectation, social influence, and system quality, which was explained on a large scale by safety, interoperability, and usability as the most important factors in adoption decisions. Thus, this paper presents a new model for the adoption of FOSS in countries with high growth potential and aims to be a significant contribution to the scientific community on the state of the art in FOSS organizations in developing countries.

3.1. Introduction

FOSS is essentially seen as a key pillar for many public and private sector organizations due to potential benefits that generally include cost reduction, improved security and interoperability, as well as a substantial increase in system quality and ability (Sanchez et al., 2020). Thus, as with many governments (AlMheiri et al., 2018; M. Silic & A. Back, 2017) in developed countries, the authors' motivation is to disruptively disseminate knowledge about FOSS in developing countries as a viable alternative to improve the development of technological solutions and promote innovation and consequently improve their efficiency and productivity levels, especially at a time when digital transformation has become a concept and a path that can lead to many opportunities. Different approaches consider the demands of providing better service in a rapidly changing digital world. FOSS (e.g., Debian GNU/Linux) is generally defined as a type of free available resource, free of licensing fees or other restrictions, giving users complete freedom to perform, copy, distribute, study, edit and improve the software (Kilamo et al., 2020; Raymond, 1999; Thankachan & Moore, 2017).

Many studies agree that FOSS and its lack of licensing fees allows for the faster adoption of technology and accelerates the innovation ecosystem (Umm-e-Laila et al., 2021). Following that, (M. Pezer et al., 2017; Sanchez et al., 2020) assert that the adoption of FOSS has the potential to provide greater contract freedom and supplier independence, as well as to contribute to the creation of the local software industry, allowing for the development of local software that is qualified for the creation of FOSS-based systems, thereby promoting entrepreneurship and, as a result, the local economy. Similarly, (AlMheiri et al., 2018; Patino-Toro et al., 2022) consider FOSS to be a valuable and promising resource for reducing digital exclusion, particularly in developing countries, as well as in less industrialized environments that lack the technological and financial resources to promote innovation and invest in efficient public-sector digital infrastructure.

However, despite the fact that FOSS is widely used in developed countries (Europe and North America) (AlMheiri et al., 2018; Patino-Toro et al., 2022), its acceptance has been an unsustainable journey in the majority of developing countries' public sector organizations.

Thus, the central idea of the article is to assess to what extent factors such as system cost and quality, as well as usability, interoperability, and security, influence the intention to use FOSS. To address this question, the authors propose a theoretical model of FOSS adoption that tests the influence of the aforementioned factors from the perception of ICT managers in the public sector. The research is based on data from questionnaires applied in Angola, an example of a developing country with a low level of literacy regarding FOSS.

The resulting theoretical model was empirically validated using the Structured Equation Model-Partial Least Square (SEM-PLS) method (Ringle et al., 2010). All structures demonstrated satisfactory reliability as well as convergent and discriminatory validity. The findings indicate a positive and significant relationship between FOSS adoption and factors such as low cost, performance expectations, and social influence, as well as system quality, which was explained primarily by system security, interoperability, and usability. The main contribution is the presentation of a theoretical model of FOSS adoption. Furthermore, the study is considered innovative because it investigates and proposes for the first time a theoretical adoption model that reflects the factors that influence FOSS adoption and use in a developing country with significant growth potential, shedding light on a new digital innovation and revolution in the public sector.

3.2. Literature Review and Hypotheses Development

3.2.1. Technology Acceptance Theoretical Background

The adoption of FOSS offers a clear cost reduction for developing countries (Syzdykova et al., 2017a), as well as some other benefits that have motivated several developed countries to consider their adoption (AlMheiri et al., 2018). However, understanding how and why some technological innovations are accepted while others are rejected has been one of the most challenging and recurring issues in the literature of information systems (IS) (Dwivedi et al., 2019, 2020), in which, as a consequence of this phenomenon, a wide variety of complementary theories were proposed to address cognitive concerns, which are emotional and contextual factors inherent in the decision of individuals to accept or reject the adoption of a particular innovation (Rogers et al., 2014; Davis et al., 1989; Venkatesh et al., 2003).

Based on the literature review, the decision-making process or acceptance of an innovation is commonly referred to as a systematic model that begins when an “individual or an organizational unit is exposed to the existence of an innovation that then gains an understanding of how it works (knowledge), starting to form an opinion, regarding the decision to adopt or reject the given innovation” (Rogers et al., 2014). This narrative on the theory of the diffusion of innovation defined innovation as an idea, practice, or object, is not necessarily new, and is only perceived as new by an individual or other unit of adoption. In addition, Rogers considered that the adoption of an innovation depends significantly on the perception of individuals in relation to the potential attributes of it. Innovations or technology products that offer better attributes over relative advantage, compatibility, and lower complexity predict a broader and faster acceptance rate compared to other innovations.

In another theoretical approach, (Davis et al., 1989) sought to establish a theoretical basis to explain and predict how an individual’s perceptions of technological innovation affects their behaviour in relation to the adoption and effective use of technology. Davis, in his theoretical basis, included and tested two specific beliefs that he believed could predict the results of an effective use of technology: The first belief—perceived ease of use, was defined as the “degree to which a person believes that using a given system would be effort-free”. The second belief, perceived utility, was defined as “the degree to which a person believes that the use of a given system would improve their performance at work”.

Similarly, (Venkatesh et al., 2003) also proposed a theoretical basis, derived from an extensive review and synthesis of alternative theoretical models, which has since been widely used by researchers to understand individual adoption and the use of technology. They theorized that the expectation of performance and the expectation of effort and social influence have significant relationships with the intention to use technologies. Recently, a series of studies have used these principles as a theoretical basis to explain the adoption of various technologies in different contexts including mobile payment (Al-Saedi et al., 2019), e-commerce (Haryanti & Subriadi, 2020), and mobile health (Dwivedi et al., 2020).

3.2.2. Factors Affecting the Adoption of Technology

As mentioned earlier, the adoption of FOSS offers several benefits for the organizations and individuals who adopt it (AlMheiri et al., 2018; Syzdykova et al., 2017a). More recently, a growing number of studies have shown that the low cost of acquisition and maintenance (total cost of ownership—TCO) has been one of the main motivators by which organizations adopt FOSS, and not only (Dhir & Dhir, 2017b; Sanchez et al., 2020). The reference (Ajila & Wu, 2007) noted that the cost of FOSS gives organizations an opportunity to experiment and fail quickly without significant financial risk. Thus, many researchers agree that the low cost of FOSS adoption facilitates innovation, and this benefit may be important, especially for developing countries (Patino-Toro et al., 2022). According to (Jokonya et al., 2013), developing countries that do not produce software end up paying for the import of software licenses or resorting to piracy. Therefore, the same study (Jokonya et al., 2013) noted that the low cost of adoption of FOSS is an important driver to avoid legal issues related to software piracy. Another significant and deeply engaging study of the use of ICT in academic institutions conducted by both (D. G. Sooryanarayan et al., 2014) and (M. Pezer et al., 2017), observed that the use of FOSS in the academic context could offer quality and economic solutions which would help the local economy.

In addition to the low-cost factor, the quality of the system was also considered a relevant attribute for the adoption of information systems and, therefore, a widely researched theme. (M. Aparicio & Costa, 2012; Chen & Chengalur-Smith, 2015; Shukla et al., 2021) articulate that the quality of the system has a substantial impact on the assessment of ICT adoption issues. Similarly, (Alrawashdeh et al., 2020) found that the quality of the system influences the behavioural intent of users to adopt FOSS systems. The “system quality” refers to the desired quality of an information system (DeLone & McLean, 2003), and can generally be driven largely by interoperability factors as well as the security and usability of the system (Alwadi et al., 2018).

Traditionally, interoperability is characterized as the ability of one system to process, integrate, and use information on behalf of (or to) another heterogeneous system in a meaningful, safe and effective manner, without any inconvenience to both parties (Jindal et al., 2022; Neinstein et al., 2016). Reports from different industrial areas point to interoperability as a fundamental requirement to improve productivity, transparency and accelerate innovation (Chalyvidis et al., 2016; da Rocha et al., 2020; Jindal et al., 2022; Neinstein et al., 2016).

Interoperability is a fundamental need for flexible ICT and to improve business agility (Leal et al., 2019). For example, with regard to the cloud computing industry (Bouzerzour et al., 2020), the authors addressed the lack of interoperability in cloud environments and highlighted the importance of achieving interoperability to avoid supplier entrapment. Research by (Tshering & Anutariya, 2022) revealed the importance of interoperability in electronic governments. They suggest that an interoperable electronic government system can improve efficiency, accountability, transparency, and gain access to services at minimal cost and reduced capital risk caused by technology or supplier obsolescence.

Interoperability has also been discussed in the health industry. Researchers such as (Adams et al., 2017) considered interoperability as fundamental to improving health care delivery. Results from other studies indicate that interoperability can minimize delayed action in a patient, reduce repetitive examinations, simplify the process of searching for complex information, and reduce medical errors (Hidayat & Hermanto, 2020). The research (Sfakianakis et al., 2007) presented their insights into the impact of FOSS on the interoperability of health information systems. The same authors noted that FOSS is a great alternative to investing in interoperability between different technologies and applications. And for this reason, many companies adopt FOSS to face the challenges related to convergence blockades. FOSS contributes to interoperability, ensuring that data and systems can be interpreted independently of the tools that generated them (Lundell et al., 2022).

Safety is also a key predictor for assessing the quality level of a system and therefore its acceptance. The authors (Alharbi et al., 2017) investigated the impact of security on the adoption of electronic government. The findings also reveal that the safety perception of individuals has a significant impact. Furthermore, the authors (Umbas et al., 2022; Amron et al., 2022) found that safety perception significantly influences the acceptability of ICT use. This is similar to the study (Tomić et al., 2022) that found that factors such as transaction security have a positive impact on the user's intention to accept electronic payment systems. According to the results of the studies, it is concluded that people prioritize the safest systems. People will not use unsafe systems.

Several studies also consider usability as an important system quality attribute that affects the adoption of information systems (Berendes et al., 2022; Llerena et al., 2019; Sagar & Saha, 2017). According to (ISO/IEC, 2001), usability concerns the ability in which a software product can be understood, learned, used effectively and efficiently in a specified usage context. Usability tests have led to some research sensitivity. In the research (Dawood et al., 2019), usability refers to software sustainability. The same authors found that the usability of the system influences the acceptance of users to adopt an information system, as well as its sustainability. The authors (Darmawan et al., 2021), in their study, found that the system usability was an important factor for the successful implementation of the Smart Regency Mobile-Apps application. Another interesting study on usability was conducted by (van der Nat et al., 2022). The authors tested patient-centred usability and found that the adoption of a personal health record (PHR) depends on its usability.

3.2.3. Research Model Proposal

Figure 3.1 describes the proposed conceptual model and combines several constructs/factors to increase the explanatory power regarding the intention to use FOSS systems, namely: behavioural intentions (BI), performance expectation (PExp), effort expectation (EExp), and social influence (SI) which were adapted from (Venkatesh et al., 2003), while system quality (SysQual), security, interoperability (Interop) and cost related to work (Alrawashdeh et al., 2020) as well as usability (Usab) (J. W. Kamau & Sanders, 2013).

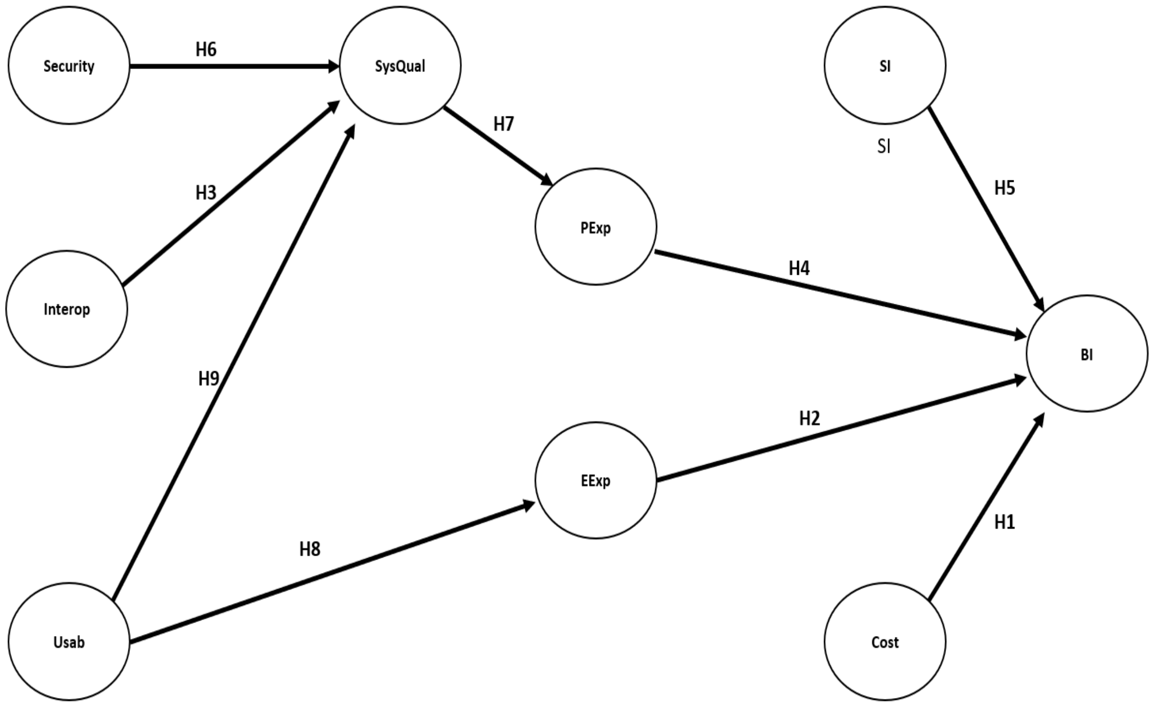


Figure 3.1: Research Model

According to the literature review, these factors are widely used in exploratory research on the adoption of information systems, and are recognized as an adequate, valid, recent, and reliable theoretical model. This model stands out for its ability to explain a high percentage of variance (R^2) in behavioral intent (Hoque & Sorwar, 2017; Kalavani et al., 2018; H. Wang et al., 2020). Studies by (Alrawashdeh et al., 2020; Dawood et al., 2019; Safadi et al., 2015) confirm the importance of these factors to improve the perception and sustainability of FOSS. Table 3.1 presents the references and defines the constructs.

Table 3.1: Model Constructs definition

Constructs	Concepts	Reference
Behavioural Intentions (BI)	Degree to which an individual associates with the impact of using the system on his or her work.	(Venkatesh et al., 2003)
Performance Expectation (PExp)	Degree to which an individual believes that using the system will help him/her make gains in his/her job performance.	
Effort Expectation (EExp)	Degree of effort or ease associated with using a system.	
Social Influence (SI)	Degree to which an individual perceives those significant others believe that he or she should use the new system.	
Cost	Degree to which an individual perceives the benefits of using a system, even if it has a monetary cost associated with it.	(Alrawashdeh et al., 2020)
Interoperability (Intero)	Degree to which a system reveals that it could openly exchange information with systems.	
Security	Degree to which individuals and organizations believe in software security.	
System Quality (SysQual)	Degree that a system discloses having desirable product characteristics, such as availability, reliability, performance, usability, and functionality.	
Usability (Usab)	Degree to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.	(J. W. Kamau & Sanders, 2013)

Previous research has established a link between financial strain and propensity to use. The authors of (M. Aparicio & Costa, 2012; J. Kamau & Namuye, 2012) referred to FOSS as having great potential to reduce acquisition (CAPEX) and operation (OPEX) costs, as well as to bridge the innovation difficulty and digital divide at a relatively low cost that would otherwise be significantly difficult to achieve, particularly in developing countries.

For the author of (Smith, 2006), financial hardship is one of the major impediments in the pharmaceutical sector, whereas (Alrawashdeh et al., 2020) demonstrated the importance of financial burdens in FOSS adoption. According to this theoretical paradigm (Bhatiasevi & Krairit, 2013), FOSS is a good stimulus for innovation because its software maintenance costs are relatively low when compared to proprietary software.

According to the present research, if the benefits of adopting FOSS systems and technologies are judged to be larger than the financial cost associated with their adoption, potential decision makers will be more inclined to accept it.

The following hypotheses are proposed by the theoretical model:

Hypothesis 1 (H1). Cost has a positive effect on behavioural intention to utilize FOSS.

In the framework of this research, it is assumed that the individual believes that using FOSS systems and technology will be simple, understandable, and effortless (Venkatesh et al., 2003). This construct is seen as critical in predicting behavioural intention, particularly in first contacts with a technology, because the perceived ease of use of that technology has a significant impact on the belief/behaviour of accepting to use the system/technology (Cimperman et al., 2016).

For users to agree to utilize a FOSS technology system, it must first be helpful and then simple to use. Potential users in the healthcare sector, for example, are likely to have little or no expertise with ICT. As a result, individuals may be frustrated early on due to a lack of official assistance and training (Bhatiasevi & Krairit, 2013). As a result, we can make the case that the technology that demands the least amount of effort will most likely be selected by users with the least amount of experience (Davis et al., 1989; Venkatesh et al., 2003).

Given the considerations presented above, the theoretical model proposes the following hypothesis:

Hypothesis 2 (H2). Expectation of effort influences behavioural intention to utilize FOSS.

The capacity of two or more software components to communicate despite variations in language, interface, and execution platform is referred to as interoperability (Wegner, 1996). In the context of the study, it refers to the degree to which an individual believes that by using FOSS, they will be able to interact with other external systems and store their documents in various formats, thereby promoting interoperability and establishing links between service providers and researchers (Muinga et al., 2018). When researching the function of FOSS in the interoperability of health information systems, (Sfakianakis et al., 2007), when studying the role of FOSS in the interoperability of health information systems (eHealth), took a different approach to this feature (eHealth). According to their findings, FOSS is the primary enabler of interoperability in eHealth.

Interoperability in the context of FOSS system acceptance has the potential to improve system quality and patient safety, safeguard against data loss, and improve care efficiency (Neinstein et al., 2016).

As a result, the theoretical model suggests the following hypothesis:

Hypothesis 3 (H3). Interoperability has a positive effect on system perceived quality.

Performance Expectancy is defined here as the degree to which an individual believes that utilizing FOSS would be beneficial in meeting operational goals and improving job performance. Previous research in various adoption situations (Ahmed et al., 2020; Zhou et al., 2019) revealed that performance expectancy has substantial predictive power about technology usage intention.

According to Davis (Davis et al., 1989), the degree to which an individual believes that using a given system will assist him in his work will contribute greatly to the system's acceptance. Following this reasoning, it is argued that the adoption of technologies seen as favourable (with high quality, security, stability, flexibility, low acquisition cost, and no vendor lock-in) as FOSS is considered, will necessarily lead to faster adoption (Gwebu & Wang, 2011).

In the context of this research, an example of this construct is when an individual realizes that using FOSS systems and technology, for example, would be useful to them, as well as more efficient in terms of productivity and speed in performing his tasks, and would allow them to enter the digital age much more easily with the desired outcome and services. As a result, the theoretical model suggests the following hypothesis:

Hypothesis 4 (H4). Performance expectancy has a positive effect on behavioural intention to use FOSS.

Social influence is assumed to be the degree to which the individual perceives that important people in his social/corporate environment, believe that it would be important for him/her to use the system in question to obtain better results. These people influence them toward the behavioural intention to use the technology.

According to preliminary UTAUT research (Venkatesh et al., 2003), social impact in the process of accepting new technologies is defined as a relevant predictor of the desire to use the system, especially in contexts where adoption is mandatory. In contrast, in voluntary use situations, social influence simply influences the perception of the system but has no substantial impact on its use. Several researchers on the usage of health-related technology have found that social influence has a considerable predictive value when it comes to using linked devices for health requirements. (H. Wang et al., 2020). In this case, the individual's use of technology is stimulated by the opinions of people close to or associated with reference groups (colleagues, managers, and other mechanisms), which increases the individual's intention to use the technology, making social influence an equally important construct in our choice for determining the acceptance of new technologies.

Given the considerations presented above, the theoretical model proposes the following hypothesis:

Hypothesis 5 (H5). Social influence has a positive impact on behavioural intention to use FOSS.

The perceived security of technology refers to how much trust companies and consumers have in the software's security. Unlike the traditional paradigm (referred to as "closed source"), FOSS is openly published and, through Freedom 1—free access to the source code, allows users to study and adapt to their operational needs (Marsan & Paré, 2013), as well as report vulnerabilities and propose complementary software improvements (Barcomb et al., 2019).

In their investigations, the authors of (Hansen et al., 2002; Raymond, 1999) concluded that FOSS has much greater levels of security than "proprietary and commercial software", since the source is available and is evaluated by more individuals. Access to the source code enables FOSS researchers, developers, and advocates to enhance the degree of security due diligence far more quickly than proprietary systems, as argued in (Raymond, 1999).

According to (Witten et al., 2001), having source code available generally benefits system security. Despite FOSS's technological supremacy, several studies contend that this development paradigm (open standards) offers a number of security issues for organizations (Crain, 2017). Similarly, access to the FOSS source code gives hackers and other stakeholders greater analytical power to attack software vulnerabilities (Cowan, 2003; Schryen & Rich, 2010).

As a result, it is stated that the perception of safety has a vital impact and can potentially increase the system's quality.

Hypothesis 6 (H6). Security has a positive impact on the system's perceived quality.

The quality of the system is another essential criterion that stands out significantly in the adoption literature. System quality is defined by DeLone and McLean (DeLone & McLean, 2003) as the total performance index of a system as evaluated by potential users. For this study, it is defined as a desirable feature of a FOSS system from the perspective of a potential user, often evaluated along the dimensions of system security, usability, and interoperability.

According to (Ajila & Wu, 2007; Wahyudin et al., 2008), certain FOSS projects have quality levels comparable to "proprietary and commercial software" development. Similarly, (Alrawashdeh et al., 2020) discovered a substantial association between system quality and FOSS component use. That is, the authors believe that the intention to utilize FOSS has explanatory value in this dimension.

According to (Chen & Chengalur-Smith, 2015; Costa et al., 2016), system quality substantially impacts evaluating ICT adoption issues. This data suggests that system quality will influence an individual's pleasure through the system performance expectation. As a result, we propose the following hypothesis:

Hypothesis 7 (H7). Quality of the system has a positive impact on performance expectation.

The authors of (Dawood et al., 2019) investigated the effect of usability on systems. The same authors concluded that usability is one of the most important factors influencing user acceptability and longevity of FOSS.

Usability is an important feature in software that has been characterized in terms of effectiveness, efficiency, and satisfaction in a specific context of usage (ISO 9241-11:2018, n.d.). In technological acceptance models, e.g., (Venkatesh et al., 2003) and the information success model, usability is a desirable attribute (DeLone & McLean, 2003). Despite FOSS's popularity, usability issues have received insufficient attention (Dawood et al., 2019).

Despite the popularity of FOSS, usability issues do not appear to have received adequate attention (J. W. Kamau & Sanders, 2013).

Keeping this in mind, we propose the following hypotheses:

Hypothesis 8 (H8). Usability has a positive impact on effort expectations.

Hypothesis 9 (H9). Usability has a positive impact on system quality.

3.3. Structure of the Empirical Study

A preliminary exam was administered to two professors and an information system professional at the outset. Small changes to the level of the questions were made. As seen in Appendix A, previously validated and tested scale items were used:

Participants

As a result, it became a suitable environment to bring together IT professionals and other entities involved in software acquisition processes within public organizations to find acceptance factors and then propose the FOSS acceptance survey model that can be used to develop possible recommendations.

Instrument

The questionnaire was created with tool Google Forms and was distributed electronically to each respondent's WhatsApp and email addresses. The measurement instrument's item development was appropriately adapted from trustworthy scales, validated from past empirical studies, and modified to fit the goal of the current study. The final measurement equipment used to test the structural model is listed in Appendix A.

This questionnaire was divided into four components. Our first section, as proposed by (Lo et al., 2015), helped give the target audience a quick overview of FOSS systems. The purpose was to guarantee that participants understood the fundamental ideas of FOSS (definition and value proposition) and could answer the questionnaire clearly. The questionnaire's second portion was developed to support demographic-type items such as gender, age, job category, years of experience, and academic level. Finally, the third and fourth sections of the questionnaire employed a five-point Likert scale with statements ranging from 1 (strongly disagree) to 5 (strongly agree) based on their FOSS experience and relevant qualities.

It is worthy of note that the questionnaire was only available for two months, from 27 November to the end of January. A total of 262 responses were obtained for the sample. Because this is a convenience sample that is not representative of the population, the results are non-probabilistic and only pertain to the sample. As shown in Table 3.2, the sample comprised 76.7 percent males and 23.3 percent females, with most males aged 31.8 years and females aged 26.4 years. It is also possible to confirm that the professional profile distribution is nearly identical for responders with consulting duties (40.1 percent) and IT support (45 percent), with professional experience ranging from 2.7 years for females to 5.7 years for males.

Table 3.2: Sample characteristics

Population	Male	201	76.7%
	Female	61	23.3%
Age	Male	31.8	
	Female	26.4	
Professional Profile	CIO	2	0.8%
	CEO	5	1.9%
	CTO	1	0.4%
	IT Support	118	45%
	Consultant	105	40.1%
	Software Acquisition	17	6.5%
	Manager	14	5.3%
Years of Experience	Male	5.7	
	Female	2.7	
Instructional level	Technical background	126	48.1%
	Bachelor's degree	98	37.4%
	Post Graduate studies	15	5.7%
	Master's	21	8%
	PhD	2	0.8%

Data Analysis

Subsequently, the SEM-PLS method was used to test and validate the proposed structural model, as defined in Figure 3.1. This method was chosen because it allows the inclusion of reflective and formative measurement models and is widely recommended in the literature as an appropriate approach in the early stages of theoretical development. It is particularly effective for testing and validating exploratory models for the purpose of theory building (Hair et al., 2011; Ringle et al., 2009).

3.4. Results and Discussion

3.4.1. Measurement Model Assessment

To ensure the internal consistency of the dimensions, that is, to validate the reliability of the measurement instrument, which in this study is represented by the research questionnaire, the indicator Cronbach's alpha for internal consistency and Composite Reliability (CR) for indicator correlation, should be more than 0.6 and 0.7, respectively. As indicated in Table 3.3, all indicators have values that are equal to or greater than 0.91, meaning that all items are similarly dependable. Table 3.3 also reports convergent validity using Average Variance Extracted (AVE), with 0.5 being the minimum value as corrected by (Hair et al., 2011).

Table 3.3: Construct reliability and validity

Constructs	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
BI	0.897	0.897	0.936	0.83
Cost	0.932	0.932	0.957	0.88
EExp	0.943	0.96	0.963	0.898
Interop	0.953	0.953	0.977	0.955
PExp	0.933	0.935	0.957	0.882
SI	0.91	0.916	0.943	0.847
Security	0.933	0.933	0.968	0.937
SysQual	0.942	0.942	0.972	0.945

Therefore, the Table 3.3 shows that all items converge and share a high amount of variance, implying that the dimensions explain more than half of the variance of their indicators on average. This consistency demonstrates that the outer loadings of the dimensions have a lot in common when it comes to measuring each of the latent variables (LV). The discriminant validity test findings demonstrate how one dimension is sufficiently distinct from another. As a result, the cross-loadings table (see Appendix B) indicates that the outer loadings of the indicators are greater than all other dimensions' loadings (Gefen & Straub, 2005).

The Fornell-Larcker criterion was also examined. This criterion is typically based on the assumption that a dimension shares more variation with its associated indicators than any other dimension. The criterion compares the AVE's square root with the LV's correlations to accomplish this (Fornell & Larcker, 1981; Hair et al., 2011). This condition is met, as shown in Table 3.4, with all model dimensions verified and the different construct measures being distinct from one another.

Table 3.4: Fornell-Larcker criterion

	BI	Cost	EExp	Interop	PExp	SI	Security	SysQual	Usab
BI	0.911								
Cost	0.786	0.938							
EExp	0.667	0.579	0.947						
Interop	0.776	0.753	0.544	0.977					
PExp	0.817	0.744	0.757	0.632	0.939				
SI	0.714	0.609	0.627	0.5	0.751	0.92			
Security	0.679	0.611	0.464	0.781	0.586	0.462	0.968		
SysQual	0.771	0.714	0.497	0.832	0.624	0.577	0.819	0.972	
Usab	0.665	0.582	0.473	0.806	0.57	0.492	0.804	0.849	0.925

In addition, the Heterotrait-Monotrait (HTMT) criterion was applied to evaluate discriminant validity. According to (Henseler et al., 2015), the HTMT criterion can assume values of 0.8 and 0.9. Based on our results, using thresholds suggested by (Henseler et al., 2015), the HTMT ratio value for all constructs is less than 0.9 >1, indicating the establishment of discriminant validity of the research model (see Table 3.5).

Table 3.5: Heterotrait-monotrait results

	BI	Cost	EExp	Interop	PExp	SI	Security	SysQual	Usab
BI									
Cost	0.859								
EExp	0.716	0.611							
Interop	0.838	0.799	0.57						
PExp	0.893	0.799	0.802	0.672					
SI	0.784	0.658	0.669	0.533	0.808				
Security	0.741	0.655	0.491	0.828	0.629	0.5			
SysQual	0.838	0.762	0.52	0.878	0.665	0.622	0.874		
Usab	0.711	0.613	0.487	0.841	0.599	0.524	0.847	0.89	

3.4.2. Assessment of the Structural Model

Once all dimensions were tested for multicollinearity, we proceeded to study the results of the structural model by calculating the Variance Inflation Factor (VIF). The results were more noticeable and there were no multicollinearity problems since all the VIF obtained were less than 4.266, as shown in Table 3.6, which means that it was well below the threshold of 10 (Diamantopoulos & Siguaw, 2006; Zainodin & Yap, 2013).

Table 3.6: Inner VIF

	BI	Cost	EExp	Interop	PExp	SI	Security	SysQual	Usab
BI									
Cost	2.271								
EExp	2.389								
Interop								3.326	
PExp	4.266								
SI	2.367								
Security								3.301	
SysQual					1				
Usab			1					3.68	

The structural model's quality was evaluated using bootstrapping, a resampling process that uses multiple samples derived from the original dataset. In this scenario, 5000 samples were used to estimate the significance of the correlations between dimensions (path significance) inside the structural mode (Ringle et al., 2009). The results of the bootstrapping technique are illustrated in Figure 3.2.

After the validation of the structural model, the structural routes were examined to validate the hypotheses of the study. The results show that Cost ($\hat{\beta}$ = 0.377, $p < 0.001$), Expectation of Effort ($\hat{\beta}$ = 0.077, $p < 0.10$), Expectation of Performance ($\hat{\beta}$ = 0.345, $p < 0.05$) and Social Influence ($\hat{\beta}$ = 0.176, $p < 0.05$) explain 75.5% of the variance in Behavioral Intention. The Effort Expectation is explained in 22.3% by Usability ($\hat{\beta}$ = 0.473, $p < 0.001$), and the Performance Expectation is explained in 39.0% by the System Quality ($\hat{\beta}$ = 0.624, $p < 0.001$). On the other hand, 80.4% of System Quality is explained by Security ($\hat{\beta}$ = 0.265, $p < 0.001$), Interoperability ($\hat{\beta}$ = 0.322, $p < 0.05$) and Usability ($\hat{\beta}$ = 0.376, $p < 0.001$).

As indicated in Table 3.7, which presents the significance values of the paths (* significant at $p < 0.10$; ** significant at $p < 0.05$; *** significant at $p < 0.001$), the model reveals that all associations have at least a slight predictive influence. Except for Expected Exertion (EExp), the four dependent latent variables explain more than half of the variations. The Behavioral Intention (BI) with $R^2 = 0.756$, the Performance Expectation (PExp) with $R^2 = 0.390$ and the System Quality (SysQual) with $R^2 = 0.804$ present significant values. In addition, the Q^2 indicator, which evaluates the predictive capacity of the model (Geisser & Eddy, 1979; Stone, 1976), was measured. The results show that BI ($Q^2 = 0.708$), EExp ($Q^2 = 0.211$), PExp ($Q^2 = 0.393$) and SysQual ($Q^2 = 0.789$) meet the desired predictive relevance. The Goodness of Fit (GoF) index was also calculated. The GoF is a measure that validates the PLS trajectory model at a global level (Henseler & Sarstedt, 2013), obtained based on the mean of the square root of the stroke and the R^2. Our results indicate that a GoF > 0.3 confirms model validation.

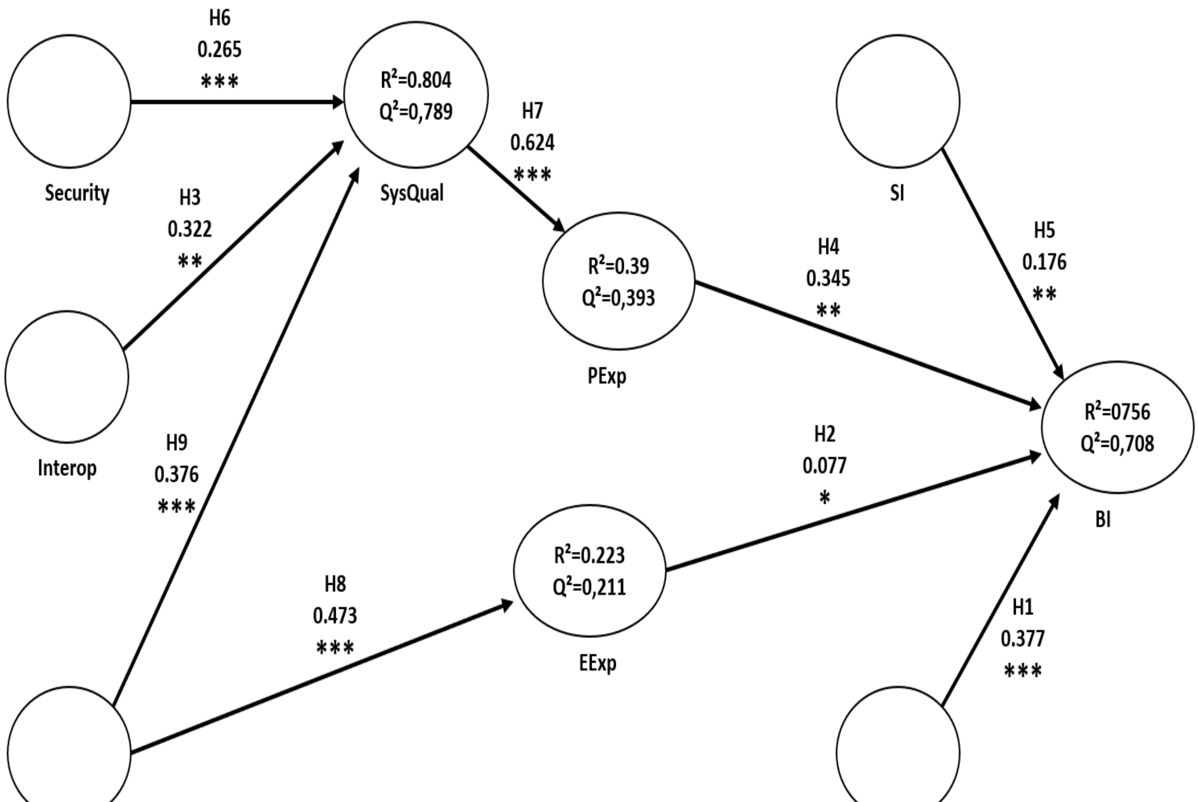


Figure 3.2: Structural model

Path: * significant at $p < 0.10$; ** significant at $p < 0.05$; *** significant at $p < 0.001$.

Table 3.7: Relationships between independent and dependent variables

	Ind. Variable		Dep. Variable	Findings	Conclusion
H1	Cost	->	BI	Positive relationship *** (β = 0.377, p < 0.001)	Supported with large effect
H2	EExp	->	BI	Positive relationship * (β = 0.077, p < 0.10)	Supported with small effect
H3	Interop	->	SysQual	Positive relationship ** (β = 0.322, p < 0.05)	Supported with medium effect
H4	PExp	->	BI	Positive relationship ** (β = 0.345, p < 0.05)	Supported with medium effect
H5	SI	->	BI	Positive relationship ** (β = 0.176, p < 0.05)	Supported with medium effect
H6	Security	->	SysQual	Positive relationship *** (β = 0.265, p < 0.001)	Supported with medium effect
H7	SysQual	->	PExp	Positive relationship *** (β = 0.624, p < 0.001)	Supported with large effect
H8	Usab	->	EExp	Positive relationship *** (β = 0.473, p < 0.001)	Supported with large effect
H9	Usab	->	SysQual	Positive relationship *** (β = 0.376, p < 0.001)	Supported with large effect

Notes: Path Coefficient $\hat{\beta}$: NS = not significant; * significant at p < 0.10; ** significant at p < 0.05; *** significant at p < 0.001. Effect size: >0.350 large; >0.150 and ≤ 0.350 medium; >0.150 and ≤ 0.350 small (Chin, 1998; Cohen, 2013).

Finally, we calculated the size of the f2 effect in relation to the variable exogenous to endogenous ratios, which are frequently supported by the values 0.150 and 0.350, respectively (values > 0.350 represent large effects, values between 0.150 and 0.350 represent medium effects, and values between 0.150 and 0.350 represent small effects).

As shown in Table 3.8, this measure had a significant and favorable influence on all the hypotheses tested.

Table 3.8: Size of the f^2 Effect and Influence on the Hypotheses Tested

Hypothesis		f^2	Effect Size	β^	p Values
H1	Cost -> BI	0.257	Medium	0.377	0
H2	EExp -> BI	0.01	Small	0.077	0.365
H3	Interop -> SysQual	0.159	Medium	0.322	0.003
H4	PExp -> BI	0.115	Small	0.345	0.001
H5	SI -> BI	0.054	Small	0.176	0.012
H6	Security -> SysQual	0.109	Small	0.265	0
H7	SysQual -> PExp	0.639	Large	0.624	0
H8	Usab -> EExp	0.288	Medium	0.473	0
H9	Usab -> SysQual	0.196	Medium	0.376	0

3.5. Discussion

All the hypotheses offered for the adoption of FOSS systems were empirically supported. For example, Cost (H1), Performance Expectation (H4), and Social Influence (H5) all significantly influenced Behavioural Intentions (BI) (p 0.001), but Cost (H1) had a medium effect and Performance Expectation (H4) and Social Influence (H5) both had a smaller effect. For the same relationship (BI), however, Effort Expectations (H2) is not statistically significant (p 0.10), and the impact is too small to be adequately explained. On the other hand, previous work has shown that the expectation of effort performance had a significant positive effect on the acceptance of FOSS (Ajila & Wu, 2007; Alrawashdeh et al., 2020).

In terms of the hypotheses that influence System Quality (H3, H6, and H9), it can be established that all have a highly significant influence (p 0.001), H3 has a strong explanatory effect (f2 > 0.350), and H6 and H9 have a small effect (0.150 > f2 > 0.020). H7 illustrates the effect of System Quality on Performance Expectations. This ratio is positive, highly significant (p 0.001), and has a large effect (f2> 0.350) on performance expectations. (Alrawashdeh et al., 2020) It has also been stated that the quality of the system has a substantial impact on FOSS acceptability. The other line of research (Ajila & Wu, 2007) also showed strong correlations between FOSS adoption and product quality gains.

H8 has an average bond (0.350 > f2> 0.150), an expectation of effort, and a strong statistical significance (p 0.001). Although it is likewise favourably and strongly associated with the model, H8 (Usability) is the least rewash-independent latent variable for FOSS adoption. In fact, the outcome is comprised of the findings of (Raza et al., 2012) in their study on the usability of FOSS.

3.6. Conclusion

As the literature review notes, the adoption of FOSS offers several benefits for organizations that adopt it. However, few studies are conducted in developing countries, so this study aims to fill this gap by proposing a new theoretical model to assess which factors influence the intention to use FOSS. The research was based on data from questionnaires applied in Angola as an example of a developing country. Our results validate the assumptions that the specified dimensions of our research model (system quality, security, interoperability, usability, costs, effort expectancy, performance expectancy, and social influence) have a strong influence on the intention to use FOSS. System quality is arguably the most significant latent variable in the model, being largely explained by the factors of security, interoperability, and usability. In addition, the low cost of FOSS, performance expectation, and social influence also proved to be important factors in influencing the acceptability of FOSS. On the other hand, respondents did not consider effort expectation as a determining factor for FOSS acceptability.

This is the first study on FOSS conducted in Angola. Theoretically, this research contributes to the current literature on FOSS by proposing a new theoretical model of adoption that includes interoperability in system adoption. Furthermore, the model identifies that cost and social influence have a significant weight, specifically in the adoption of this type of system. And this, in practice, may enable decision makers to promote FOSS in developing countries.

This study, like all empirical research, has limitations. Initially, all analyses are based on survey data. In addition, our questionnaire was applied only in large cities. Although the results are statistically significant, additional studies with a broader geographic scope would improve the explanatory ability of the model. The proposed model suggests further investigation of the strength of the system's influence on other regions. In summary, there could be more studies on this type of subject.

Chapter 4

Promoting Accessibility in Healthcare: An Approach Using Artificial Intelligence and Interoperability

This chapter describes the proposal of an architecture that includes Artificial Intelligence (AI) concepts and support for Interoperability. The study contained in this chapter of the thesis was published in a scientific journal. Access to health care is a global issue, particularly in disadvantaged populations. Digital technologies such as mHealth have been instrumental in solving this problem. However, the lack of system compatibility hinders the wider adoption of digitalization in healthcare. In this regard, this article presents the prototype of a digital health architecture that combines AI capabilities and the Fast Healthcare Interoperability Resources (FHIR) protocol to increase accessibility in healthcare services. The authors aim to promote access to healthcare services for all patients, regardless of their geographic location, using AI and the HL7 FHIR standard. The architecture includes essential features such as patient registration, vital parameters registration, and appointment scheduling. Access to services is simplified and easy using regular voice calls on a mobile phone. The design science survey methodology (DSRM) was used to build the architecture, which provided an organized and successful approach. The architecture was evaluated, and the results indicate that the use of the proposed architecture can provide considerable benefits in terms of accessibility and solve interoperability problems in healthcare.

4.1. Introduction

Access to healthcare has long been identified as a global issue (Tao & Cheng, 2019; Upadhyay et al., 2022). This question becomes even more difficult when considered in the context of developing countries, where a lack of technological infrastructure and transportation presents significant barriers to people with disabilities and the elderly in rural areas (Mangundu et al., 2020), having been even more essential during the COVID-19 pandemic scenario, when governments throughout the world enforced limitations on mobility and social gathering to minimize the virus's spread (Ghorbanzadeh et al., 2021; Tuczyńska et al., 2022).

These constraints made on-site care impossible. Patients suffering from chronic diseases like as diabetes and heart disease have difficulties in accessing necessary care due to the cancellation of medical assistance, routine exams, surgeries, and other treatments unrelated to COVID-19. The issue of access to healthcare is addressed in the literature from various perspectives, and the motivation for this research is to highlight how digital technologies, such as mobile health technology (mHealth), can improve the level of accessibility with which people receive healthcare, avoiding cancellations and the need for in-person medical consultations. The medical literature presents a wealth of empirical evidence emphasizing the critical role of mHealth in improving access to healthcare services by breaking down geographical barriers and allowing people in rural or remote areas to access specialized medical services (Alam et al., 2020; Park et al., 2022).

Some studies, such as (Adans-Dester et al., 2020), investigated the use of mHealth to monitor and mitigate the effects of COVID-19 pandemic, demonstrating how these apps may aid in detecting symptoms, providing relevant information about the disease, and contributing to virus control and prevention. In the same vein, the study (Agnihothri et al., 2020) investigated the use of mHealth in the management of chronic diseases such as diabetes and hypertension. The authors emphasized how these applications may aid in continuing health monitoring by measuring vital signs, blood glucose levels, blood pressure, and other crucial indicators.

Despite the benefits of mHealth, as mentioned in previous studies (Khilnani et al., 2020; Scheibner et al., 2021; Xie et al., 2022), significant challenges must be overcome to ensure its adoption in many contexts of the healthcare system. Aside from the shortage of health professionals and the digital exclusion (which includes inefficient infrastructure and limited Internet access), as reported in various studies (Ahouandjinou et al., 2021; Almazroi et al., 2022; Latif et al., 2017), the reduced interoperability of these systems is also cited in the literature as one of the potential barriers to widespread adoption of healthcare digitization and, as a result, to the improvement of healthcare quality (Adams et al., 2017; Blobel, Bernd, 2018).

Numerous studies have identified interoperability as an important aspect in reaping the benefits of a digital health system (Lehne et al., 2019) as well as improving healthcare coordination, efficiency, and effectiveness (Lee et al., 2021). To address these challenges, some studies use FHIR resources and REST APIs to achieve interoperability in healthcare (Bettoni et al., 2021; Braunstein, 2019; Hidayat & Hermanto, 2020; Saripalle, 2019). Further study has demonstrated the application of artificial intelligence (AI) to improve access to healthcare services (Garcia Alonso et al., 2022; Katiyar & Farhana, 2022).

This article discusses a prototype of a digital healthcare architecture that includes AI and HL7 FHIR resources to promote accessibility and interoperability among healthcare providers. The purpose is to increase patients' access to health care regardless of their geographic location, as well as to encourage clinical information sharing with any other health system. The architecture explores a few functionalities that can assist with patient registries, vital parameters registration, and appointment scheduling. The authors employ the design science research methodology (DSRM) in their development (Peffers et al., 2007). The contributions to the article are as follows: (1) Technically, the article contributes to improving access and quality of healthcare services; (2) socially, the article addresses the needs of communities in resource-constrained areas, improving patient care conditions and, as a result, reducing crowding caused by unnecessarily long wait times for medical services; and (3) theoretically, the article contributes to the scientific literature in the healthcare community.

4.2. Previous Work

Interoperability is frequently defined as the ability of different systems, devices, or applications to communicate and exchange data in an efficient manner. Adoption is complicated since it involves several conceptual aspects. In the study (Tolk et al., 2007; Whitman & Panetto, 2006), the authors address various levels of interoperability, and the levels are interpreted through methodology and the level of abstraction of the data collected; semantics, syntactics, and technique are the most addressed levels in the literature. As the name implies, technical interoperability addresses aspects related to the ability of various systems, devices, or applications to communicate with and integrate with one another. This includes communication protocol compatibility, data format compatibility, and user interface compatibility.

Studies conducted across several industrial segments highlight interoperability as a critical requirement for improving productivity, transparency, and accelerating innovation (Chalyvidis et al., 2016; da Rocha et al., 2020; Jindal et al., 2022; Neinstein et al., 2016). Recent studies (D. Xiao et al., 2021) have shown that interoperability between health systems is required to ensure efficiency in the communication of medical data between different health systems and devices and to allow healthcare professionals to have a complete view of the patient's clinical history, thereby improving the quality of healthcare.

The state of the art in digital health has highlighted a variety of studies and projects that are being explored, including mobile health platforms, EHRs, and telemedicine solutions. These systems were evaluated in several scientific studies, which highlighted their advantages and limitations. The study (Ranjan et al., 2019) describes the Radar-base platform, which gathers and analyses health data utilizing sensors, wearable devices, and mobile devices. The platform enables users to monitor real-time health data to enhance their health and well-being. This study (Sun et al., 2020) investigates how cell phones and wearable technologies are utilized to track behavioural changes during the COVID-19 pandemic. They collect data on physical activity, sleep, and location to determine the impact of the epidemic on health and well-being. Although ethical and privacy concerns are raised, it is decided that these gadgets are a valuable tool for studying the impact of the epidemic.

This article (Wong et al., 2020) outlines research to assess the efficacy of an AI-based health platform with biosensors in the early identification of COVID-19. The research was divided into two parts: examination of the biosensor data and comparison with standard testing. The goal is to examine if AI might help with early detection of COVID-19 and better response in future pandemics. This paper (Mawji et al., 2020) highlights the use of a sepsis screening tool termed " Paediatric Rapid Sepsis Trigger (PRST)" for children in clinical settings. The tool assists healthcare providers in identifying sepsis early and initiating treatment as soon as possible. The goal is to assess the efficacy of PRST in the early diagnosis of sepsis in children and to enhance its treatment. The HeartMan DSS (Bohanec et al., 2021) is a system that employs mobile phones, wrist sensors, and an app to help individuals with congestive heart failure monitor symptoms, control their condition, and get alerts from healthcare specialists. The objective is to enhance patients' quality of life while avoiding significant problems. In addition, new trends in digital health include artificial intelligence interoperability with virtual agents such as chatbots, voicebots, and IVRs to improve the efficiency of medical care, improve communication between health professionals and patients, and provide personalized health recommendations to patients in real time. It is possible to state that virtual agents are computational artifacts that, when implanted, may interact with patients in a conversational manner, increasing patient satisfaction. Virtual agents can be used in a variety of contexts, including health information and simple diagnostics, self-care support, and navigation assistance in a health system, which can be accessed via mobile devices, computers, or voice assistants (Montenegro et al., 2019). This eliminates the concept of geographic distance for access to health services (Oproiu et al., 2020). For example, this article (Chung & Park, 2019) describes a healthcare service based on chatbots that uses a knowledge base for cloud computing. The chatbot provides an interactive interface for patients to get health information, advice, and recommendations. The knowledge base provides trustworthy and up-to-date information to the chatbot, making the service more efficient and effective for the patients. The goal of the service is to improve patient access to information and healthcare by utilizing cloud computing and artificial intelligence. This paper (Revathy et al., 2020) describes a surgical advice system that employs a Naive Bayes Multinomial algorithm to provide guidance to patients via a voicebot. The system's goal is to improve access to information and support in the field by utilizing artificial intelligence and voice recognition technology. The authors of the paper (Vuppalapati et al., 2017) offer an architecture for integrating voice services with EHR using the virtual agent, Alexa. The research focused on resolving ambulatory data communication issues using voice applications, to promote interoperability and improve ambulatory care. The research (Oproiu et al., 2020) used VoIP (Voice over IP) to integrate the ambulance service as a remote patient monitoring system. With the use of this application, the medical team may get data from the patient such as body temperature, heart rate, blood pressure, blood sugar level, and level of physical activity. This article describes how technical interoperability was achieved with a combination of protocols such as SIP signaling, FHIR APIs, and DTMF to receive data through keys. The impact of using virtual agents with IVR as a tool to improve access to healthcare in remote areas has been studied (Brinkel et al., 2017). The results revealed that the quality-of-service experience was the most important factor in user acceptance.

4.3. Method

As previously stated, the DSRM technique proposed by Peffers and colleagues (Peffers et al., 2007) is used in this research Figure 4.1 depicts an overview of the process, which consists of six steps: issue identification and motivation, description of solution objectives, design and development, demonstration, assessment, and communication. In the Results section, each phase of the DSRM is discussed, along with its related result. Our findings concentrate on stages 3, 4, and 5 of the DSRM, because steps 1 and 2 are depicted in the introductory section, and step 6 is the writing and publishing of this work.

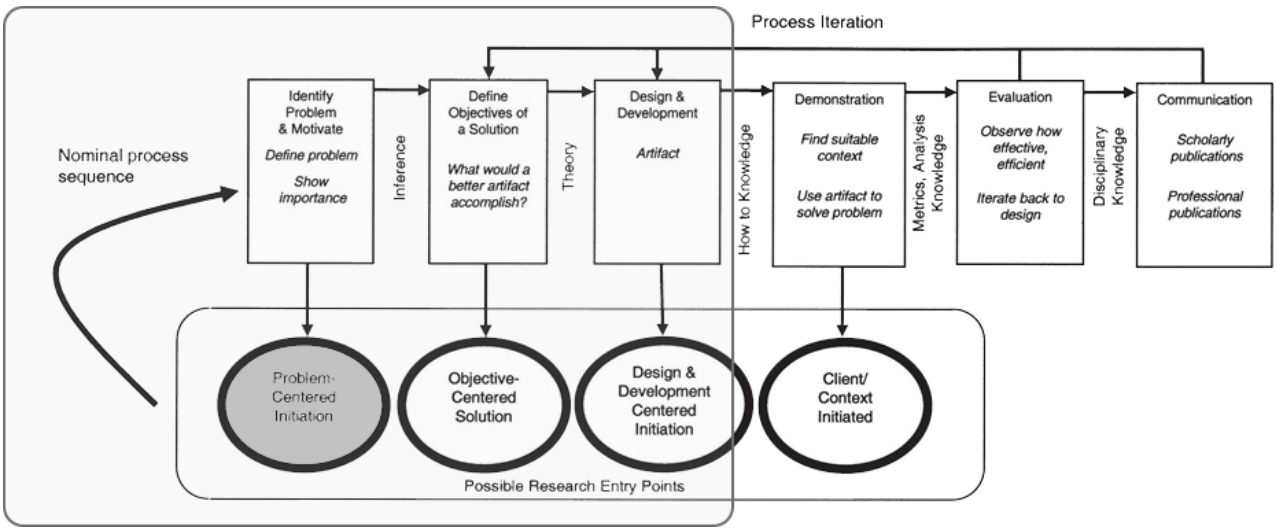


Figure 4.1: DSRM process model:Source (Peffers et al., 2007)

4.4. Proposed Solution

4.4.1. Design and Development

This phase involves the development of the project, where the architecture is defined, including the specifications of the integrated components and the functional needs. The proposed architecture is a digital health support framework (Figure 4.2). To address the lack of connectivity in isolated regions, the authors developed services that patients can access offline, using phone calls as an alternative to the internet.

This approach ensures that patients receive the treatment they need, especially in areas where technological resources are limited. Access to health services through a common telephone connection significantly extends the reach of services, eliminating technical barriers and ensuring that rural regions are not left unattended. This strategy represents a crucial step forward in promoting health equity, reducing disparities in access to quality care.

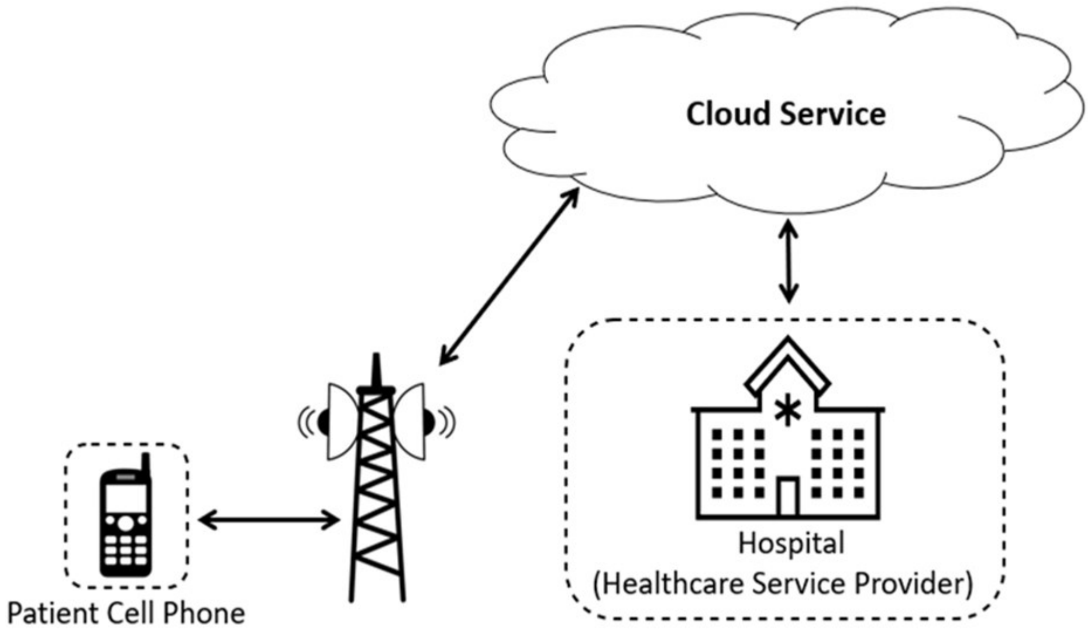


Figure 4.2: Proposed architecture

4.4.2. Components

The suggested artifact is made up of the following components: 1) Patient; 2) Telephony System; 3) Bot Engine; 4) HL7 FHIR; 5) HIS; and 6) External API. These components were carefully selected with the primary purpose of enhancing access to healthcare for patients living in distant and difficult-to-reach places. The artifact is a unique patient-centered method in which the authors combine the solution, AI resources owing to their adaptability and high efficiency in virtual reality dialogues with patients. Furthermore, the HL7 FHIR standard is employed as a reference framework to ensure interoperability with other hospital information systems (HIS) and stakeholders Figure 4.3 depicts the artifact's components in detail.

Patient: The patient is the most important component of the system. He interfaces with the system via a standard phone conversation, using DTMF (Dual-tone Multi-Frequency) or voice input to supply information and make particular choices.

Telephony system: A telephony system is a component that handles phone calls and sends patient requests to the relevant component. He works as a link between the patient and the rest of the system, ensuring that phone calls are routed appropriately.

Bot Engine: The Bot Engine is the component in charge of processing the patient's interactions and providing appropriate responses. Uses natural language processing (NLP) techniques to understand the patient's intentions based on the inputs provided, whether by DTMF or voice entry.

Health Level Seven Fast Healthcare Interoperability Resources (HL7 FHIR): HL7 FHIR is an interoperability standard for the transmission of electronic health information. In this design, it acts as a bridge between the Bot Engine and the HIS.

Hospital information system (HIS): HIS is the system in charge of managing patient information, medical records, appointment schedules, and other hospital management activities. He receives HL7 FHIR data, processes it, and stores it appropriately.

External API: describes the interface that facilitates communication between the system and external parties of interest, such as hospital systems, laboratories, or other healthcare services. This API allows him to exchange information and interface with other security and stakeholder systems.

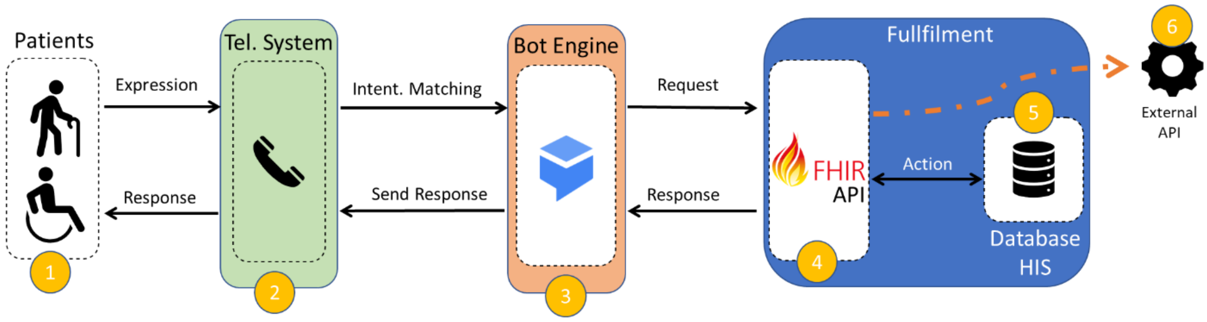


Figure 4.3: Architecture Components

4.4.3. Demonstration

In the demonstration phase, the effectiveness of the architectural prototype and its perceived usefulness were evaluated to address the challenge identified in the study. The architecture is made up of three main functions: patient records, vital parameter records, and appointment scheduling. These functions were developed using FHIR features and APIs to ensure interoperability with expressive and well-structured data models (*Resourcelist - FHIR v5.0.0*, n.d.). Figure 4.4. Figure 4.5 and Figure 4.6 illustrate the class structure of the Patient, Observation, and Consultation features in Unified Modeling Language (UML).

For instance, the "Patient" class (Figure 4.4) encapsulates essential attributes such as personal information (e.g., name, gender, birth date) and communication preferences, linking to other entities like "Contact" for patient relationships and "Communication" for language preferences. This structured approach in the UML diagrams not only supports the core functions but also ensures seamless interoperability and data management within the healthcare architecture.

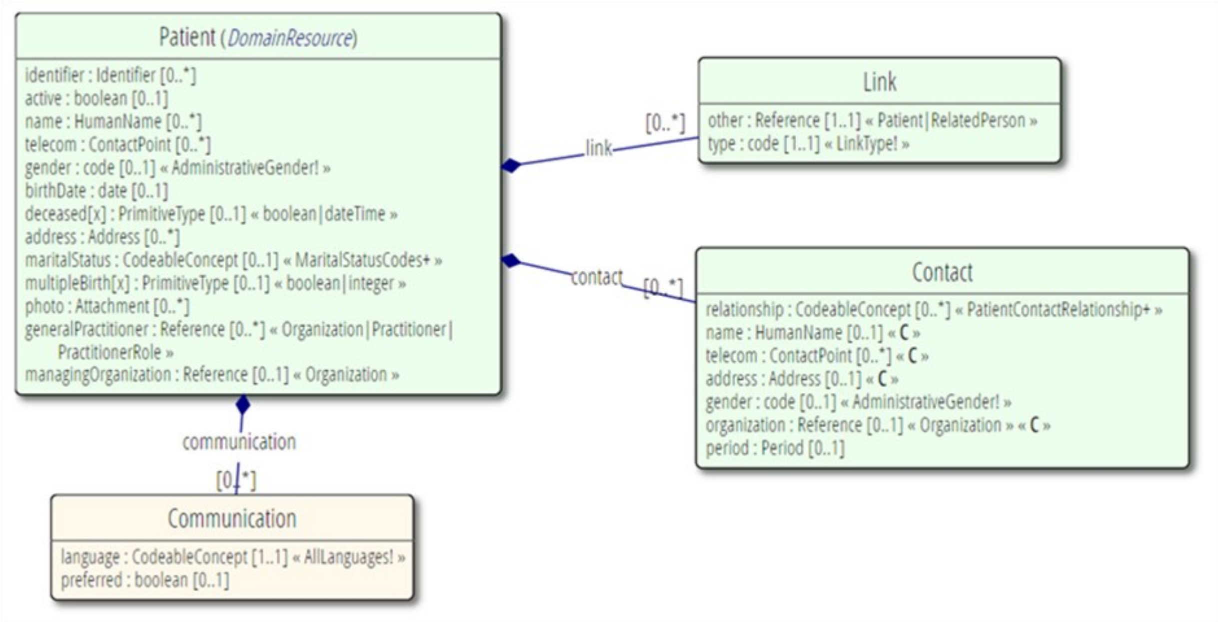


Figure 4.4: UML class diagram Resource Patient (*Patient - FHIR v5.0.0*, n.d.)

As for the "Observation" class (Figure 4.5), it serves as a core, storing detailed information about each observation, from the patient's identity to the specifics of the clinical data collected. It is associated with the "TriggeredBy" class, which provides context by recording the events that generated the observation, and the "Component" class, which allows the capture of multiple measurements in a single observation, thus enabling the structured recording of complex clinical information. Finally, the "ReferenceRange" class defines normal parameters for the observed values, which is critical for accurate data interpretation. These classes work together to ensure that clinical data is captured and interpreted effectively and interoperably, promoting better information management in healthcare settings.

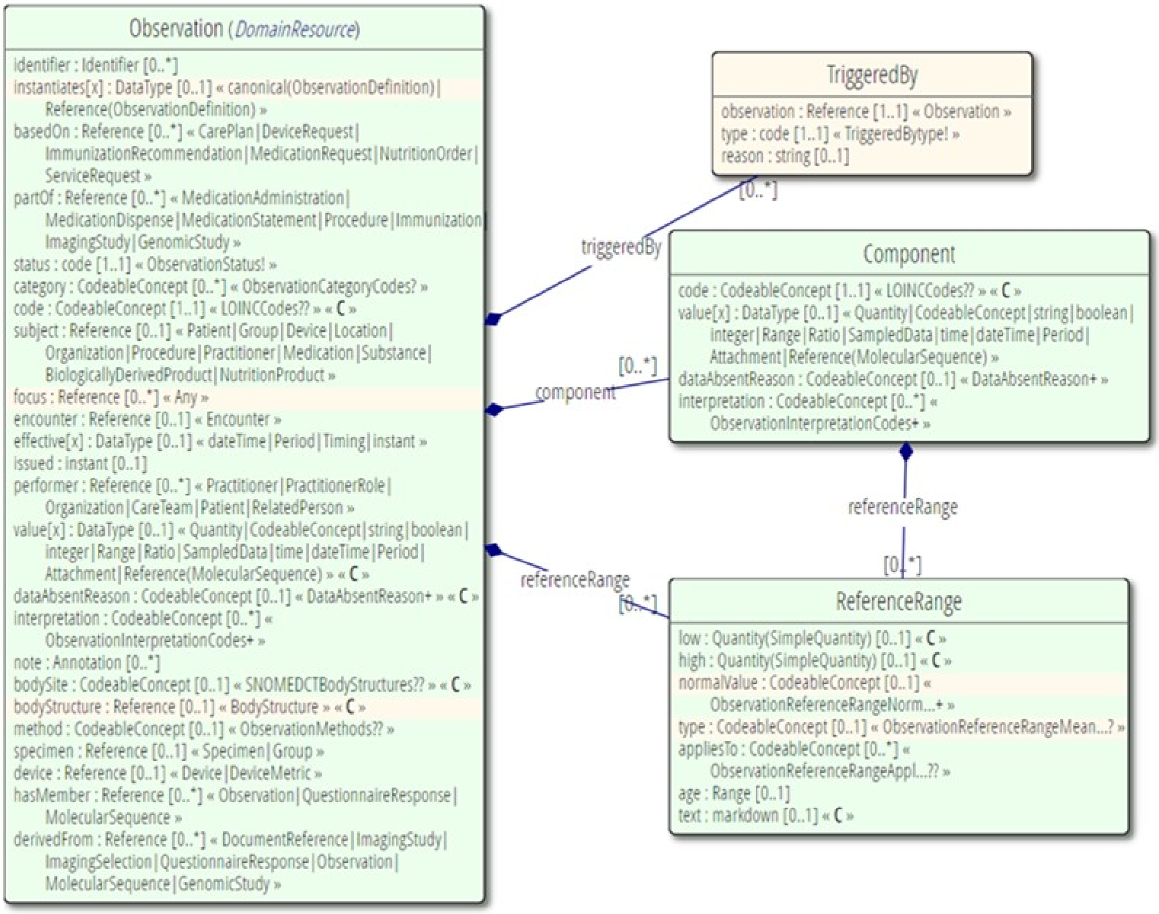


Figure 4.5: UML class diagram Resource Observation (*Observation - FHIR v5.0.0*, n.d.)

The Figure 4.6 reflects the "Appointment" class that encapsulates all relevant data for an appointment. To deal with the complexity of recurring appointments, different recurrence templates are used represented by the "WeeklyTemplate", "MonthlyTemplate", and "YearlyTemplate" classes. These templates are managed and applied to individual appointments through the "RecurrenceTemplate" class. Finally, the "Participant" class ensures that all parties involved in the commitment, such as patients and physicians, are properly registered and managed in the system. Together, these classes form a robust system for managing medical appointments, accommodating both one-time and recurring appointments.

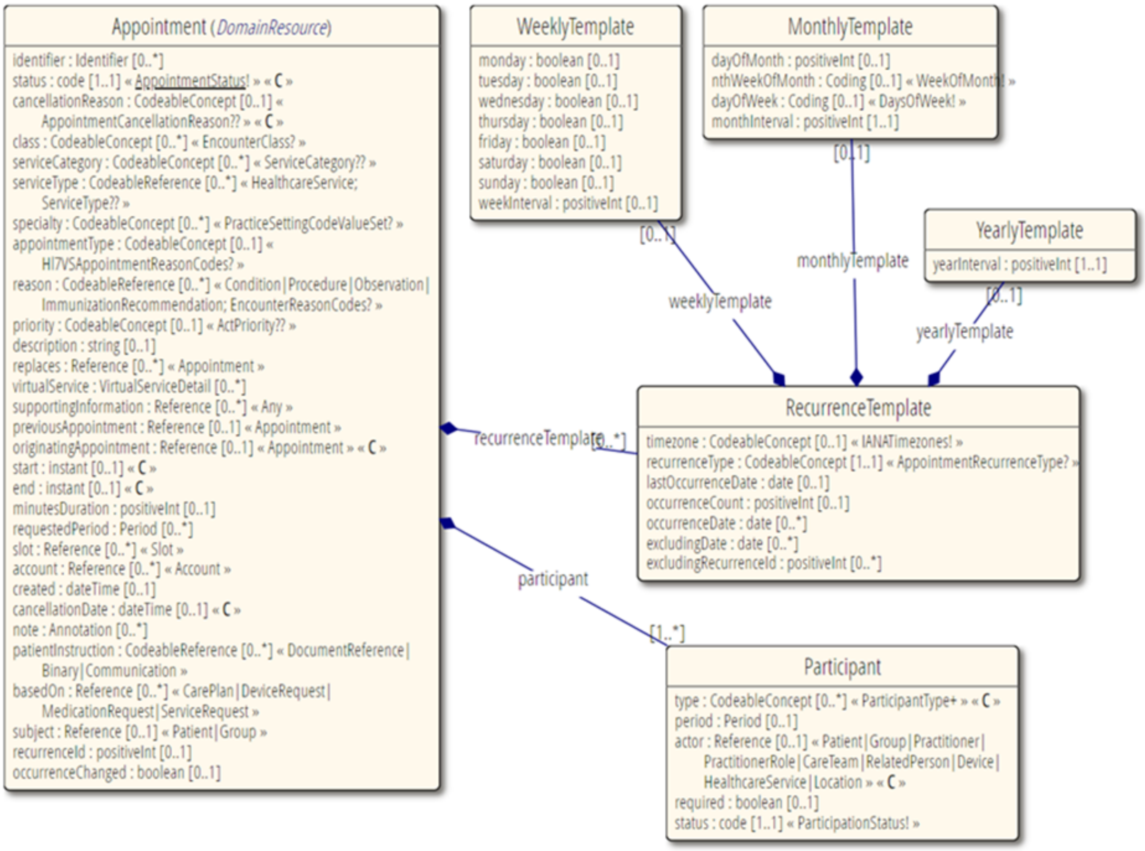


Figure 4.6: UML class diagram Resource Appointment (*Appointment - FHIR v5.0.0*, n.d.)

Therefore, this UML-structured approach not only represents the essential functions, but also how it is envisioned to handle interoperability and continuous data management within the healthcare architecture.

In the suggested solution's operational view, the process begins with the patient, who is the principal actor, supplying personal information such as sex, birth date, address, contact information, or login, if one exists in the system. The patient may then register vital indicators such as body weight, arterial pressure, and temperature via DTMF or voice input, and the device will store this information accordingly. Aside from that, the patient may arrange appointments via the phone system by selecting the desired day and time, and the system will verify availability and confirm the appointment. Figure 4.7 depicts the use case for each macrotask.

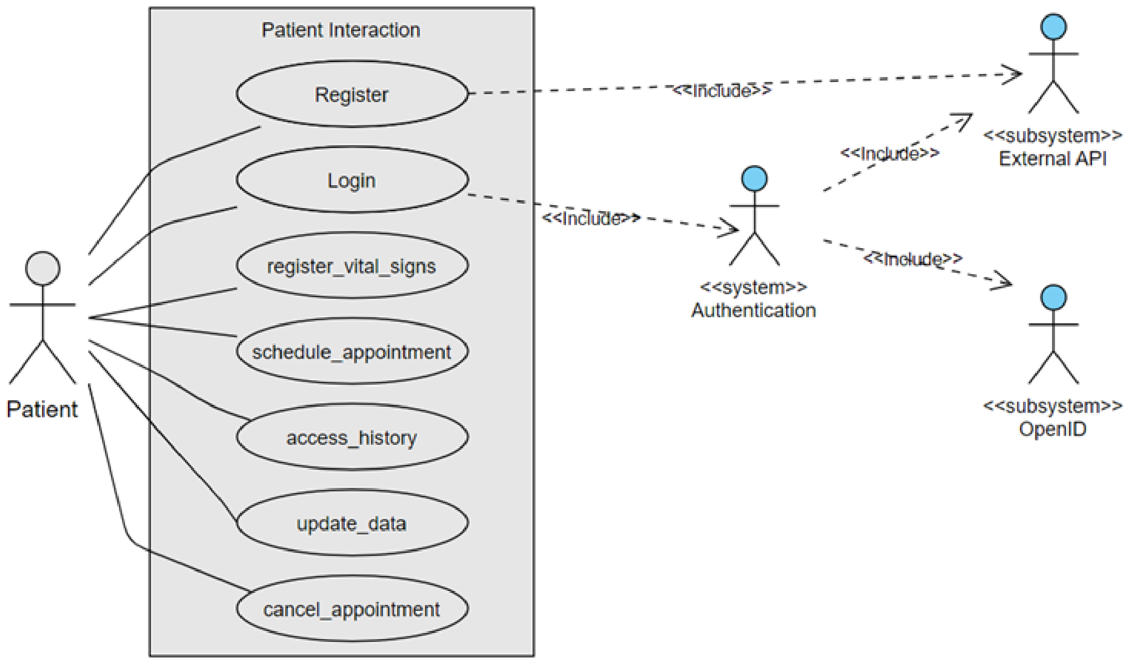


Figure 4.7: UML use case diagram Patient Interaction

The remainder of this part use a UML sequence diagram to depict a high-level description of a typical interaction between the patient, the system, the Bot Engine, the HL7 FHIR, and the HIS. We build and transfer data between the patient and the subsystems using the necessary FHIR APIs. Figure 4.8 and Figure 4.9 demonstrate how patient information is gathered, evaluated, and transferred to relevant systems for tasks such as appointment scheduling and blood pressure monitoring. The sequence of events may vary depending on the individual functions included in the proposed architecture.

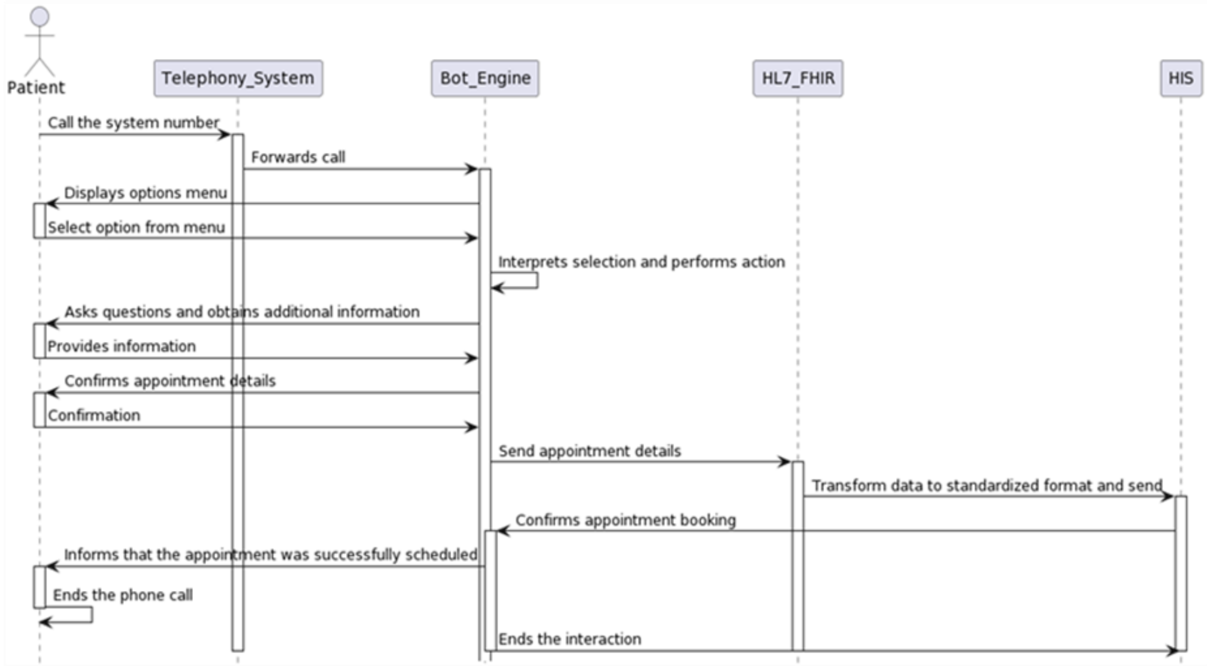


Figure 4.8: UML sequence diagram Appointment scheduling

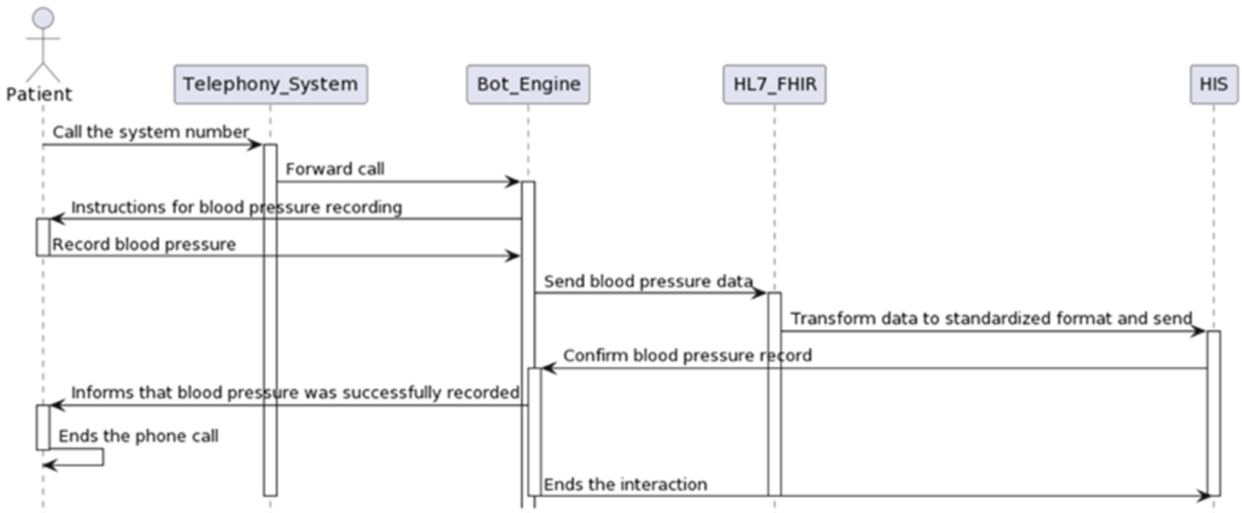


Figure 4.9: UML sequence diagram Blood pressure vital signs recording

4.5. Results

This stage involves evaluating non-functional aspects such as the architecture efficiency and efficacy in meeting previously defined goals. This may be accomplished through controlled experiences, user data collection, and the assessment of key metrics. The goal is to determine whether the prototype meets the needs of users and can resolve problems identified during the project phase. This enabled to verify the results obtained during the demonstration phase.

The tests were performed in a controlled environment using an automated call generation script (Appendix C) - the script simulates the patient's call. We have implemented all the components of the architecture in a single Raspberry Pi 3 Model B, equipped with a Broadcom BCM2837 64-bit processor, clocked at 1.2 GHz and quad-core ARMv8 CPU, as well as 1 GB of RAM (Figure 4.10).

Figure 4.10: Raspberry Pi 3

The tests carried out evaluated the architecture for the maximum capacity of simultaneous calls and the use of resources, such as CPU and RAM, during the processing of these calls. The call generation script has been configured to run a high number of calls (100) with a maximum duration of 30 seconds each.

The results of this test indicate the maximum number of calls that the system can handle at the same time, as well as the use of computational resources such as CPU and RAM during call processing. The analysis reveals that the system has demonstrated efficiency in dealing with up to 80% of simultaneous calls before experiencing performance issues. During the call processing, the CPU used up to 85% of its available resources, while RAM used up to 70 percent (Figure 4.11). This indicates that the system was working close to its resource limit and may have performance issues if the load is increased.

Therefore, we determined that the system effectively accomplished the goal of improving access to healthcare services. The system optimized processes such as patient enrolment, vital-parameter tracking, and consultation scheduling, resulting in a 20% reduction in average response time. The obtained results corroborate with the proposed architecture's objectives, indicating that the proposed solution may be a useful tool; the 80 percent of established calls indicate the number of patients who might be served if we were in a production environment. These values may be improved since they vary depending on system configuration and environment, as they are related to hardware limits, foundational processes, and workflow.

Compared to other studies, the system showed good performance in terms of accuracy and response time. In addition, it seems to be a preferable solution for underserved regions since potential users would not need to use the Internet to benefit from its services.

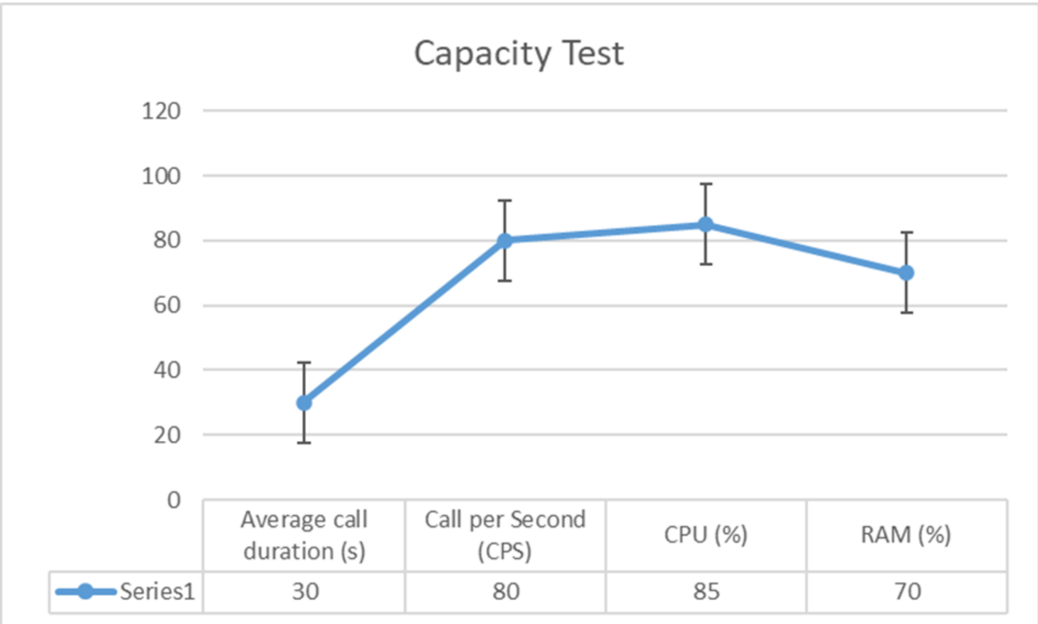


Figure 4.11: Performance test results: Source: Authors

4.6. Discussions

Interoperability is a fundamental need, and its importance is often highlighted in the literature of information systems. Research conducted in different industrial segments highlights interoperability as a fundamental requirement to improve productivity, transparency, and accelerate innovation (Chalyvidis et al., 2016; da Rocha et al., 2020; Jindal et al., 2022; Neinstein et al., 2016). Thus, this study presented a digital health infrastructure based on virtual care agents. We applied technical interoperability principles to integrate all elements of the infrastructure. This means that we adopted the same interface standards and communication protocols in all elements, namely, IP, SIP, RESTful API, DTMF, and SOCKET. Our research effectively used the open standard to support technical interoperability. This standard facilitates the integration and convergence of new manufacturers to the solution requirements.

With regards to the state of the art, our results are consistent with the literature that highlights the importance of interoperability for equitable access to healthcare. However, this research differs from existing studies by proposing an offline digital health solution from the user's point of view (patient) and offers significant advantages in terms of data security and greater accessibility, especially in areas with low internet connectivity.

However, it is important to emphasize that there were some limitations in this research. Firstly, the study focuses only on technical interoperability. Syntactic and semantic aspects are not discussed in this research. However, it is important to note that technical interoperability is only one part of the problem, semantic and syntactic interoperability are also essential to ensure the continuity of care. Therefore, it is essential for health organizations to work together to develop effective, secure, and user-friendly technical interoperability solutions. However, we believe, as (Aarestrup et al., 2020; Gavrilov et al., 2020), that in a first approach, it makes sense to consider the level of technical interoperability, define the necessary communication protocols and interfaces to operate the infrastructure. Secondly, the test results were not applied to actual users but to the call generator script, and metrics such as ease of use and usability were not considered.

However, in relation to the study objectives, our results demonstrate that interoperability is an important feature of the digital health structure to improve access to healthcare and reduce inequality in health distribution. This highlights the importance of investing in interoperability technologies and establishing policies that promote interoperability in the health sector.

4.7. Conclusions

The research discusses the digital health infrastructure to improve access to healthcare and reduce inequality in health distribution. The role of interoperability is highlighted as critical to achieving these objectives as it allows for medical information to be easily shared between different health systems and organizations. Interoperability is seen to promote equity in the provision of healthcare by enabling people to access relevant medical information regardless of where they receive medical attention.

As such, a computational artifact is presented in this article. The proposed solution adopted technical interoperability principles between virtual agents and EHRs. An evaluation of the solution was carried out through user identification and authentication and request for basic health services tests using pre-set IVR options. According to the test results, the adopted concept can significantly improve the quality of healthcare and reduce geographical distance. In conclusion, technical interoperability is crucial to ensure that health systems can communicate and share information efficiently and securely. Furthermore, the article highlights the use of IVR as a viable

option to ensure technical interoperability between health systems as it allows for automated communication between systems without human intervention. This can help improve the quality of healthcare, increase process efficiency, and reduce operational costs.

In summary, the article concludes that the digital health infrastructure can be an effective way to improve access to healthcare e and reduce inequality in health distribution if interoperability is prioritized and effectively implemented.

Chapter 5

Conclusions

5.1. Main Conclusions

This thesis represents a significant academic effort, which comprehensively investigated the adoption of FOSS in the public sector of developing countries and its implications for digital transformation, with Angola as a case study. The research was carefully structured around the specific objectives (**SO1** to **SO4**), to robustly answer the proposed research questions (**RQ1** and **RQ2**). To achieve the established objectives, the research employed a variety of data sources and applied diversified methodologies, each of which required specific analytical approaches and led to distinct results. This multifaceted methodological approach allowed for a detailed exploration of the different dimensions of the problem, resulting in a rich and in-depth analysis that supports the conclusions of the thesis.

Thus, in the chapter dedicated to the literature review and the state of the art (0), a comprehensive analysis of the academic production on FOSS was carried out, with a specific focus on developing and low-income countries. The results of this analysis not only confirmed a significant growth in literary production on the subject, but also revealed the geographical and thematic distribution of this production, highlighting the United States as the main contributor, followed by countries such as India, South Africa, and Brazil (Figure 2.3). The identification of these countries as leaders in FOSS research is crucial, as it suggests the existence of an established knowledge base that can be explored and expanded to support FOSS adoption in regions with emerging needs, such as Angola.

The results of the literature review were organized into four main themes—open systems, healthcare, information systems, and the human costs and implications—offers a structured view of the areas where FOSS has been most impactful (Figure 2.6). This thematic mapping is particularly beneficial for researchers and policymakers, as it provides a clear understanding of where research efforts are concentrated and what gaps still need to be addressed. For example, the focus on "open systems" and "health" underscores the importance of FOSS in creating flexible and accessible platforms for the healthcare industry, while the theme of "costs and human implications" highlights the relevance of considering both the economic benefits and social consequences of FOSS adoption.

In addition, the identification of emerging themes, such as the Internet of Things (IoT) and machine learning, reflects contemporary research trends and indicates promising areas for future investigations. These topics not only broaden the scope of FOSS, but also open new opportunities for the application of these technologies in public health settings, especially in developing countries. By acknowledging these trends, the chapter provides a solid foundation for future studies exploring how FOSS can be integrated with these emerging technologies to address complex challenges in the public sector of developing and low-income countries, confirming full compliance with **SO1**.

The second study of the thesis (Chapter 3) focused on the factors that influence the adoption of FOSS in the public sector (**SO2**) and on the construction and validation of the conceptual model that maps these factors (**SO3**). Confirming full compliance with these SO. This conceptual model offers a structured and holistic view of the variables that affect the decision to implement FOSS in public sector environments, allowing managers, decision-makers, and developers to understand more clearly the dynamics involved in this process. By identifying and categorizing factors such as cost reduction, performance expectation, social influence, and system quality, the model provides a solid foundation for formulating strategies that can increase the adoption rate of FOSS in public institutions.

Additionally, the model highlights the importance of crucial technical considerations such as security, interoperability, and usability, which are often cited as barriers to the adoption of new technologies in healthcare settings. With this understanding, the conceptual model not only guides the most effective implementation of FOSS, but also facilitates the creation of policies that directly address the concerns and needs of end users. For example, by prioritizing interoperability, the model promotes more efficient integration of FOSS with existing systems, minimizing resistance to change, and maximizing the benefits of the new technology.

Therefore, the conceptual model developed in this research is not only an academic tool; It has straightforward practical applications. It serves as a guide for managers and developers in creating FOSS-based solutions that are aligned with the specific realities and demands of the public sector, particularly in developing countries. Thus, **RQ1** was fully answered, with the identification of critical factors that influence the adoption of FOSS.

Based on the findings of previous studies, the third study presented the construction of an innovative architecture for the health sector, which was detailed in (Chapter 4). This architecture represents a disruptive step for developing and low-income countries, by integrating AI and support for the FHIR HL7 protocol to solve critical interoperability problems in healthcare. By addressing these issues, full compliance with SO4 is confirmed.

The proposed architecture incorporates essential functionalities, such as patient registration, monitoring of vital parameters and appointment scheduling, all facilitated through voice calls on mobile devices. This innovative design not only simplifies access to healthcare services but also democratizes care by allowing individuals in geographically isolated areas or with limited infrastructure to receive quality healthcare without the need to travel. The use of voice calls is a strategic solution, considering that many remote regions have limited access to the internet but have good mobile phone coverage.

The test results of this architecture demonstrate its potential impact and robustness, even under limited hardware conditions. During testing, the architecture was able to efficiently handle 80 of the 100 concurrent calls before experiencing performance issues, evidencing its ability to support a substantial volume of users in real-time. This performance is particularly remarkable considering the limitations of the hardware used, which suggests that the architecture is scalable and can be optimized to operate in resource-constrained environments, a common reality in remote regions and low infrastructure.

Therefore, if we project these results in the real world, it is estimated that approximately 80 patients could benefit from the medical services offered by architecture, without the need for physical travel. This data is highly significant, as it demonstrates the ability of architecture to expand the reach of health services, substantially reducing the physical and geographical barriers that traditionally hinder access to medical care. In addition, the efficiency demonstrated by the system in managing a considerable volume of simultaneous calls indicates that it can be a vital resource in emergency situations or in places with high demand for medical services.

Therefore, the results indicate that the proposed architecture not only achieves its goals of improving the accessibility and efficiency of healthcare services in remote areas, but also demonstrates considerable potential for expansion and enhancement. With additional adjustments and optimizations, the capacity for simultaneous service can be significantly expanded, making this solution even more effective and comprehensive. In this way, **RQ2** was thoroughly addressed, with the clear demonstration of how FOSS can be instrumental in driving digital transformation in challenging contexts.

5.2. Main Contributions

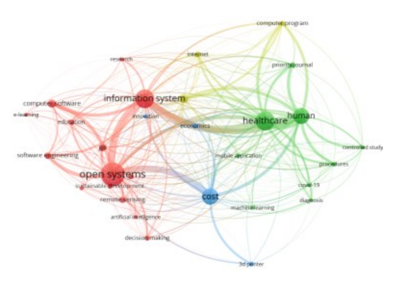
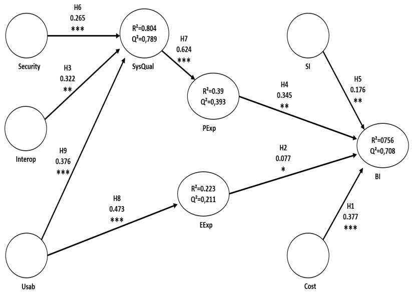
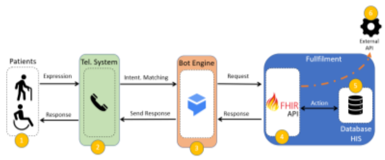
The contributions of this thesis are broad and diverse, covering theoretical advances and practical implications of great relevance to the field of ICTs, especially in the context of developing and low-income countries that are in the process of transitioning to digital transformation. First, from a theoretical point of view, this research contributed to the advancement of knowledge at two different levels. The thesis carried out a systematic review of the literature on the adoption of FOSS in the public sector, establishing the state of the art in this field of study. This review made it possible to identify the main trends, gaps and challenges faced, offering a deep and critical understanding of the context in which FOSS is adopted in developing and low-income countries. Secondly, the thesis contributed to the existing body of knowledge on theoretical models of ICT adoption by proposing a new conceptual model that articulates the interoperability, usability, security, and quality of the system. This contribution responds to the gaps identified in the literature on the barriers and enablers of technology adoption in developing country contexts, providing a solid basis for future studies that seek to explore these aspects in different geographic and sociodemographic contexts.

At the methodological level, the thesis introduces significant contributions by using bibliometric research techniques, which allowed to map and analyse the evolution of academic production related to FOSS. The application of the PRISMA protocol in the systematic review of the literature ensured a high methodological rigor, ensuring the robustness and replicability of the results presented. This methodological approach has not only strengthened the validity of the conclusions reached, but also offers a structured path for future research that wishes to deepen the study of the adoption of emerging technologies in resource-constrained settings.

From a practical point of view, the thesis offers a valuable contribution by proposing an innovative architecture for the modernization of public health services in developing countries, with a focus on improving access to health care in remote areas. The architecture developed, which integrates AI and interoperability principles, is a concrete example of how FOSS-based solutions can be adapted to meet the specific needs of vulnerable populations, overcoming technological and geographical limitations. Finally, the thesis complements the contribution by offering a strategic action plan for the implementation of the results obtained, with clear guidelines for the creation of a local technical support infrastructure, government involvement, implementation of pilot projects and sustainable expansion of the use of FOSS.

In summary, the contributions of this thesis are broad and deep in nature, encompassing theoretical, methodological, and practical advances that have the potential to influence both the academic field and professional practice around ICT in public sector. By addressing critical issues related to FOSS adoption in developing countries, this research not only enriches the existing body of knowledge, but also offers innovative and applicable solutions that can contribute to digital transformation and improved quality of life in resource-constrained contexts.

Table 5.1: Main Contributions

Overview of FOSS Research (2001-2023)	New Theoretical Model for FOSS Adoption	Architecture to Modernize Access to Public Health
		
	Guidelines	
		

5.3. Future Work

For future research, there are several promising directions to explore, especially considering the contributions of this thesis. A relevant area is the broadening of the geographical scope of FOSS studies, investigating their adoption and impact in different regions and organizational contexts, for example in public administration, education, and finance. This will allow to evaluate the applicability and effectiveness of the models and solutions developed in this thesis in varied environments, providing a more global and comprehensive view of the challenges and opportunities associated with FOSS.

Another relevant avenue for future research is the integration of emerging technologies, such as IoT, artificial intelligence and machine learning, within the FOSS framework, especially in applications aimed at the public sector. Studies that explore how these technologies can be combined with FOSS to address complex challenges in public health, education, and other essential services could contribute to the development of more robust and innovative solutions.

In addition, future research could investigate the scalability of proposed architectures in different contexts, testing their applicability and impact on public health systems with diverse characteristics. This type of analysis can help identify critical success factors and barriers to implementation, offering valuable insights for adapting and scaling up these solutions in different regions.

Longitudinal analysis of the impact of FOSS on digital transformation in low- and middle-income countries also represents a promising area of research. Monitoring how the adoption of these technologies evolves over time, and identifying the factors that influence this trajectory, can provide a deeper understanding of the sustainability and long-term potential of FOSS as a driver of digital transformation.

Finally, it would be of great value to investigate the interaction between public policies and the adoption of FOSS, especially in terms of how legislation and regulations can facilitate or hinder the use of these technologies in the public sector. Studies that analyse the role of government policies in promoting or restricting FOSS can contribute to the development of more effective policy strategies, aligned with the innovation and efficiency needs of developing countries.

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Appendices

Appendix A

Questionnaire (Study 2)

Constructs	Concepts	References
Behavioural Intentions (BI)	**BI1:** I intend to adopt Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR in the future. **BI2:** I will try to adopt Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR in the coming months. **BI3:** I am willing to use Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR frequently	(Venkatesh et al., 2003)
Performance Expectation (PExp)	**PE1:** I would find Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR, useful in my work. **PE2:** Adopting Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR, will allow me to accomplish my tasks faster. **PE3:** Adopting Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR, would increase my productivity.	
Effort Expectation (EExp)	**EE1:** My interaction with Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR, would be clear and understandable. **EE2:** It would be easy for me to become skilled in using Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR. **EE3:** I would find Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR, easy to use.	
Social Influence (SI)	**SI1:** I will adopt Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR if the people who influence my behavior think I should use it. **SI2:** I will adopt Free and Open-Source Software like Linux Ubuntu, Libre Office, and OpenEMR, if the people who are important to me think I should use it. **SI3:** I will adopt Free and Open-Source Software like Linux Ubuntu, Libre Office, and OpenEMR, if the instructors of my apprenticeship are helpful in using such a system.	
Cost	**Cost1:** The total cost of Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR is reasonably low. **Cost2:** The total cost Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR is cost-effective. **Cost3:** In general, Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR is a good alternative to reduce financial burden.	(Alrawashdeh et al., 2020)
Interoperability (PI)	**Int1:** Free and Open-Source software such as Linux Ubuntu, Libre Office and OpenEMR may provide services and accept services from other systems. **Int5:** In general, Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR can interact with other systems and exchange data with them	
Security (Sec)	**Sec3:** I believe that no one can access my private data stored on Free and Open-Source Software systems like Linux Ubuntu, Libre Office and OpenEMR without my permission. **Sec4:** Free and Open-Source Software such as Linux Ubuntu, Libre Office and OpenEMR do not share my personal information with others	
System Quality (SysQ)	**SysQ3:** Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR decreases the number of errors when using the computer. **SysQual4:** Free and Open-Source Software like Linux Ubuntu, Libre Office and OpenEMR require less maintenance	
Usability	**Usab1:** Free and Open-Source Software systems like Linux Ubuntu and Libre Office are easier to use than proprietary software like Microsoft Office and Windows **Usab2:** Free and Open-Source Software systems like Linux Ubuntu and Libre Office have familiar icons that are easily recognizable than proprietary software like Microsoft Office and Windows	(J. W. Kamau & Sanders, 2013)

	Usa3: Free and Open-Source Software systems like Linux Ubuntu and Libre Office have better help facilities, tutorials, and support than proprietary software like Microsoft Office and Windows **Usab4:** I generally like the user interface of Free and Open-Source Software like Linux Ubuntu and Libre Office than proprietary software like Microsoft Office and Windows **Usab5:** Navigating while doing other tasks on Free and Open-Source Software systems like Linux Ubuntu and Libre Office is easier than proprietary software like Microsoft Office and Windows

Appendix B

Cross-Loadings (Study 2)

	BI	Cost	EExp	Interop	PExp	SI	Security	SysQual	Usab
BI1	0.866	0.791	0.591	0.896	0.712	0.575	0.8	0.875	0.821
BI2	0.931	0.668	0.599	0.603	0.745	0.674	0.512	0.615	0.503
BI3	0.936	0.688	0.633	0.619	0.775	0.701	0.541	0.615	0.491
Cost1	0.737	0.915	0.566	0.657	0.718	0.613	0.489	0.61	0.44
Cost2	0.73	0.96	0.542	0.746	0.661	0.535	0.63	0.704	0.611
Cost3	0.745	0.939	0.52	0.715	0.714	0.565	0.6	0.696	0.586
EExp1	0.705	0.613	0.955	0.587	0.765	0.631	0.478	0.529	0.477
EExp2	0.64	0.543	0.956	0.475	0.736	0.611	0.427	0.486	0.482
EExp3	0.529	0.472	0.931	0.475	0.636	0.528	0.406	0.379	0.369
Interop1	0.757	0.714	0.533	0.977	0.588	0.468	0.773	0.814	0.796
Interop5	0.759	0.757	0.531	0.977	0.646	0.51	0.752	0.812	0.779
PExp1	0.76	0.73	0.712	0.642	0.902	0.647	0.538	0.525	0.495
PExp2	0.771	0.671	0.73	0.582	0.968	0.703	0.562	0.595	0.558
PExp3	0.769	0.698	0.692	0.56	0.946	0.762	0.552	0.635	0.55
SI1	0.613	0.562	0.579	0.436	0.654	0.914	0.434	0.544	0.474
SI2	0.621	0.515	0.542	0.421	0.637	0.947	0.388	0.509	0.457
SI3	0.722	0.597	0.604	0.512	0.766	0.899	0.449	0.537	0.431
Sec3	0.669	0.594	0.435	0.739	0.586	0.463	0.967	0.784	0.774
Sec4	0.646	0.589	0.463	0.773	0.55	0.433	0.969	0.802	0.783
SysQ3	0.757	0.702	0.483	0.808	0.618	0.573	0.788	0.972	0.828
SysQ4	0.741	0.687	0.484	0.81	0.596	0.549	0.805	0.972	0.823
Usab1	0.548	0.477	0.398	0.698	0.494	0.432	0.711	0.754	0.947
Usab2	0.612	0.53	0.44	0.733	0.493	0.462	0.701	0.786	0.915
Usab3	0.526	0.504	0.358	0.717	0.461	0.346	0.69	0.724	0.92
Usab4	0.668	0.557	0.504	0.759	0.566	0.497	0.806	0.815	0.928
Usab5	0.699	0.61	0.469	0.81	0.606	0.522	0.797	0.834	0.916

Appendix C

Script Generates Answered IVR Calls (Study 3)

```
<?php

// Require the PAMI library to communicate with Asterisk via AMI
require_once("PAMI/Autoloader/Autoloader.php");
use PAMI\Client\Impl\ClientImpl;
use PAMI\Message\Action\OriginateAction;

// Define the number of calls to generate
$callCount = 100;

// Define the number of answered calls
$answeredCallCount = 0;

// Connect to the Asterisk server using AMI
$options = array(
  'host' => '127.0.0.1',
  'scheme' => 'tcp://',
  'port' => 5038,
  'username' => 'admin',
  'secret' => 'secret',
  'connect_timeout' => 10,
  'read_timeout' => 10,
);
$client = new ClientImpl($options);
$client->open();

// Loop to generate the specified number of calls
for ($i = 0; $i < $callCount; $i++) {

  // Create an OriginateAction to generate the call
  $action = new OriginateAction("SIP/1000");
  $action->setContext("ivr");
  $action->setExtension("100");
  $action->setPriority(1);
  $action->setTimeout(30000);

  // Send the OriginateAction to Asterisk
  $response = $client->send($action);

  // Check if the call was answered
  if ($response->isSuccess()) {
    $answeredCallCount++;
  }
}

// Close the connection to the Asterisk server
$client->close();

// Display the number of answered calls
echo "Number of answered calls: $answeredCallCount\n";
```

This PHP script generates answered IVR calls in Asterisk and evaluates the performance of how many calls are possible. It does this by using the Asterisk Manager Interface (AMI) to make API calls to the Asterisk server.

Here is a step-by-step explanation of the script:

Requiring the PAMI library: The first step is to include the PAMI library, which provides a convenient way to communicate with the Asterisk server via AMI.

Defining the number of calls: The script defines the number of calls to generate as a variable `$callCount`.

Connecting to the Asterisk server: The script then connects to the Asterisk server using AMI. The connection parameters, such as the hostname, port, username, and password, are defined in an array and passed to the PAMI client when creating a new client object.

Loop to generate calls: The script uses a loop to generate the specified number of calls. On each iteration of the loop, the script creates an `OriginateAction` object, which is used to generate a call. The `OriginateAction` object specifies the destination, context, extension, priority, and timeout for the call.

Sending the `OriginateAction`: The `OriginateAction` object is then sent to the Asterisk server using the PAMI client. The response from the server is stored in a vari-able.

Checking if the call was answered: The script checks if the call was answered by checking if the response from the server was successful. If the call was answered, the script increments the `$answeredCallCount` variable.

Closing the connection: After the loop has completed, the script closes the connection to the Asterisk server.

Displaying the results: Finally, the script displays the number of answered calls by echoing the value of the `$answeredCallCount` variable.

This script provides a basic example of how to generate answered IVR calls in Asterisk and evaluate the performance of how many calls are possible.

Guidelines

The authors then present a strategic action plan and practical guidelines to implement the results of the thesis, aiming to promote the adoption of FOSS in the public sector of developing countries, with a focus on Angola. The guidelines integrate theoretical and empirical findings from the research, offering a clear roadmap to turn these contributions into concrete practices that drive digital transformation. The proposed approach combines technical support, government involvement, practical experimentation, and sustainable planning, with the aim of fostering an inclusive and sustainable digital transformation, adapted to the needs of resource-constrained contexts.

Creating Local Help Desk Infrastructure

Objective: To establish a local technical support infrastructure to mitigate one of the main obstacles to the adoption of FOSS: the lack of specialized support.

Table 5.2: Guideline: Step 1

Actions	Step 1
Setting up a local startup for technical support	Step 1.1: Create a startup specializing in technical support for FOSS
	Step 1.2: Develop a portfolio of services (consulting, ongoing support, training)
	Step 1.3: Establish 24/7 support
Strategic partnerships	Step 1.4: Collaborate with universities and technical training centers
	Step 1.5: Create specialized courses for the public sector, focused on FOSS

Government Engagement and Public Policy Formulation

Objective: To ensure the engagement of government authorities and the formulation of public policies that facilitate the adoption of FOSS in the public sector.

Table 5.3. Guideline: Step 2

Actions	Step 2
Engaging with Policy Makers	Step 2.1: Ongoing dialogue with government entities
	Step 2.2: Organize FOSS seminars and workshops
	Step 2.3: Establish 24/7 support
Public Policy Development	Step 2.4: Propose tax incentives and incentive policies for FOSS
	Step 2.5: Collaborate on the creation of interoperability standards and regulations

Implementation of Pilot Projects in Strategic Sectors

Objective: To demonstrate the feasibility and benefits of FOSS adoption through pilot projects in strategic sectors of government.

Table 5.4: Guideline: Step 3

Actions	Step 3
Identification of Sectors	Step 3.1: Select sectors such as public health and education for pilot projects
	Step 3.2: Set specific goals for each project
Continuous Monitoring and Evaluation	Step 3.3: Create a monitoring committee
	Step 3.4: Produce periodic reports on results and practices

Expansion and Long-Term Sustainability

Objective: To ensure the sustainable expansion of the use of FOSS in the public sector, ensuring the continuity of the benefits in the long term.

Table 5.5: Guideline: Step 4

Actions	Step 4
Scaling of Initiatives	Step 4.1: Develop a plan for expansion into other industries after the success of the pilots
	Step 4.2: Create a collaborative network in the public sector to maximize impact
Guarantee of Resources and Financing	Step 4.3: Seek ongoing funding through partnerships and innovation funds.