Customization of Generic Open Source Software for Health Sector in Developing Countries

A Practice Based Approach

by

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To my family, especially

my parents Madalena Mouzene and Benjamim Saugene

and

the memory of my siblings

Amelita Saugene and Almeida Saugene

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Acronyms and abbreviations

CoP	Community-of-Practice
DHIS	District Health Information Software
DHIS2	District Health Information Software version 2
GIS	Geographic Information Systems
Geodata	GIS data or spatial data
GPL	GNU General Public License
GDP	Gross Domestic Product
HIS	Health Information Systems
HISP	Health Information Systems Programme
HMIS	Health Management Information System
iHRIS	Integrated Human Resource Information System
ICT	Information and Communication Technology
IT	Information Technology
ITU	International Telecommunication Union
LMIC	Low and Medium Income Countries
MDG	Millennium Development Goal
MOH	Ministry of Health
MCH	Mother and Child Health
INASA	National Institute of Public Health
INE	National Institute of Statistics
NoP	Networks-of-Practice
NGO	Non-Governmental Organization
OgIS	OGUMANIHA Information System
OSS	Open Source Software
OpenLMIS	Open source Logistics Management Information Systems
OpenMRS	Open Medical Record System
WAHO	West Africa Health Organization
WHO	World Health Organization

Abstract

A consequence of globalization has been the increased use of generic software in multiple contexts. Customization is one of the activities adopted to make these systems to fit the local contexts. This activity is a non-trivial challenge, involving the need to engage with various technical and institutional issues. These challenges are magnified in the public sector context of low and middle income countries (LMICs), which face extreme challenges of human resource capacities, poor infrastructure, and inflexibilities in the institutional arrangements. Our understanding of these customization related challenges and the approaches to deal with them, remains limited.

A key aim of this thesis is to examine customization related challenges and approaches within the context of the public health sector of LMICs, and formulate a model that can help to guide customization and capacity-building efforts. To study software customization dynamics, a practice-based perspective was adopted and the notions of situated practice and networks of practice were take on as the analytical lenses.

The research took place as an interpretive study within the Health Information Systems Programme (HISP) action research framework. Empirical material is drawn mainly from three case studies carried out in healthcare organizations in Malawi, Mozambique and Guinea-Bissau, all related to a generic open source software called the District Health Information Software, developed and maintained by the University of Oslo. Data collection took place in the period between 2009 and 2012, and involved the use of multiple sources, including participant observation, actual customization work, interviews, artefact examination, brainstorming and reflexive discussions.

Key findings emphasise that while generic software systems provide several benefits, there are challenges related to weak skills and competence, software misfit, poor supporting infrastructure and others. Strengthening and sharing of experiences and ideas across different groups was an overarching principle. The first kind of practices included improvisation and *bricolage*, the querying for artefacts and requesting for help and were used to support work performance. Secondly, the interplay between different customization sites enabled the emergence of competence-building practices of cross-site interaction, tailored training and co-located learning. Finally, the practice of interaction across sites permitted the development of requirement that led to the customizability or strengthen of the generic software systems.

This thesis contributes to practice-based theory by (a) providing an alternative paradigm to study improvisation, the human-centred improvisation; (b) discussing the *situatedness* of software customization; (c) illustrating the boundaries spanned during customization; (d) discussing the process of participatory design during software customization; and (e) conceptualizing customization capacity-building as situated and clustered. The practical contribution of the thesis consists of a model that highlights the main building blocks of OSS customization, with especial focus on capacity-building. The model suggest combining the customizers knowledge with exposures to (i) the complexity of the sites and domains where the software will be applied, (ii) guests that support and help with the customization work, and (iii) environments where customizers can develop a broader view of their activity through inter-professional collaborations.

1. Introduction

This chapter is devoted to the introduction of the thesis. It starts by providing a brief background of the reported research, within which the motivation, the problem context and the research objectives and questions are presented. Furthermore, the chapter gives an overview of the theoretical perspective and the empirical contexts. The chapter ends with presentation of the summary of the thesis' contributions, and the document structure.

1.1. Research Background

1.1.1. Research Motivation

The tendency to spread businesses, technologies or philosophies throughout the world gave birth to a phenomenon which is known as globalization. Tremendous changes have been observed in various spheres of society with globalization affecting sectors of health, economy, politics and also software systems. The phenomenon has, for instance, encouraged companies and organizations working in the software sector, to both expand their business activities and develop systems that reach users from foreign countries. This have necessarily involved the challenge of building and using systems for multiple contexts, embedded within different socio-cultural, infrastructural, economic, as well as political systems.

This thesis is focused on the phenomenon of designing, customizing and using information systems for multiple contexts within the settings of public health in Low and Medium Income Countries (LMIC). Globalization can be argued to have significant implications in the public health sector, shaping the health of populations around the world (Koplan et al., 2009), for example through initiatives around disease control, health policy, and various information technologies for supporting care management and evidence based decision making. These institutions are supported by international donors with activities in multiple countries. These trends are broadly described under the label of 'global health'.

Various initiatives are on-going in this domain. For example, the Health Information Systems Programme (HISP) from the University of Oslo in Norway has been engaged in the process of strengthening Health Information Systems (HIS) in the South for more than a decade, and these efforts have touched more than thirty countries in Asia and Africa. A key component of these efforts has been the design and development of a free and open source software called District Health Information Software (DHIS) for use in these countries. Similarly, the OpenMRS (Open Medical Record System) was designed as a framework upon which medical records system can be developed. Other examples include the iHRIS

(integrated Human Resource Information System) developed by the Capacity Project in United States of America, to help LMICs to build and sustain the health workforce; the OpenLMIS (Open source Logistics Management Information Systems), an initiative launched by a global consortium of multiple donors and implementing partners named VillageReach to help in designing effective and sustainable supply chain systems for drugs and other commodities; the WHO ICD (International Classification of Disease) standard used to classify diseases and other health problems; and the HL7 (Health Level Seven) framework for the exchange, integration, sharing, and retrieval of electronic health information.

The adoption of such global systems, technologies, frameworks and standards, typically, takes place through a process of customization which refers broadly to the activity of modifying them to better suit the needs of particular tasks in local contexts. This process is non-trivial in its level of complexity.

Over the years, researchers have regarded health sector as a complex field, where its characteristics have strongly contributed to not so successful implementations of systems. Tsiknakis and Kouroubali (2009), for instance, state that healthcare environment is one of the most versatile industries, which is in constant flux and continuous change. Moreover, while Chilundo and Aanestad (2004) associate this complexity with the existence of multiple health programs such as TB, HIV/AIDS; Kimaro and Nhampossa (2007) and Mosse (2005) emphasize the human resources challenges surrounding the introduction of information systems in these settings.

Lessons from Information Technology (IT) projects, especially in LMICs emphasize multi-faceted challenges of weak human resources capacity, (in)flexibility, complexity of the public health domain, poor infrastructure, networks, donors influences (Kimaro & Nhampossa, 2007) and the socio-historic and political context (Mosse, 2005). Kimaro and Nhampossa (2007), also emphasize the challenges of the lack of flexibility of the tools and user-friendliness, and the lack of organizational control over the source-code. Thus, the existence of many interacting components, the heterogeneity (both in terms of range of tasks, and the ways that they can be performed) and inherent unpredictability contribute to the health sector to be regarded as a complex system (Runciman et al., 2007; Paige et al., 2012).

Thereby, at a time when many projects are being set-up with the goal of implementing generic software systems, little is known about the practices on how this customization can be best carried out. In generic software systems, expertise and practices are conceived as a combination of experiences and lessons from multiple implementations. Thus, since new adopters (end-users and customizers) may find themselves confronted with the highly

complex and, at first glance, not very transparent generic software systems, strategies on how to customize this to local contexts and tasks are demanded.

This thesis examines the process of capacity-building towards customization of generic software for LMIC contexts, the challenges experienced, and approaches to deal with these challenges.

1.1.2. The Problem Context

The problem context which this thesis investigates is the challenges and approaches towards the customization of generic software for different LMIC public health sector settings. Four dimensions of complexity involving technology, domain, human resources, and e-readiness are discussed.

The *technology complexity* dimension indicates the difficulties around the artefact being customized. Aiguier et al. (2008), stress that software systems are complex as they cannot be reduced to simple rules of property inference. According to Wirfs-Brock (2010), two major reasons contribute to this complexity: one, if the problem being solved requires complex solutions; and two, the software that is long-lived and not extended to support changing/growing requirements. Overall, I can say that, software complexity can result from the way information flows are modelled in the application, various interdependencies, lack of user-friendliness, design complexity, and structure of the source-code.

The *domain complexity* dimension refers to the challenge the health domain provides, including those impacting on the adoption of IT, such as scale of constant flux (Tsiknakis & Kouroubali, 2009), and heterogeneity both in terms of the range of tasks, and the ways that they can be performed (Runciman et al., 2007). For instance, the historical independence of healthcare organizations and the existence of autonomous units with little sharing of information (Grimson et al., 2000), has fostered a climate of fragmentation in the use of IT (Chilundo & Aanestad, 2004). For Paige et al. (2012) the complexity of the healthcare system is due to its susceptibility to emergent activities which leads to increasing rates of requirement change, multiplicity of components (e.g., numbers and types of stakeholders), unpredictability and increasing size of the system.

The *human resource capacity* dimension highlights the influence of people skills and competence in the execution of software customization. Over the years, various researchers (e.g., Braa et al. (2007), Heeks (2002) and Sahay and Walsham (2006)) have advocated the need for technically skilled people. Mosse (2005), while studying the adoption of computer-based HIS in Mozambique, asserted the influences of the socio-historic and political context, such as how colonization contributed to exclusion of people and a serious shortage of

professional staff in the post-independence period and subsequently by the civil war. Kimaro and Nhampossa (2007), have emphasized the adverse influence of donors on the lack of technical skills.

The *e-readiness* dimension reflects the readiness of LMICs to adopt Information and Communication Technology (ICT) based systems. Bottlenecks include the lack of appropriate infrastructure, for limited access and long waiting times and costs to obtain access to contemporary technologies, such as internet and mobile phones (RAJESH, 2003). Autocratic government structures adversely uptake technology, as it also affect and creates fear of potential visibility of information. Financial barriers also hinder IT adoption including dependence on foreign assistance (Kimaro & Nhampossa, 2007; Baskaran, 2001). Cultural factors such as language and diversity also impede IT adoption (Grazzi & Vergara, 2012; Heeks, 2002), which is also magnified by workforce (Liese et al., 2003; Huddart & Picazo, 2003) and budget crises (Unger & Criel, 1995).

While the above highlighted problems provide important particularities characterizing this study domain, they make the process of customization a task of non-trivial complexity. The next section outlines the research focus.

1.1.3. Research Focus

This thesis has the following three research aims. Firstly, from the perspective of LMIC organizations, to understand how software customization is performed, and the different interactions involved. Secondly, to investigate the challenges involved in performing customization tasks. Thirdly, to formulate a model that can help to guide customization of generic software systems in the public health domain of LMICs. These research aims lead to the formulation of the following research questions:

RQ1: What potential and constraints exist in customizing open source software systems for and by healthcare organizations in LMICs?

RQ2: What are effective approaches to deal with software customization processes?

RQ3: How can customization sites be organized to strengthen their capacity for carrying out customization?

These questions were studied, firstly, through case studies of three customization projects described in Section 1.3. Each, case employed different data collection methods including and participatory observations through conducting software customization work, interviews and reflexive discussions. The empirical studies spanned over two and half years. Multi-case

analysis was adopted to develop inferences around challenges and approaches to customization both within and across cases.

1.2. Theoretical Perspectives

The dynamics between technology and its contexts has been a long standing problem in understanding IT adoption processes. Because of its special capacity to "understand how organizational action is enabled and constrained by prevailing organizational and societal practices" (Vaara & Whittington, 2012, pg. 286), a practice-based perspective was adopted in this research to study these dynamics. Such a perspective helps to: (a) access actions in specific places and times, and develop generalizable principles of how action might unfold in other settings (Parmigiani & Howard-Grenville, 2011); (b) access people's situated behaviour and explore how problems are solved or how competencies are constructed in practice (Corradi et al., 2010); and, (c) access the tools and artefacts that people use in doing customization work (Jarzabkowski, 2005). This thesis focuses specifically on understanding the practices adopted by actors when shaping the software customization process. Practices, in this regard, refers to "routine bodily activities made possible by the active contribution of an array of material resources" (Nicolini, 2013, pg. 4) and represents the basic units of analysis for understanding organizational phenomena in practice-based studies. The analytical lenses adopted can be described through the perspectives of *situated practice* and *networks of practice*.

As situated practice, the research was specifically concerned with the study of practice as a flow of activities (Jarzabkowski, 2005), which constitute the day-to-day activities of software customizers through the notion of *situatedness*. Activity is seen to both shape and be shaped by the society within which it occurs (Suchman, 2007), and is performed "by engaging more deeply in the empirical details of organizational life on the ground" (Orlikowski, 2010, pg. 24). Contributing to the understanding of situated practices, are the notions of *bricolage* and *improvisation*. While bricolage is used to understand how customizers use what is in their hands to perform work (Rolland & Monteiro, 2002); improvisation concentrates on understanding actions or work performed after enhancing skills (Chelariu et al., 2002).

Given that the customization of generic software systems involves working across settings and domains, the network of practices approach allows to study the attitudes and practices of people that enter into territory in which they are unfamiliar and, to some extent unqualified (Suchman, 1994; Tsui & Law, 2007) and introduce elements of one practice into the other (Fisher & Atkinson-Grosjean, 2002). The perspective helps also to contextualize capacity-

building actions by understanding interactions between the 'expert' and 'local' dimensions of people's knowledge (Corradi et al., 2010). Network of practices perspective enables stronger contextualization of the software customization process and is done through the notions of *boundary spanner* and *boundary object*. While boundary spanner refers to individuals that enable crossing to occur, i.e., the developers, customizers and end-users; boundary objects embody the artefacts exchanged and used to support the crossing process.

In summary, the above analytical elements conceptualize software customization as a socially accomplished activity where actions are not only situated in contexts, but also distributed across multiple actors (humans and non-humans). Broadly, each of the analytical elements provides different but complementary angle from which to examine customization as practice. The analysis of their interrelationships, as it is argued in this thesis, helps to understand the dynamics surrounding the customization of software system in and for the healthcare domain of LMICs.

1.3. Empirical Context

The research presented in this thesis has been performed under the umbrella of an on-going action research project called HISP. HISP is a global south-south-north collaborative network of institutions comprising of various entities including universities, Ministries of Health, international agencies like the World Health Organization (WHO) and the Norwegian Agency for Development Cooperation (NORAD), and in-country implementing agencies (Braa & Sahay, 2012). The network is coordinated by the Global Infrastructures Research Group at the Department of Informatics of the University of Oslo and aims to support the improvement of healthcare systems in developing countries.

Towards that, HISP has developed the DHIS software framework. In this thesis DHIS and DHIS2 (the version 2 of DHIS) are used interchangeable to refer to a generic software system that has been customized and deployed in various countries such as Kenya, Ghana, Mozambique, India, Tanzania, Malawi and Guinea-Bissau. Empirical material for this thesis is drawn, mainly, from projects performed in three countries: Mozambique, Malawi and Guinea-Bissau, which are now briefly introduced and elaborated later in Chapter Four.

Guinea-Bissau: DHIS2 was adopted as an effort between the Government of Guinea-Bissau through its National Institute of Public Health (INASA), the West Africa Health Organization (WAHO) and the HISP project. The case study analysed the national HIS as a whole, with a key focus on the customization practices around DHIS.

Malawi: The aim was to understand the practices adopted while customizing DHIS2 to manage healthcare data collected by the Ministry of Health and the HIV/AIDs programme. This study focused, firstly, on challenges and approaches used to customize the *OpenHealthMapper* module of the DHIS2, and also the DHIS2 Tracker. Core customization activities consisted of analysing the business processes, discussing requirements with the end-users, performing the adaptation of the DHIS2 to fit end-user needs and demands, and finally sharing with the global HISP community the outcome of the activities.

Mozambique: A group of seven NGOs (known as OGUMANIHA) led by the World Vision adopted DHIS2 as a framework to develop a software application that could be used to manage project indicators implemented under the auspices of the Ministries of Health, Agriculture, and Public Works and Housing. By studying this project, my aim was to identify the customization and management practices in an organization that did not have a formal contact/agreement with HISP, the DHIS2 software developer.

These three cases taken together help to understand the dynamics surrounding the customization of DHIS2 for healthcare sector of three LMICs, including patterns of challenges and approaches (such as related to problem solving, capacity building and governance) experienced. These were further informed by my engagement with DHIS2 also in other countries where also DHIS2 and HISP are involved.

1.4. Research Contributions

This section gives an overview of the papers included in this thesis and the thesis' contributions.

1.4.1. Selected Papers

This thesis consists of the following six papers.

Paper I: SAUGENE, Z. & SAHAY, S. "The Challenge of Customizing Global Open Source Software to Local Country Contexts: The Case of DHIS GIS for Health Management". *IFIP WG 9.4: Social Implications of Computers in Developing Countries.* Kathmandu, Nepal.

Paper II: SAUGENE, Z., JUVANE, M. & ERNESTO, I. "Factors affecting Geographic Information Systems implementation and use in Healthcare Sector: the Case of OpenHealthMapper in Developing Countries". *In:* RAJABIFAD, A. & COLEMAN, D. (eds.) *Spatially Enabling Government, Industry and Citizens: Research and Development Perspectives.* USA: GSDI Association Press.

Paper III: SAUGENE, Z. & KAASBØL, J. "Extending System Capacity in Low Resource Environments through 'Flexible' Competency Building in Open Source Applications Customization". *Int. J. of Healthcare Technology and Management (IJHTM), Special Issue on: "Extensible Electronic Health Records". (in Review)*

Paper IV: SAUGENE, Z. "The Influence of Community Structures in the Development of Software Customization Capacity". *The Journal of Community Informatics – Special Edition on Community Informatics in Southern Africa. (in Review)*

Paper V: SAUGENE, Z. "Leveraging from customization to inform Generic Software Systems development: DHIS tracker and its introduction in healthcare". *IFIP WG 9.4: Social Implications of Computers in Developing Countries.* Montego Bay, Jamaica.

Paper VI: SAUGENE, Z., KAASBØL, J. & SAHAY, S. "Software customization in healthcare domain of low-resource settings: a model for building capacity". *Journal of Information Technology for Development, Special Issue on ICT and Development in Africa. (in Review)*

Overview of the papers is presented in Chapter Five and the complete papers are as attachments in the Appendixes.

1.4.2. Contributions to Theory and Practice

The key contribution of this research lies in developing a model to understand customization of generic software for public health settings in LMICs. As mentioned, this empirical investigation is based on three separate studies. These studies, however, do complement one another, thus this thesis provides a more comprehensive view of software customization.

Broadly, this thesis proposes implications relevant to practice-based theory. Five theoretical contribution areas are developed. First, the thesis provides an alternative paradigm to study improvisation, which I term as human-centred improvisation. Building on the understanding that software customization is socially situated, the second contribution take a network perspective to discuss the *situatedness* of software customization. Third, the thesis contributes to the understanding of whether boundary spanners should be formally nominated or emerges from practice, as well as understanding of boundaries that are spanned to building organization competence. The fourth contribution discusses the process of participatory design during the customization of generic software systems. Finally, the thesis contribute to the literature on learning-by-doing by conceptualizing software customization capacity-building as situated and clustered.

The practical contribution of the thesis consists of a framework that highlights the main building blocks of OSS customization, especially when it is performed in and by healthcare

organizations of LMICs. These building blocks include performing customization work, building capacity and contributing to the customizability of the generic software system. A specific model is suggested for dealing with capacity building. The model combines the team skills and knowledge with three overlapping approaches: guest - having guest people supporting the customization while promoting team practice and collaborative problem solving; cluster - helping customizers to appreciate the balance between their perspectives and others as they develop a broader view of practice trough inter-professional collaboration; and *situatedness* - revealing the realities of the practice through exposure to the domain complexity.

1.5. Thesis Structure

This thesis is composed of six chapters. This chapter has outlined the research approach, and has articulated the intent and focus of the research as well as the contributions. Chapter Two puts the research in a context. Chapter Three presents relevant literature on software customization, and an overview of the conceptual framework adopted. Chapter Four outlines the methodology used, including a description of research strategy, the case study sites, data collection methods, and the data analysis strategies. Chapter Five presents key findings from the different papers included in this thesis. Chapter Six describe the contributions and conclusions of the thesis.

2. Research Context

This chapter presents the context within which the research was located. As depicted in Figure 2.1, two broad contexts are empirically relevant. First, the research focuses on health systems, generic software systems and the work performed by organizations such as the WHO, WAHO, Global Fund, and HISP. Secondly, the research operates within a framework of three countries, Guinea-Bissau, Malawi and Mozambique, that customized DHIS2 to address their data management needs and demands.

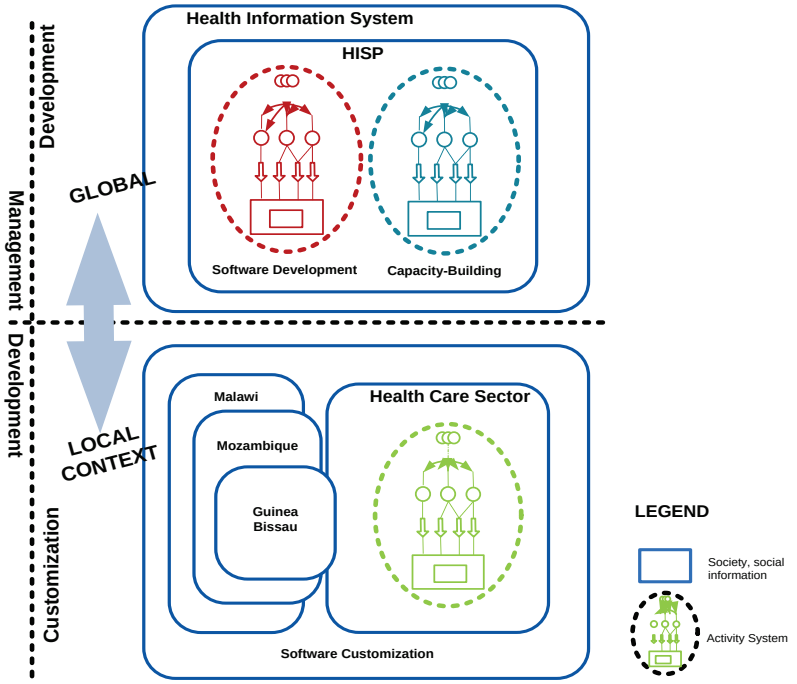

Figure 2-1: Overview of the research context [Symbols used in this figure are borrowed from activity system representation (Korpela et al., 2002) and the landscape methodology (Korpela et al., 2008)]

The presentation of these contexts is structured as follows. The first section presents a brief introduction about health systems. Section two presents a brief review about generic and free/open source software systems for health. Finally, the third section presents the profiles of the countries in which the customization of DHIS2 were carried out. Besides country demographic data, socio-economic, health status and ICT infrastructure of the country is presented.

2.1. Health Information Systems

2.1.1. Public Health Systems

Public health efforts of governments are to provide protection, promotion and restoration of peoples' health. To fulfil this mission, a health system approach as described below is relevant (Melnick, 2003):

> "A health system consists of all organizations, people and actions whose primary intent is to promote, restore or maintain health. This includes efforts to influence determinants of health as well as more direct health-improving activities. A health system is therefore more than the pyramid of publicly owned facilities that deliver personal health services. It includes, for example, a mother caring for a sick child at home; private providers; behaviour change programmes; vector-control campaigns; health insurance organizations; occupational health and safety legislation. It includes inter-sectoral action by health staff, for example, encouraging the ministry of education to promote female education, a well-known determinant of better health" (WHO, 2007, pg. 2).

Traditionally, health systems are the concern of governments, through their administrative levels and structures. In a country like Guinea-Bissau, for instance, this process is done across three levels - facility, region and national, while on others there can be 4-6 levels. As depicted in Figure 2.2, health data travels across the levels starting from the operational level up to the strategic level, with expected transformations for data to information to action.

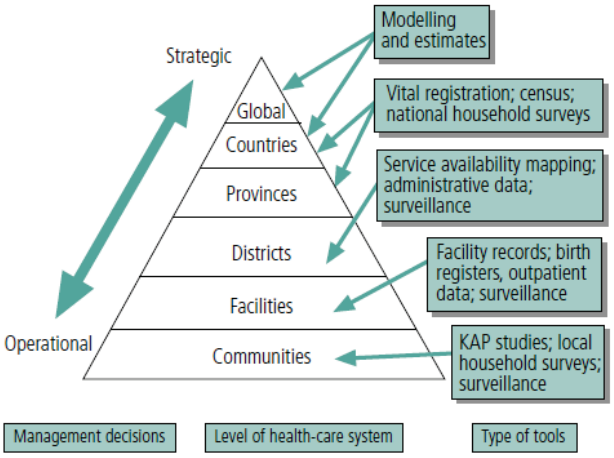

Figure 2-2: Data Needs and Sources at Different Levels of the Health Care System [Source: AbouZahr and Boerma (2005)]

Regardless of how health systems are organized, responsibilities for providing services; developing health workers skills; mobilizing and allocating finances, and ensuring leadership and governance are shared across levels (WHO, 2007). In Guinea-Bissau, for instance, the facility level comprises of community initiatives and health facilities providing different types of interventions. Information, at this level, is expected to support effective management of the health facilities and also the various community initiatives. The regional level which is made of hospitals, regional directorates of health and health teams, is responsible for examining the regional situation, providing plans for human resources, ensuring the provision of material and financial resources, and monitoring and evaluation. The regional health teams are responsible for supervising and monitoring standards and the implementation of treatment protocols in regional hospitals and health facilities. Finally, the national level is constituted of national programmes, the national hospitals, and reference facilities. Management at this level is ensured by the Ministry of Public Health with its directorates, and services departments. This level is responsible for setting guidelines for regions concerning national priorities, financial and human resources, programming and monitoring and evaluation. The ministry also interfaces with global entities like WAHO and WHO.

Despite enormous investments in setting up health systems, i.e., defining the levels, the activities carried out by each level, and so on, the overall performance of health systems varies from country to country. It is possible to find countries with similar structures (e.g., same number of care levels), levels of income, education and health expenditure differing in their ability to attain key health goals (Murray & Frenk, 2000).

In order to assure that institutional goals are met HIS play a key role. Lippeveld et al. (2000) assert that the improvement of healthcare management decisions at all health system levels is enabled through these HISs. They define HIS as a set of organized elements (e.g., components and procedures) with the objective of generating information which will improve health care management decisions at all levels of the health system.

The Health Metrics Network, advocates that a HIS should integrate (HMN, 2013):

- Resources: They include legislative, regulatory and planning frameworks required for a fully functioning HIS comprising of personnel, financing, logistics support, ICTs, and coordinating mechanisms within and between the six components.
- Indicators: A core set of indicators and related targets is the basis for a HIS plan and strategy. Indicators need to encompass determinants of health; health system inputs, outputs and outcomes; and health status.

- Data Sources: These include (a) population-based approaches (censuses, civil registration and population surveys) and (b) institution-based data (individual records, service records and resource records). Various forms of data collection approaches are involved including occasional health surveys, research, and information produced by community based organisations.
- Data Management: This covers all aspects of data handling from collection, storage, quality-assurance and flow, to processing, compilation and analysis.
- Information Products: Data must be transformed into information that will become the basis for evidence and knowledge to shape health action.
- Dissemination and Use: The value of health information is enhanced by making it readily accessible to decision-makers and enabling its use.

2.1.2. Global Health Initiatives

Global health is a research and practice area that places priority on improving health and achieving equity for all people worldwide. It involves many disciplines within and beyond health sciences such as social and behavioural sciences, economics, history, environmental sciences and public policy, and promotes interdisciplinary collaboration (Koplan et al., 2009).

Global health as a phenomenon highlights transnational health issues, determinants, and solutions. Issues such as climate change, urbanisation and polio eradication are examples of global health initiatives influenced by transnational determinants (Koplan et al., 2009) such as disease control, health policy and ICT.

Various organizations and initiatives including the WHO, the Health Metrics Network (HMN), the WAHO, Global Fund, Global Alliance for Vaccines and Immunizations (GAVI), and the US President's Emergency Plan for AIDS Relief (PEPFAR) have made health systems strengthening their main agendas. HISP too represents a global initiative focussing on HIS strengthening. Some of these initiatives are now briefly described.

- The WHO is a specialized agency of the UN that is concerned with public health. In addition to supporting health systems strengthening in individual member states, internationally the agency plays three main roles. First, it produces global norms, standards and guidance. Second, builds and shapes international systems (e.g., for identifying and responding to outbreaks and emergencies) that impact on health. Third, works with other international partners to support health systems strengthening and to support the above two roles (WHO, 2007).

- Established in 2005, HMN was a global partnership operating as a network of global, regional and country partners. The network was dedicated to strengthening HIS of countries. As a country-owned and partner-driven platform, it assessed HIS and sustainably improves them (HMN, 2013). For that, HMN provided technical and financial support to countries for HIS strengthening. Today, HMN has closed down.
- The Global Fund, GAVI and PEPFAR are three of the world largest initiatives that emerged due, in part, to the emergence of a major new funder for global health - the Gates Foundation - which emphasized a technologically driven approach and provided billions of dollars of funding for disease-specific initiatives (Hafner & Shiffman, 2013) with implications for health systems strengthening. For instance, between 2005 and 2007, GAVI disbursed US$315 million in 53 countries; in 2005 Global Fund disbursed US$83 million; and PEPFAR approved US$520 million between 2009 and 2010 (Hafner & Shiffman, 2013).
- Since 1994, HISP has devoted most of its time in designing and developing an open source software framework known as DHIS (overview of this framework is provided in Chapter Four). The framework became a national standard tool for the management of health system in several countries in Africa and Asia. HISP also developed a capacity-building approach known as networks-of-action (Braa et al., 2004), which enabled a wide range of healthcare organization, researchers and local country people into practical tasks, to share products, resources and experiences with each other.

2.2. Generic Open Source Software Systems

A number of generic information systems such as DHIS, OpenMRS, iHRIS and OpenLMIS, are being widely promoted as part of various global HIS initiatives. This is a response to needs of software systems that are *extensible* - to support quick updates and additions to address new needs; flexible - to support growing range of requirements; *portable* - to reduce the effort of constant adaptation; *reliable* - to ensure that applications are robust and tolerant to faults; *scalable* - to enable application to handle larger numbers of clients simultaneously; and *affordable* - to ensure that software (acquisition and evolution) costs are not prohibitive (Schmidt et al., 2004). Next I first present a brief overview of generic software systems and then one of the members of its family known as open source systems.

2.2.1. Generic Software Systems

Generic software systems, as opposed to custom systems - software systems that target specific users or group of users (Bansler & Havn, 1994), are tools designed and developed for

general use, i.e., applied to a wide community (Daniels et al., 2010). Examples of these tools include Microsoft Office suite, Enterprise Resource Planning packages, among others.

Generic software systems are delivered by developers in form of frameworks, i.e., as reusable and "semi-complete" tools that can be specialized to produce custom applications (Schmidt et al., 2004; Calefato & Lanubile, 2009). The development of most of them follows the principles of modularity, reusability and extensibility (Fayad & Schmidt, 1997), ensuring standardization, i.e., permitting them to be applied to a wide community, reducing development costs, and providing access to a larger group of developers to their customers (Calefato & Lanubile, 2009; Eoin et al., 2006). In particular, generic software systems allow for (Schmidt et al., 2004): *design reuse*; *implementation reuse*; and *validation reuse*. They benefit *software designers* by offering the possibility of adapting systems' functionality to changing user needs and requirements (Dourish, 1995). Designers benefit from external resources being used to fit the software adaptation into local use contexts. Likewise, by leveraging the domain knowledge and prior experiences presented in the frameworks, designers can create domain-specific solutions for particular problems (Schmidt et al., 2004).

Generic software systems also benefit *software maintainers* by enabling the offloading of maintenance tasks to 'local developers'. Further benefits of generic software systems go to *software users* who can change, add and delete features as required (Fischer & Scharff, 2000; Dourish & Edwards, 2000). Fischer and Scharff (2000) assert that customizable software system allows "users to invest the world with their meaning, to enrich the environment with the fruits of their vision and to use them for the accomplishment of a purpose they have chosen" (Fischer & Scharff, 2000, pg. 398).

Often generic software systems are developed on open-source software platforms which are now described.

2.2.2. Open Source Software

Open Source Software (OSS) is a name given to a movement that combines two initiatives: free programs and open source software enabling software packages distributed with its source code, often under a license that sets conditions for modification, reuse and re-distribution (Subramanyam & Xia, 2008). This movement is gaining momentum globally and enabling the spread of generic software systems.

The notion of free software, created by Massachusetts Institute of Technology (MIT) researcher Richard Stallman, is based on the idea that a software program and its source code are scientific knowledge that cannot be hidden. If hidden from the public, we run the risk of

having few people controlling knowledge. Four levels of that freedom include: using the software, changing the software according to personal needs, improving the software and to distribute copies to the community. To guarantee these freedoms, OSS relies on GPL (GNU General Public License) model which states that every program that uses fragments of programs licensed under the GPL must also gain the GPL status (Rosen & Einschlag, 2004). Besides that, the model reinforces social consciousness and encourages cooperation and community spirit of sharing knowledge, and limits lock-in by proprietary software vendors (Chen et al., 2010).

In open software, the source-code is protected by copyright law, which is very different from free software. Popular open software licenses include Berkeley Software Distribution, MIT, Apache, Mozilla Public License, Common Public License, Academic Free License and Open Software License.

The provision of software products under OSS movement represents a global sourcing strategy (Hauge et al., 2010) in which communities collaborate in solving their own as well as shared technical problems, and freely reveal their innovations to others (Hippel & Krogh, 2003). This voluntarism is also known as 'bazaar' and is claimed as being cost-effective and supporting the development of more reliable software.

As result of these benefits, OSS is now being also promoted by global agencies such as Global Fund and WHO, and many LMICs are also engaging to adapt open-source based applications.

2.3. Profile of Countries – My research sites

To characterize the local settings where this research took place, the dimensions of economy, health status and ICT infrastructure are considered for each country.

2.3.1. Guinea-Bissau

The Republic of Guinea-Bissau is located in the West Coast of Africa, bordering the Atlantic Ocean to the west; north and east by Senegal and the Republic of Guinea Conakry (see Figure 2.3). With the total area of 36,125 square kilometres, in 2012 the population of the country was estimated to be around 1,628,603 inhabitants (InternetWorldStats, 2012).

Portuguese is the official language, but the commonly spoken language is Portuguese Creole. As a former Portuguese colony, the country gained its independence in 1974, and since then has experienced considerable political and military upheaval, including the military coup of 12 April 2012. According to 2010 estimates a total of 54.2% of the population were literate (IndexMundi, 2012).

Economy overview: The economy of the country depends mainly on farming and fishing (CIA, 2012; IndexMundi, 2012). From 2004 to 2006, economic growth was, respectively, 2.2%, 3.5% and 1.8%, not matching the 2.3% population growth rate.

GDP per capita fell by about 25% from the 90's, standing at around US$ 539.4, in 2010. The recurrent fighting has destroyed much of the country's infrastructure and caused widespread damage to the economy (CIA, 2012), while simultaneously creating large donor dependencies (IndexMundi, 2012).

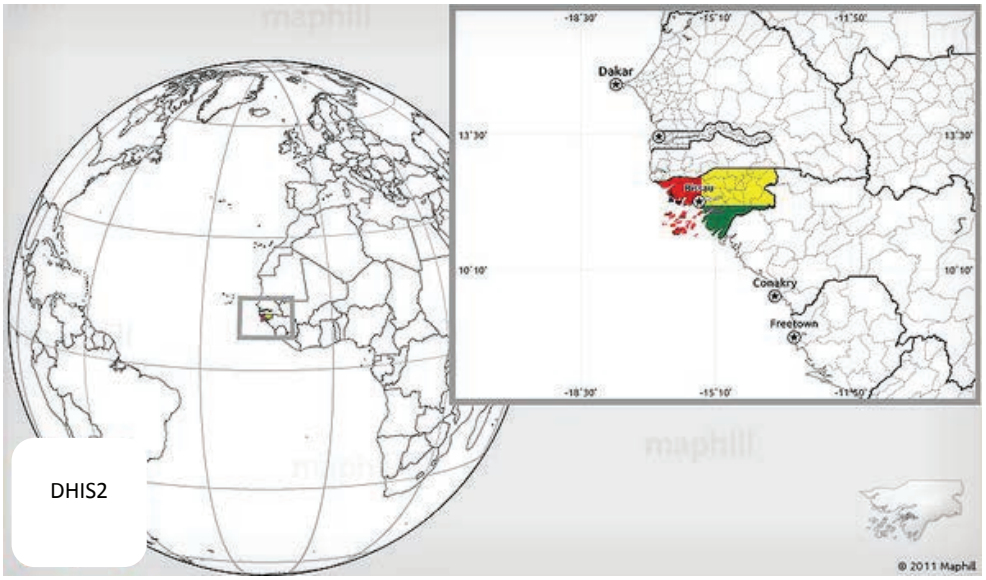

Figure 2-3: The geographical location of Guinea-Bissau

Public health issues and concerns: The epidemiological situation of Guinea-Bissau is marked by the predominance of communicable diseases, including malaria, diarrhoea, acute respiratory infections, HIV/AIDS and associated tuberculosis.

Malaria is undoubtedly the biggest concern and the leading cause of morbidity, mortality, disability and absenteeism. Infections and diarrheal diseases are respectively the second and third leading causes of infant and child mortality. Malaria, acute respiratory infections and acute diarrheal diseases are responsible for 65% of deaths amongst the infant and adolescent population (OMS, 2004).

According to the National Institute of Statistics (INE) and UNICEF, neonatal mortality rate is 45 per 1000 live births, and post-neonatal mortality of 19 per 1000 live births. This shows that three quarters of all child deaths occur during the first month of life. Infant mortality rate is 63 per 1000 live births and the rate of child mortality (under 5 years) is 116 per 1000 live

births: which means that 1 in 16 children die before reaching the age of one year, while 1 in 9 children did not survive their fifth birthday (INE & UNICEF, 2010).

The fertility rate of adolescents is 141 per 1000, and the percentage of early pregnancy (before 18 years) is 33%. While 41% of deliveries are conducted at health facilities, 58% are still conducted in family homes (INE & UNICEF, 2010). The maternal mortality rate is estimated to be between 405 to 818 per 100 000 live births (OMS, 2008). These deaths are mostly associated with direct obstetric complications (bleeding 25%, puerperal infections 15%, 13% eclampsia, and 8% foetal-pelvic disproportion), but are also linked to malaria, anaemia and other nutritional deficiencies, among others (OMS, 2004).

Despite efforts being made to improve the health status of the population, service coverage is estimated at 40% for a radius of five kilometres, a situation exacerbated by poor conditions of roads and poor means of communication, especially for emergency situations.

ICT infrastructure landscape: Guinea-Bissau, in 2005, had a total of 0.2 per 100 inhabitants with a computer (IndexMundi, 2012), which increased with the advent of mobile devices. In 2010, 39.5 per 100 inhabitants were telephone subscribers (UNSD, 2012), which increased to 56.2 per 100 inhabitants in 2011(ITU, 2013).

Internet services were introduced in 1997. In 2011 the country had 37,123 internet users corresponding to 2.3% of the population per International Telecommunication Union (ITU) (InternetWorldStats, 2012). Currently, internet access is mostly available in Bissau, the capital, with limited connections in other regions and villages. The development of these services is limited due to the country's lack of electricity. No undersea cable is slated to connect for Guinea-Bissau (OAFRICA, 2012).

To date little has been done by government toward the improvement of infrastructure and ICT policies, or the creation of an information society (OAFRICA, 2012) despite the UN support efforts (WHO, 2010). Significant challenges to date remain in building and enabling an environment to support ICT adoption due to the lack of a stable supply of electricity, high costs of Internet provision as well as lack of ICT skilled personnel.

2.3.2. Malawi

The Republic of Malawi is located in southeast Africa, landlocked between Zambia in the west, Mozambique in the east, south and south-west and Tanzania in the north (see Figure 2.4). It has an area of 118 484 square kilometres, of which 94 276 square kilometres is land and the remainder is water.

The country is divided into three administrative regions: Northern, Central and Southern Regions with six, nine and thirteen districts respectively (see Figure 2.4).

Projections from 2012 show that its population is around 16,323,044 (InternetWorldStats, 2012). The official language is English, but there are other languages spoken such as Chichewa, Tumbuka, Lomwe and Yao. Estimates from 2010 indicate that 74.8% of the total population is literate (IndexMundi, 2012).

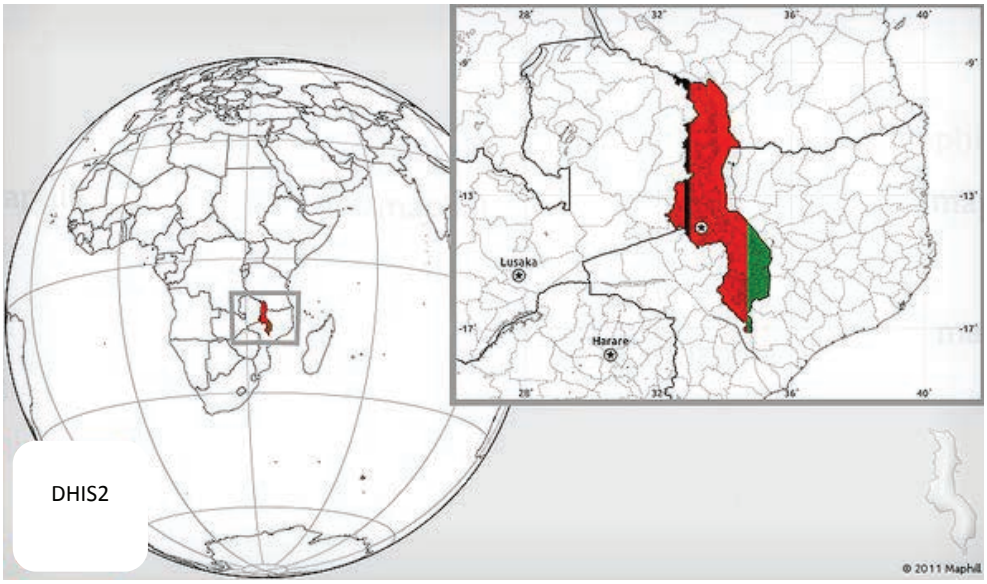

Figure 2-4: The geographical location of Malawi

Economy overview: Malawi ranks among the world's least developed countries with 80% of the population living in rural areas, with 39% under the poverty line in 2009 (IndexMundi, 2012). Fourteen per cent of the population in urban areas and 43% of rural population live below the poverty line. In 2010 the Gross Domestic Product (GDP) per capita was US$ 357.

The government has in recent years managed to reduce some of the economic development problems. However, in 2009 the country experienced some setbacks including shortage of foreign exchange, inability to pay for imports (CIA, 2012; IndexMundi, 2012), which contributed to fuel shortages, unreliable power, water shortages, poor telecommunications infrastructure, and high costs of services. Moreover, due to a negative IMF review on governance issues, donors suspended general budget support, which was about 36% of government revenue (CIA, 2012).

Public health issues and concerns: Malawi, like much of sub-Sahara African countries, faces a growing burden of disease, characterized by a high prevalence of communicable

diseases including HIV/AIDS, malaria and tuberculosis; high incidence of maternal and child health problems; an increasing burden of non-communicable diseases; and resurgence of neglected tropical diseases (WHO, 2009b).

HIV prevalence in adults is estimated at 12%. Heterosexual contact is the principal mode of HIV transmission, while mother-to-child transmission accounts for about 25% of all new HIV infections (WHO, 2009b). Annually, close to 28 000 cases of all forms of Tuberculosis are notified countrywide, and about 70% of these cases are HIV positive (WHO, 2009b). Moreover, malaria alone accounts for 40% of outpatient consultations in health facilities nationally (Government-of-Malawi, 2010).

According to Office and Macro (2011), the maternal mortality ratio in the country was at 675 deaths per 100 000 live births, contributed-to by haemorrhage, infection, unsafe abortions, pre-eclampsia/eclampsia and obstructed labour. Teenage motherhood is at 35% and accounts for 20% of maternal deaths, contributed to by low levels of literacy amongst women (Office & UNICEF, 2008).

While under-five mortality rate was estimated at 112 per 1000 live births in 2010, infant mortality rate was 66 per 1000 live births in the same period (Government-of-Malawi, 2010). The major causes of infant deaths are pneumonia (23%), underweight (22%), diarrheal diseases (18%) and malaria (14%). The Government-of-Malawi (2010) shows that the country may achieve the Millennium Development Goal (MDG) targets if such decreasing trends for under-five mortality rate and infant mortality rates continue. Despite these achievements, challenges still remain and are due to poor facilities, lack of equipment, lack of qualified human resources and weak management.

Staffing in Malawi is the lowest in the region with two physicians and 59 nurses per 100 000 population (WHO, 2009b), who are also unevenly distributed across the country. Although it is reported that 50% of deliveries are conducted by skilled health attendants, the quality of care remains a concern. In 2005 only 18.5% of women with obstetric complications were treated in emergency obstetric care (EmOC) facilities. Access to health services is limited and only 46% of the population lives within five kilometres of a health facility (WHO, 2009b).

The generation and use of information for decision-making is constrained by inadequate resources. The total per capita expenditure on health that stood at US$ 20 in 2004/05 falls short of the US$ 34 recommended by the WHO Commission on Macroeconomics and Health for LMICs. The Total Health Expenditure per capita is also not adequate to cover the Malawi Essential Health Package that is estimated to cost about US$ 17.5. About 60% of the Total

Health Expenditure is obtained from external sources. As at 2004/05, the government Total Health Expenditure as a percentage of total government expenditure was about 9.3%; far below the Abuja target of 15% (WHO, 2009b).

ICT infrastructure landscape: Telecommunication infrastructure in the country is not adequate. Malawi had, in 2004, a total of 1.3 per 1000 inhabitants with a computer (IndexMundi, 2012). In 2010, 21.5 per 100 inhabitants were telephone subscribers (UNSD, 2012) which increased to 25.7 per 100 inhabitants in 2011 (ITU, 2013). The first Internet connection for an e-mail service was established in 1993 (Bichler, 2008a). Internet users as of Jun/2010 were 716 400 corresponding to 4.5% of the population (InternetWorldStats, 2012).

However, connectivity is an enormous barrier for ICT diffusion in Malawi, contributed-to by the lack of appropriate ICT infrastructure, inexistence of proper policies and laws, shortage of skilled ICT manpower, and strong donor dependencies (Bichler, 2008b; Dzidonu, 2003). Access to Internet used to be based on satellite services, making the service very expensive and extremely slow (Bichler, 2008a). Currently Internet is mostly provided through a combination of satellite and fibre optic cables.

Bichler (2008a) states that the Malawian telecommunications infrastructure is not really capable to accomplish services such as e-Health. However, several ICT initiatives are being rolled-out by government including Government Wide Area Network, telecenters in some districts, data centre for public administration (Mtingwi & Belle, 2012), and DHIS for strengthening HMIS (Muyepa, 2006).

2.3.3. Mozambique

The Republic of Mozambique is located in the southern region of Africa and is bordered by the Indian Ocean, over approximately 2800 km (see Figure 2.5). It has about 4330 kilometres of land bordering with Tanzania, Malawi, Zambia, Zimbabwe, Swaziland and South Africa.

With a total area of about 799,380 square kilometres, projection shows that the country had in 2012 a population of about 23,515,934 distributed across ten provinces and the City of Maputo, which has the status of a province and has 128 districts (InternetWorldStats, 2012).

Portuguese is the Mozambican official language, but there are a lot of other indigenous dialects. Large-scale emigration, economic dependence on South Africa, a severe drought, and a prolonged civil war have hindered the country's development until the mid-1990s (CIA, 2012), including literacy which, in 2010, was estimated at 56.1% (IndexMundi, 2012).

In Mozambique, my DHIS2 research site was Zambézia province which is located in the central region of the country (see Figure 2.6). The province is one of Mozambique's poorest

and the second most populous province, with 3,892,854 inhabitants (2007 Census). The rural environment in Zambézia is resource constrained, with extremely limited human resources, poor healthcare coverage, lack of opportunities and infrastructure for economic development, and vulnerability to food insecurity.

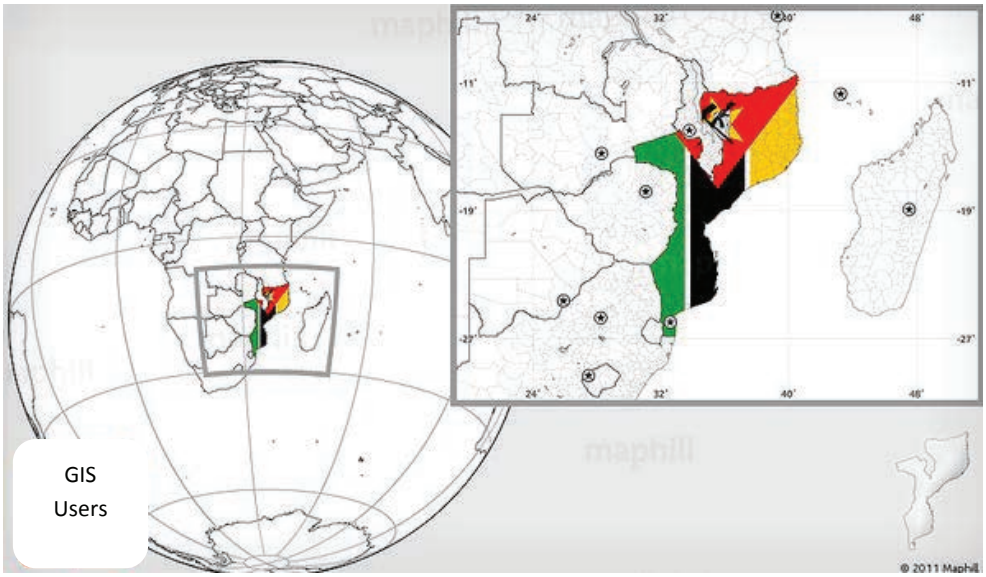

Figure 2-5: The geographical location of Mozambique

Figure 2-6: The Province of Zambézia in Mozambique

Economy overview: At independence, in 1975, Mozambique was one of the world's poorest countries, and this exacerbated by the civil war that lasted from 1977 to 1992. With the end of the war and the multi-party elections in 1994, the government embarked on a series of macroeconomic reforms. These steps, combined with donor assistance and with political stability, led to dramatic improvements in the country's growth rate, reported at 7.6% and an average annual per capita income of 5% in the period 2005-2009. Despite this growth, the country remains one of the poorest countries in the world, and was ranked in 184th position among 187 countries according to the Human Development Report of United Nations Development Programme (UNDP) in 2011 (Observatory, 2013). More than half of its annual budget is dependent upon foreign assistance. In 2008, 54% of the population remained below the poverty line (CIA, 2012; IndexMundi, 2012), steadily declining from 69% in 1997 to 54% in 2003, but stabilising during 2003-2009. The increasing cost of living prompted citizens to riot in September 2010, after fuel, water, electricity, and bread price increases were announced. In an attempt to contain the cost of living, the government implemented subsidies, decreased taxes and tariffs, and instituted other fiscal measures. Real growth of 7.2% was achieved in 2011 (CIA, 2012; IndexMundi, 2012).

Public health issues and concerns: The epidemiological picture of Mozambique is largely dominated by communicable diseases, including malaria, HIV/AIDS, diarrhoea, acute respiratory infections and Tuberculosis, but with rising non-communicable diseases (cardiovascular diseases, injuries, cancers, among others), particularly in urban areas (WHO, 2009c). The main epidemic-prone disease is cholera, contributed-to by high levels of poverty and malnutrition, and inadequate access to clean water and sanitation. Approximately, six million cases of malaria are reported each year. Mabunda et al. (2007), show that 15.8% of households had at least one insecticide-treated bed-net, but only 7.3% of pregnant women and 6.7% of children under-five sleep under those nets. Malaria contributes to nearly 26% of hospital deaths (WHO, 2009c), including 24% under-five deaths. Many of the high numbers of maternal deaths registered in Mozambique are directly or indirectly caused by malaria infection (Observatory, 2013).

Mozambique has a projected incidence rate of 431 cases of Tuberculosis per 100 000 people and ranks 19th among the 22 high-burden countries in the world. The case detection rate (49%) and the DOTS treatment success rate (83%) for registered new smear positive cases are still below the global outcome targets (WHO, 2009a). In 2008, it was estimated that 1 800 000 people were living with HIV and more than 370 000 were in need of antiretroviral treatment (ART), while only 128 000 people received it. Among people on ART, 7.3% were

HIV-positive children (WHO, 2009c). AIDS-related illnesses are a major threat to mother and child health. Only one-third of pregnant women were enrolled in a programme for prevention of mother-to-child transmission (PMTCT) (coverage 29.8% in 2007), despite a rapid increase in the number of PMTCT sites, from 222 in 2006 to 504 by the end of 2008 (WHO, 2009c).

Neonatal mortality is still a problem: 48 new-borns out of every 1000 still die before they reach the 28th day of life. The leading causes of child mortality are preventable and treatable diseases such as malaria, respiratory illnesses, diarrhoea and AIDS-related illnesses. Chronic malnutrition affects 41% of under-five children and the trend is increasing (Mabunda et al., 2007). Despite promising progress towards population health, the health system is facing numerous challenges, mainly due to insufficient and poorly-trained health workers, scarce financial resources, inadequate tools for data management and inadequate supervision and feedback. Further, access to primary health care is affected by an unequal geographical distribution of health facilities and only 36% of people have access to a health facility within 30 minutes of their homes (WHO, 2009c).

The lack of human resource capacity is reflected in figures of 3 doctors and 21 nurses per 100000 inhabitants, which are one of the lowest health worker densities in Africa (WHO, 2006). Health staff distribution around the country still shows considerable asymmetries. The output of training institutions is insufficient to respond to the growing demand for a larger and better-trained workforce. The prospect of attaining the MDG target of 250 maternal deaths per 100 000 live births could be affected by the low rate of skilled birth attendant (55% in 2008) and unsatisfactory coverage of EmOC services, which covered 1.13 health facilities per 500 000 in 2007 (WHO, 2009c).

Total health expenditure per capita is estimated at around US$ 13 (2007/2008), far below the target of US$ 34 recommended by the WHO Commission on Macroeconomics and Health. According to the Medium-Term Expenditure Framework projections, health expenditure per capita is expected to reach US$ 15 by 2011. As of 2006/2007, government total expenditure on health as a percentage of government expenditure was about 9%, far below the Abuja target of 15% (WHO, 2009c).

ICT infrastructure landscape: ICT readiness in the country is very weak and characterized by lack of adequate infrastructure, high telecommunication costs and lack of trained ICT staff (Morris, 2006). Physical access to infrastructure is constrained by several factors including the geographic distribution of the population, many of whom live in remote areas, limited availability of computer technology, uneven electricity coverage, and low levels of technological skills, and high concentration of infrastructure in the capital.

In 2004, the country had a total of 3.5 per 1000 inhabitants with computer (IndexMundi, 2012). In 2010, 31.3 per 100 inhabitants were telephone subscribers (UNSD, 2012), and in 2011, 32.8 per 100 inhabitants were mobile subscribers (ITU, 2013). Internet services were initiated by the Eduardo Mondlane University through its Informatics Centre in 1993, and in 2011 these services were provided by 10-12 active ISPs. In 2010, 4.2 per 100 inhabitants were internet users, 75% of who were living in the capital (Rambe & Mawere, 2011).

The government approved the country's ICT Policy in December 2000 and its implementation strategy in June 2002. The policy defines several priorities including education, human resource development, health, infrastructure, universal access and governance (Morris, 2006). e-Health initiatives focused on several areas including management of health information (Nhampossa, 2005), HIV/AIDS, Telemedicine (Morris, 2006) were implemented. eLearning & ICT for Education initiatives such as SchoolNet Mozambique that aimed at supporting schools by building ICT access, facilitating training of teachers and authoring content, the Virtual Multimedia Academy and the African Virtual University were also implemented (Morris, 2006).

3. Theorizing the Customization of IT-Artefacts

This chapter presents the theoretical perspective underlining the thesis. The chapter starts with an outlook of IT-artefact customization, and relate that to relevant research as conceptualized through practice-based lenses. In order to do so, the analysis rests upon two broad assumptions about the nature of IT-artefact customization work. First, customization work is considered a situated practice. Second, the work is driven by an array of networks.

3.1. The Customization of IT-artefacts

The creation of artefacts in contexts in which the designers and users are physically, culturally, and economically distant, involves the activity of customization. Customization is a goal-oriented activity where actions are performed by individual or groups of individuals to ensure that artefacts suit to the needs of particular local tasks (Leonard-Barton, 1988).

Effective execution of this activity is dependent on how the artefact was originally constructed, i.e., its customizability. Swaminathan (2001) asserts that this customizability depends on three principles: modularity, standardization and predictability. While modularity ensures that complex and larger IT-artefacts are divided into simpler and more manageable modules, thus making them more adaptable (Sullivan et al., 2001); standardization allows multiple customizations to be performed on the same line without major changes. Predictability, on the other hand, refers to the degree to which software developers can predict what the software will and is needed to do. It also refers to the extent to which unexpected events confront users regardless of how such events will be handled (Bell, 1966). Michaud (1999) groups these factors under four parameters: *what*, *when*, *who* and *how*.

What should be customized? IT-artefacts developed envisioning a large user community has the flexibility on the data, the presentation, and the control mechanisms. Flexibility on data consists of enabling the artefact to adapt its data exchange mechanism in order to be able to share information with any environment or other artefact. Adapting data means making changes to both its format and content. Likewise, changing the *format* of data and metadata consists of making the artefact mechanisms of reading and writing compatible with different information sources; and the *content* consists of customizing the way of managing and processing the data described by the metadata. Presentation consists of changing the visual appearance of the artefact. This can occur in two ways: the information architecture, i.e., how information is organised and accessed through the display and the graphical design which affects the aesthetics and the look and feel of the artefact. Adapting control consists of

changing the artefact behaviour, for example, selecting the features to include in a view, as well as more complex tasks, such as writing macros to automate tasks (Michaud, 1999). Adaptation through feature coordination involves changing how two or more features working together to achieve a single task or set of tasks.

How should customization be performed? Methods used in the customization of artefacts are quite varied and can be placed in two categories (Michaud, 1999). First, the *source-code adaptation* category includes all the methods that operate directly on the software source-code. Adapting a system through these methods offers a greatest amount of flexibility, but is difficult. The second category is referred to as *Interaction Styles* (Michaud, 1999) or *End-User Programming* (Cao et al., 2010; Huang et al., 2008) and consists of all methods that does not involve interacting with source-code.

When customization occurs? Customization take place at three stages of the IT-artefact life cycle (Michaud, 1999). These stages are represented in Figure 3.1 by the boundaries. Thereby, customization starts during the development of the IT-artefact. Here developers define a set of features and their functions and the interaction mechanism that will allow the adaptation of the IT-artefact in future stages. The result of this stage is a generic IT-artefact which is released to the customizers. Along with this artefact follows its design logics (patterns, components and framework), documentation and source-code (which might be visible or invisible for the next stages). The second customization stage occurs when IT-artefact are transformed from generic into a tool specifically designed for users. From this transformation born what I have named, in Figure 3.1, custom IT-artefact. Similar to the generic artefact, custom artefacts are released to the end-users with their design logics, documentation and source-code. The final customization stage occurs when custom artefacts are in active use.

Who performs customization? Making effective customization requires a large body of skills and knowledge. As portrayed in Figure 3.1 this knowledge is spread across developers, customizers and users. The developers are responsible for development of the generic IT-artefact. They specify the design patterns, components and frameworks, and define the artefacts default settings. They are required to hold knowledge about the domain and be experts in programming. Based on inputs from the customizations they produce knowledge which will guide them to shape future changes and versions of the artefacts.

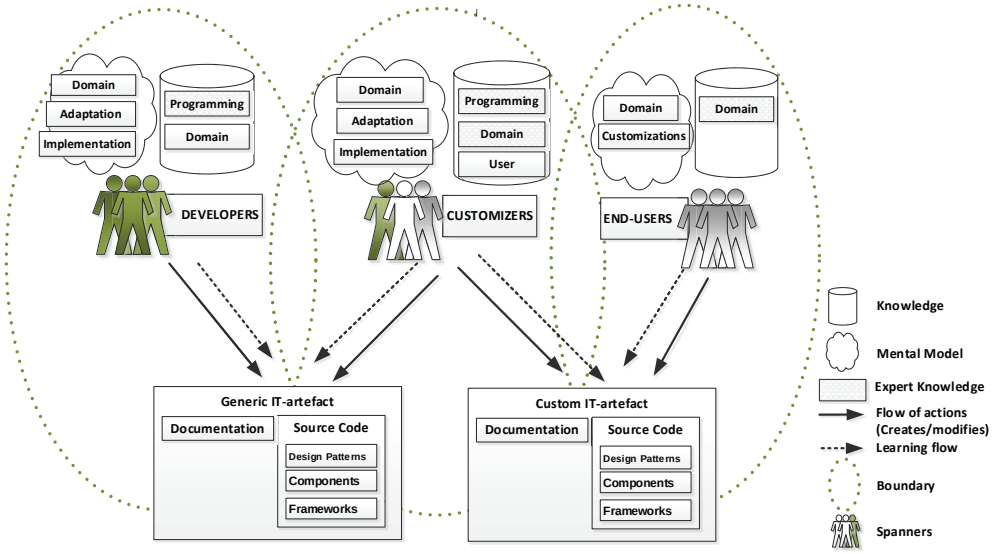

Figure 3-1: Components of an adaptable sociotechnical system [Adapted from Michaud (1999)].

Customizers are responsible for taking a generic IT-artefact and tailoring to suit the needs of a group of users (Nardi, 1993). In some cases they are referred as consults (Winston, 2002) or as 'guests'. In this thesis these terms are used interchangeably. To perform their duties they need to understand how the generic artefact works and how it can be adapted to meet the user needs, thus requiring knowledge about the technology as well as the domain. They are also required to have knowledge about the end-user group. Their knowledge is produced by interacting with developers and end-users, as well as with the different artefacts including the generic IT-artefact and documentation (paper or electronic) provided to support the customization processes. End-users are individuals applying the IT-artefact to perform specific tasks, for example the Ministry of Health (MOH) staff using the DHIS2. These individuals would possess knowledge about the domain, e.g., healthcare, maternal and child health, Tuberculosis treatment process and so for. The typical end-user does not have the skills necessary to perform complex software changes (Nardi, 1993), but can perform some types of customization described above.

3.2. Related Research

The dynamics between technology and their use contexts has been a long standing problem in understanding the adoption of IT-artefacts. I drew inspiration from the works of Orlikowski (2000), Suchman (2007), Nicolini (2013) and others, to adopt a practice-based perspective to understand the dynamics of open-source software systems customization in LMICs. The

central idea to the practice-based approach is that social life is an ongoing production and thus emerges through peoples' recurrent actions (Feldman & Orlikowski, 2011).

When practice-based approaches are adopted to the design and implementation of technologies, helps in focusing on what people actually do rather than on what they say they do or on what they ought to be doing (Schultze & Boland, 2000). Through this approach researchers like Orlikowski (2000) and others, examined how people, as they interact with a technology in their on-going practices, enact structures which shape their emergent and situated use of that technology. This perspective helped to understand how organizational action was enabled and constrained by prevailing organizational and societal practices.

Two perspectives through which the customization of IT-artefacts is shaped form part of the building blocks for my theoretical framework. These building blocks include IT-artefact customization as *situated practice* and as *networks of practice*.

3.2.1. The situated practice perspective

Practice appears as one key and central component to the practice-based paradigm (Barkham & Mellor-Clark, 2003). Depending on the area being studied, practice can have a different meaning and consequently a different definition. Nicolini (2013), for instance, defines practices as "routine bodily activities made possible by the active contribution of an array of material resources" (Nicolini, 2013, pg. 4). These activities include, for instance, improving one's ability to do something, temporally unfolding and spatially dispersed nexus of doing and saying, and performing action. Practice is also defined as "recurrent, materially bounded and situated action engaged in by members of a community" (Orlikowski, 2002, pg. 256), and as a concept in-between habit and action (Gherardi, 2009a). Because of that they are conceptualized as means through which knowledge dynamics unfold, i.e., the unit of analysis for understanding knowledge processes in organizations (Tagliaventi & Mattarelli, 2006).

As most practice-based studies, practice in this research means undertaking or engaging fully in a task execution, job, or profession (Brown & Duguid, 2001). Orlikowski (2010) asserts that work processes such as software customization are performed "by engaging more deeply in the empirical details of organizational life on the ground" (pg. 24). Meaning that practices are always embedded in contexts whose meaning is constituted by people, their actions, and interrelated objects (Nicolini et al., 2003; Gherardi, 2009b; Orlikowski, 2000; Corradi et al., 2010).

This fundamental character of practice is captured by the notion of *situatedness* and denotes how activity both shapes and is shaped by society within which it occurs

(Jarzabkowski, 2005). Corradi et al. (2010), for instance, asserts that *situatedness* can be used to explore how individuals solve their problems as well as how they construct their competence in practice, and share knowledge and practices (Tagliaventi & Mattarelli, 2006). In this regard, practice conceive resources as something that an organization has, and how capabilities emerge, are developed, modified and changed over time (Jarzabkowski, 2005).

In order to deal with design-reality gaps (Heeks, 2006), the *situatedness* is supported by several practices, such as of *learning-by-doing* and *working side-by-side*. Learning-by-doing is defined as the mechanism of solving problems that applies to production processes in the use context (von Hippel & Tyre, 1995). Tagliaventi and Mattarelli (2006) argue that "working side-by-side and having common organizational values are important bases for knowledge transfer between professional groups which belong to different networks of practice" (Tagliaventi & Mattarelli, 2006, pg. 291). Customization activity is also constructed through practices of improvisation and *bricolage*, which are "key success factors which can keep together a faltering organization in extreme situations" (Ciborra, 1999, pg. 79).

Improvisation has been used in the domains of organizational learning (Miner et al., 2001), technology implementation (Rolland & Monteiro, 2002) and the development of IT-artefacts (Magni et al., 2009), and to understand emergent behaviours arising during the execution of activities. *Improvisation* represents a process that assumes changes as unpredictable and evolving out of situated experiences, involving temporal sequences of planning and acting (Magni et al., 2006), whereby time to wait for optimal resources to perform the activity is abundant (Pina e Cunha et al., 1999). Orlikowski and Hoffman (1997) and Pina e Cunha et al. (1999) stress that improvisation emerges in response to the need for managing unexpected opportunities or breakdowns, which help to increase competencies.

Lanzara (1999) describes *bricolage* as an work-around practice consisting of the use of immediate-available resources or resources at hand (Baker, 2007), whilst executing unexpected situations (Magni et al., 2006). *Bricolage* can mean designing immediately, i.e., using ready-at-hand materials (Weick, 1993) or combinations of already existing pieces of technology, knowledge, and skills to perform emerging activities (Büscher et al., 2001).

3.2.2. The network of practice perspective

The notion of network of practice was originated by Brown and Duguid (2001) and refers to set of networks that facilitate information exchange between individuals with practice-related goals. In this notion, the term network is used as a metaphor and refers to "structures of interdependence involving multiple organizations or parts thereof, where one unit is not

merely the formal subordinate of the others in some larger hierarchical arrangement" (O'Toole Jr, 1997, pg. 45). In other words, network implies a set of individuals who are connected through social relationships, involving different professional groups to enable problem solving (Tagliaventi & Mattarelli, 2006). The relationships allow also professionals to 'go the extra mile' and share practices with network members and expect them to apply such practices in their daily activities.

Takhteyev (2009) and Brown and Duguid (2001) assert that networks of practice do not produce new knowledge, but spreads existing knowledge, and allows individuals to continuously combine and modify knowledge through their interactions, and then circulate the new created knowledge in the practice (Tagliaventi & Mattarelli, 2006).

Given the geographic spreading nature of their participants, these networks are also known as distributed networks of practice (Hustad & Arntzen, 2012). The geographical distance within these networks of practice is conceptualized as a boundary, representing both a barrier between different sets of practice and, also an opportunity for cross-fertilization of different perspectives (Tagliaventi & Mattarelli, 2006; Kerosuo, 2001; Akkerman & Bakker, 2011), and the creation of pathways through which knowledge may be shared (Tagliaventi & Mattarelli, 2006).

Since structural and cultural diversity amongst boundaries can be higher than within them, Hustad and Arntzen (2012) considers that the activity of spanning boundaries or the building of network of practice is challenging, as they contain members with different professional and educational backgrounds (Hustad & Arntzen, 2012). Further, diversity proves challenging to the development of trust, confidence, support, and respect, necessary to enhance learning (Orlikowski, 2002).

Despite these difficulties, the spanning of boundaries allows the building of (Hustad & Arntzen, 2012): a) *problem-solving networks*, i.e., expert groups that share, over time, practices that help address particular business problems; b) *business-improvement networks*, i.e., group of people that alter or liquidate practices with the aim of developing best practices in their daily work activities; and c) *innovation networks*, i.e., people that intend to foster unexpected ideas and innovations by combining different perspectives and building new capabilities through product development.

Networks of practice are dependent on *boundary objects* and *boundary spanners*. Boundary objects represent a shared repertoire within networks of practice that participants use to communicate and share knowledge, and allows different groups to work together (Star, 2010) by establishing a shared syntax for individuals to represent their knowledge (Carlile,

2002). These objects address the "limitations implied by the reliance on boundary-spanners who […] may advance self-interest, have a limited social network or face temporal and physical constraints" (Levina & Vaast, 2005, pg. 339). In order to effectively support this process, they must provide tangible means for individuals to specify and learn about their differences and dependencies (Carlile, 2002), and be up-to-date and accessible (Levina & Vaast, 2005).

Boundary spanners are individuals or groups of people that establish and maintain inter-organizational relations (Stock, 2006; Lindgren et al., 2008). Tagliaventi and Mattarelli (2006) asset that the possibility of sharing knowledge at the boundaries of networks depends in part on the ability of the boundary spanners to do so, and the intense involvement of people in a single network. This will reinforce a sense of belonging, relational mutuality and common repertoire with each other (Tagliaventi & Mattarelli, 2006).

However, various challenges exist, for example in dealing with multiple technical languages (Bechky, 2003), and the limited opportunities for people to meet face to face (Tagliaventi & Mattarelli, 2006). Networks thus need to have planned opportunities for knowledge exchange, such as cluster meetings and trainings.

Clusters represent geographic concentrations of interconnected individuals, groups or institutions that benefit from mutual proximity (Porter, 1998; Cortright, 2006), enabling the sharing of practices between network members (Delgado et al., 2011). This sharing can help to learn and adopt common standards (Porter, 1998), define and share common beliefs, attitudes, and agendas (Stonehouse & Snowdon, 2007). This helps to diagnose and discuss common strengths and challenges, and identify realistic ways to shape future directions (Cortright, 2006). Capacity-building efforts within a cluster framework can help reduce costs, and enhance knowledge and information transfer especially for individuals that rely only on informal infrastructures. Even if these clusters are activated for a short period (days or weeks), they help the building of trust (Stonehouse & Snowdon, 2007), which can contribute to transforming the networks.

3.2.3. Theoretical Framework

This thesis is focused on understanding the process of IT-artefact customization in the context of public health of LMICs. To date, the number of studies that focus explicitly on IT-artefact customization is quite limited, especially within the public health domain of LMICs. However, there are several bodies of literature that contain studies relevant to IT-artefact

customization. In the Table 3-1, I provide an overview of the selected bodies of literature from which I draw on.

Table 3-1: Overview of the papers and their theoretical frameworks

Paper Details		Objective of the paper	Key concepts
Paper I	"Software customization in healthcare domain of low-resource settings: a model for building capacity"	Taking a cross-site perspective the paper attempts to answer the following research question: how different software stakeholders interact to shape customization capacity?	Practice, *situatedness* and Activity system
Paper II	"Extending System Capacity in Low Resource Environments through 'Flexible' Competency Building in Open Source Applications Customization"	This article evaluates competency development in multidisciplinary workgroups.	Boundary, boundary spanner and boundary object
Paper III	"The Challenge of Customizing Global Open Source Software to Local Country Contexts: The Case of DHIS GIS for Health Management"	The paper aims at understanding the nature of customization challenges in tailoring GIS applications; as well as understanding the approaches used to deal with challenges	Improvisation or work-around
Paper IV	"Factors affecting Geographic Information Systems implementation and use in Healthcare Sector: the Case of OpenHealthMapper in Developing Countries"	The paper aim at investigating the factors surrounding *geodata* production and sharing; as well as discussing the approach to address *geodata* tensions and problems.	Boundary and boundary object
Paper V	"The Influence of Community Structures in the Development of Software Customization Capacity"	The paper aims at discussing the influence of communities in the customization of GSS applications, especially regarded to the issue of capacity building.	Improvisation, *bricolage*, community-of-practice and cluster
Paper VI	"Leveraging from customization to inform Generic Software Systems development: DHIS tracker and its introduction in healthcare"	The paper discusses cross-country software customization and highlights its importance in informing software evolution or maturity.	Boundary spanner and boundary object

Briefly I can say that, this research began with a comprehensive description of the way individuals actually conduct their customization work. Literature on activity system, practice and *situatedness* was used as framework of analysis. While practice was adopted to help in understanding people's actions in their everyday work; *situatedness* assisted in revealing the realities of the practice through exposure to the domain complexity. In addition, activity-theoretical concepts were chosen to clarify software customization as outcomes of social change and the processes of changing them.

As this study concentrate also on investigating the dynamics of software customization and capacity building processes; I evaluated the nature of customization challenges in tailoring generic software systems, as well as the approaches used to deal with those challenges.

Literature on boundary spanning, improvisation and *bricolage* was taken as framework of analysis.

Moreover, I evaluated how different software stakeholders interact to shape customization capacity. The notions of 'communities of practice' and clusters were adopted to explain the way multidisciplinary groups interacted and created a shared context for knowledge work. While community of practice represented "social learning systems where practitioners were informally connected to solve their problems, share ideas, set standards, build tools, and develop relationships with peers and stakeholders, clusters appeared as a supplement to community of practice and provided mechanisms for coordinating cooperation, especially for individuals who did not have the opportunity to have face-to-face meetings with other stakeholders.

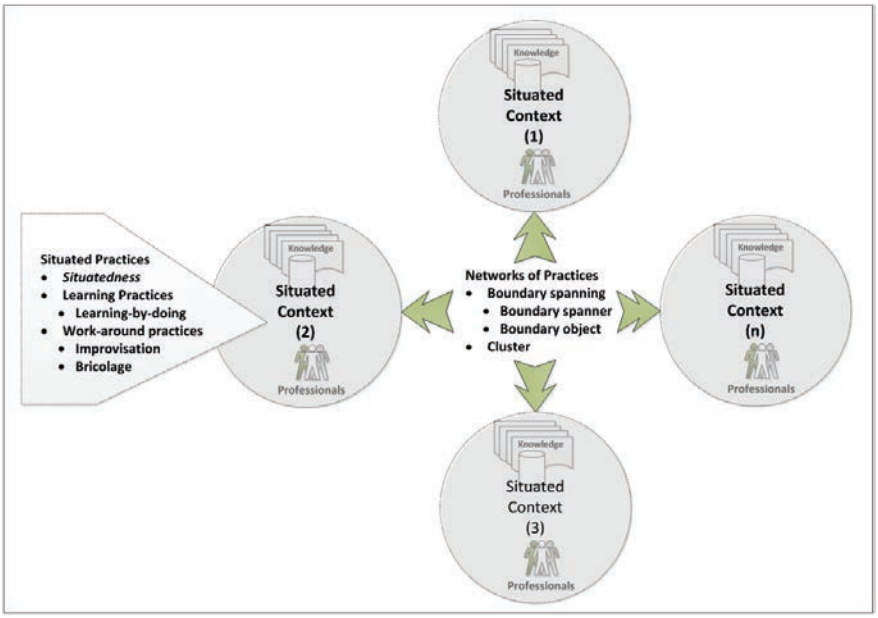

Figure 3-2: Theoretical Framework

While the discussion presented in the papers has revealed the existence of various theoretical lenses that may be used to understanding the process of IT-artefact customization, important theoretical aspects in common were identified. For instance, regardless of what was the core issue studied in each paper, IT-artefact customization was regarded as an activity or process crosscutting boundaries of peoples and practices. In order to grasp the dynamics of this process nothing becomes better than to investigate the situated and the shared (or networks of) practices (see Figure 3.2). The *situated practice* represents the context where the

activity of IT-artefact customization takes place, serving as a sense-making tool to access the situated behaviour and actions of professionals performing the tasks. This notion helps to recognise the gap between generic IT-artefacts and user organisation practices, and provides guidance on how to solve problems. Improvisation and *bricolage* are important in this regard. The *network of practices* recognizes that customization endeavours are aspects and effects of interconnected human practices. Specifically, the perspective is applied to the clustering of knowledge, individuals and social practices, where communication is mediated by networks. Notions of boundary spanner, boundary object and clusters help to understand these processes.

Taken together, these building blocks help understand the practice of customization despite it being a fragmented activity involving a multiplicity of individuals and practices. Kamensky et al. (2004) argue that this enables the investigation of "how to bring about enough cooperation among disparate community elements to get things done - and to do so in the absence of an over-arching command structure or a unifying system of thought" (Kamensky et al., 2004, pg. 64).

4. Research Methodology

This chapter presents the thesis research framework. It starts with an overview of the design strategy (Section 4.1) and followed by the methods for data collection and analysis in sections 4.2 and 4.3. The chapter ends by describing how empirical work was conducted, including the timeline and the overview of the empirical experiences. Broadly, the strategy and methods adopted in this research belong to qualitative research paradigm (Mason, 2002b), and theory, data generation and data analysis were developed simultaneously throughout the duration of the research. Detailed description of this process is provided in the following sections.

4.1. The research design

The research attempt has been to describe and analyse the real and very complex activity of customizing generic software systems in public health sector of LMICs. Toward that I have adopted a multi-case study approach as the foundation for gathering the data and interpretive approach as a way to analyse and move further with the data.

4.1.1. A multiple-case study approach

A case study represents a research approach or tradition within the qualitative research paradigm (Creswell, 2006) in which one or a few instances of a phenomenon are studied in depth (Given, 2008; Stake, 2011). The approach is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. A case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest that data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis (Easterbrook & Aranda, 2006).

Case studies attempt, on one hand, “to arrive at a comprehensive understanding of the event under study but at the same time to develop more general theoretical statements about regularities in the observed phenomena” (Fidel, 1984, pg. 274). However, within the qualitative research paradigm, they are used primarily when researchers wish to obtain an in-depth understanding of a relatively small number of individuals, problems, or situations (Patton, 1990).

While much case study research focuses on a single case, often chosen because of its unique characteristics, the strength of conclusions from single case study is not very high

(Yin, 1993). In this regard, multiple case studies design are seen to allow the researcher to explore the phenomena under study through the use of a replication strategy (Yin, 1993). The approach is preferred because analytic conclusions independently arising from two or more cases will be more powerful than from a single case; the differences in context of multiple cases that have common conclusions provide for expanded generalizability of findings; and if two deliberately contrasting cases are selected and findings support the hypothesized contrast, the results represent theoretical replication and strengthen external validity (Easterbrook & Aranda, 2006; Perry et al., 2004).

This study adopted a multiple case study design strategy where the cases are drawn mainly from healthcare organizations of LMICs. In these cases, data was collected from interactions with software customizers, developers, users and data managers, over two broad stages. In the first, contact was established with institutions (sixteen in Mozambique, two in Malawi and four in Guinea-Bissau) dealing with Geographic Information Systems (GIS) and spatial or GIS data. These institutions were selected opportunistically through my personal contacts as well as through networks of local HISP nodes (e.g., in Malawi). This research took place in four time frames: spring of 2009 in Mozambique, spring 2009 and 2010 in Malawi and finally in autumn 2011 in Guinea-Bissau. The second stage helped to sharpen the focus of the research through deeper exploration of the issues identified in the first phase. Data collection was continuous and lasted from 2009 until December 2012. It started with me joining a team working toward the introduction of DHIS2 in Malawi and was extended to Mozambique, Tanzania and Guinea-Bissau. While in Malawi, Mozambique and Guinea-Bissau I participated in the customization activity, assessment of the customization in Tanzania was done during DHIS2 workshop trainings and in informal discussions with fellow researchers and customizers. This case gave me the main empirical material for my analysis. The replication strategy followed Yin (2009) approach illustrated in Figure 4.1.

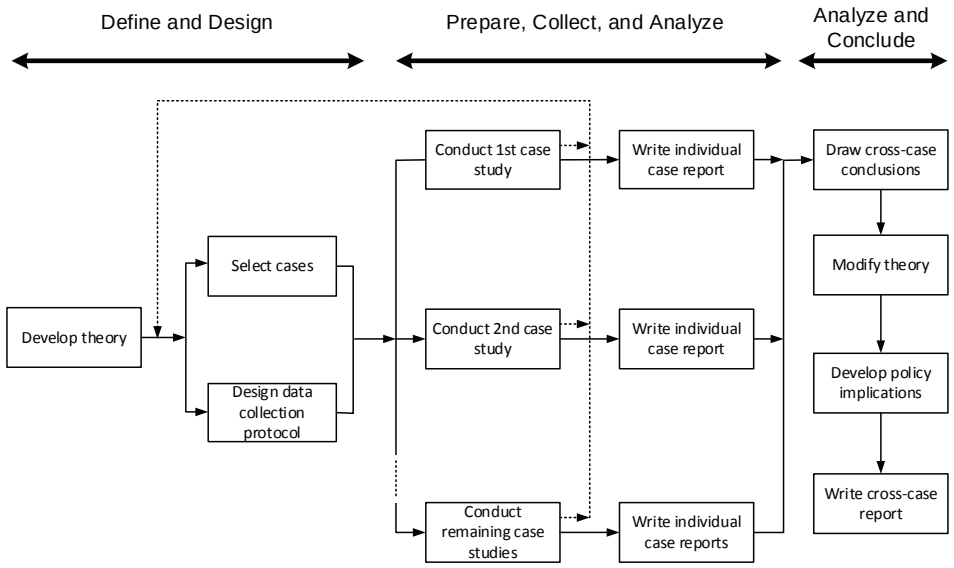

Figure 4-1: The Case Study Method. Source: Yin (2009)

4.1.2. An interpretive approach

As the purpose of my study is to "investigate the challenges and approaches toward the customization of generic software for different LMIC public health sector settings", it is fair to say that my research is based on qualitative research paradigm. The paradigm enables the researcher to explain and understand social and cultural phenomena and may be conducted using epistemological approaches.

Several research epistemologies such as positivist, interpretive and critical may be used in doing qualitative research (Given, 2008). Walsham (1995), discuss two epistemological approaches, the positivist and the interpretive. According to Given (2008) "there is no single thesis that counts as positivism, no single criterion that defines it" (Given, 2008, pg. 650), but "it is usually assumed that positivists believed in a determinate reality and in the possibility of a correspondence between that reality and representations of it" (Given, 2008, pg. 648). However, Walsham (1995) defines positivism as "the position that facts and values are distinct, and scientific knowledge consists only of facts" (pg. 75). Interpretivism, on the other hand, is based in a philosophical position, which is concerned with how the social world is interpreted, understood, experienced or produced (Walsham, 1995; Given, 2008).

Given that real world problems are, inevitable, highly complex and multidimensional, and qualitative data can provide a rich insight into the problem situations experienced by people (Mason, 2002b), it has been natural to choose an interpretative approach when conducting the

study described in this thesis. The assumption, here, is that there are no overall qualities that describe reality, because the researcher decides what reality looks like and this means that there is no true reality. The principles for interpretation are aimed at letting the empirical data have a dialogue with existing theories, earlier experiences and the pre-knowledge which the research has. During this process, while methods are used to produce understandings of both the context of the information system and the process that influences and is influenced by the context (Klein & Myers, 1999); theories attempt to make sense of the world through subjective shared meanings (Walsham, 2006). These shared meanings take form of concepts, which in my case included primarily 'situated practice' and 'networks of practices'.

4.2. Data Collection

As described above, I chose the qualitative research tradition (Iivari, 2010; Walsham, 1995; Walsham, 2006) which helped me "understand issues or particular situations by investigating the perspectives and behaviour of the people in these situations and the context within which they act" (Kaplan & Maxwell, 2005, pg. 30). Research, according to Mingers (2001), proceeds through a number of phases and combine several methods. The methods combined in this research included participant observation, actual customization work, interviews, artefact examination and brainstorming and reflexive discussions.

Participant observation: Mason (2002a) asserts that researchers need to be at the place where actions are carried out in order to observe and record the events as they happen. This method of data collection consists on the researcher taking part in everyday activities related to an area of social life in order to study an aspect of that life through the observation of events in their natural contexts (Given, 2008). Spradley (1980) describes participant observations as an approach that helps to (1) engage in activities 'appropriate to the situation' and (2) view and note the "activities, people, and physical aspects of the situation" (Spradley, 1980, pg. 54). By observing the context where customization activity was performed a large amount of data was generated, and allowed me access to resources (e.g., people and artefacts) that would be otherwise difficult to reach (Labaree, 2002).

Further, as an 'involved researcher' (Walsham, 2006) or participant-as-observer (Given, 2008), I acted as a customizer of DHIS2, experiencing the customizers' day-to-day life, learning first-hand challenges, and how to share and solve them. I also provided advice and feedback, and shared customization experiences from other countries. Furthermore, given that the projects unfolded over long periods of time, I could observe unfolding of events over time, following them while being there, and over electronic means when absent. Figures 4.2

illustrate different moments of intervention both in the customization settings and in DHIS2 workshops.

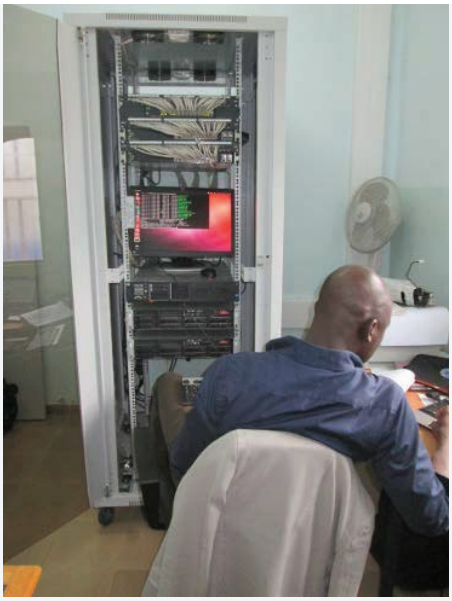

Figure 4.2a: Setting up the DHIS2 server in Guinea-Bissau

Figure 4. 2b: Demostration and testing of DHIS2 during regional meeting in the region of Cacheu in Guinea-Bissau

Figure 4. 2c: Customization session in Guinea-Bissau

Figure 4. 2d: DHIS2 Academy session in Tanzania

Figure 4-2: Interventions and workshops

Data was also collected though *artefact examination*. Artefacts provide a rich source of data, i.e., they offer story about "the person who made it, how it was used, who used it, and the beliefs and values associated with it" (Given, 2008, pg. 23). In this research project proposals, HIS manuals, data collection and reporting tools, DHIS2 application and its documentation and various others artefacts were examined. This helped me to understand DHIS2 design, obtain first-hand knowledge about the system features, and the customization issues which spanned different DHIS2 versions during the period between 2009 and 2013. I

also followed the DHIS2 mailing lists and webpage to be current on the issues. Furthermore, during participant observation and customization work, I jointly analysed the software features. In the local settings examination of DHIS2 was performed both in private settings (e.g., Figure 4.2a) and in public presentation and testing (e.g., Figure 4.2c and 4.2d).

Figure 4.3a: Discussion with nurse at Chankhungu health center in Malawi.

Figure 4.3b: Discussion with data clercks at Mansoa Health Facility in Guinea-Bissau

Figure 4.3c: A GIS data manager showing the process of extraction of *geodata* from GPS device in Mozambique

Figure 4.3d: A GIS expert in Malawi showing how *geodata* is processed.

Figure 4-3: Observations and interview sessions

I also conducted semi-structure, formal and informal *interviews* (Kitzinger, 1995) outside work environments (e.g., during workshop training events) and some in the course of work. As illustrated in Figure 4.3, several interview sessions were performed with different purposes. For instance, while in Malawi the discussion was focused on understanding the Mother and Child Health (MCH) workflow (Figure 4.3a); in Guinea-Bissau we were discussing procedures used to record and report TB data (Figure 4.3b). Moreover, the electronic medium, for example through Skype, email exchange, phone calls, enabled

informal discussions on issues. In some settings, the interviews were formal (e.g., in Mozambique while assessing the institutions dealing with GIS data (geodata), in others (e.g., Malawi and Guinea-Bissau) they were relatively informal.

Reflexive discussions and brainstorming sessions with developers, customizers and users helped to understand user issues, reflect on the challenges they were facing, and provide focused inputs into new DHIS2 releases. Reflexivity can be broadly described as engagement in examination and explanation of how these challenges have influenced a research project (Given, 2008). These sessions also served as training experiences for customizers and users. For instance, fieldwork transcriptions made by a MCH researcher helped to understand user needs through reflexive discussions between researchers (Figure 4.4a) and between involving researchers and users (Figure 4.4b). I also had opportunity to participate in reflexive meetings initiated by software developers which offered me the opportunity to observe and gain insights about how problems and solutions were shared within the community.

Figure 4.4a: Analysing the requirements of MCH programme with fellow researcher

Figure 4.4b: Validating requirements with Nathenje Health Facility Service Provider

Figure 4-4: Reflexive discussions

The Table 4-1 present a summary of the methods, activities and periods that the techniques were applied in each setting.

Table 4-1: A Summary of Data and Research Methods

Research Method and Description		Activities, Place and Period
Participant observation	Field research technique used to study customizers' day-to-day life through involvement into their environments and with their activities.	Participant observation was applied when I took the role of customizer (that I was studying) and lived the customization everyday experiences in health care organization, enrolling in customization tasks, training local customizers and users, testing the accessibility of the application from the regional and health facilities. In Malawi this happened in several occasions and occurred from 23rd February 2009 until my last visit that ended in January 13th, 2011. In Mozambique, however, it was done in a week that lasted from March 27th to 2nd of May 2011. In Guinea-Bissau two visits were performed. The first started in June 27th and ended in 28th August 2011 and the second was from 11th January until 1ST March 2012. Observation was also performed during four DHIS2 training academy workshops, two in the west Africa and the other two in the east Africa.
Interview and conversation	Technique used to collect data as well as to gain knowledge from individuals through formally and informally interchange of views.	Semi-structured face-to-face and virtual interactions where performed in all research settings. In Mozambique, for instance, eleven GIS data managers were interviewed. Questionnaires were handed to them and to other five organizations dealing with GIS data. During the DHIS2 Academy Workshop held from 18th to 29th of June 2011 in Tanzania, seven customizers were approached. Four GIS data managers in Guinea-Bissau and two in Malawi were also interviewed. Data was also obtained through unstructured conversations with people I met in the customization sites, co-customizers and fellow researchers.
Artefact examination	A research technique used to examine paper and digital artefacts.	Paper and digital artefacts were collected in all the settings and analysed. The artefacts consisted of project proposals, data collection and reporting tools, organizational and technical infrastructure documents, modules and several versions of DHIS2, and the DHIS2 technical documentation and manuals. This included also online discussions and articles published in the DHIS2 website.
Process mapping, brainstorming and reflexive discussion	Techniques used to discuss the processes, as well as collect data based on discussions, brainstorming and reflexions on the data.	On-going engagement in process mapping, brainstorming and reflexive discussions with researchers, customizers, users and developers was used to analyse the fieldwork data and experiences. For instance, I attended seminars and workshops meetings debating and generating ideas on DHIS2 and other HMIS issues. Likewise, in Malawi I had opportunity to discuss with service providers of two health facilities (Natchenje Health Center on 10th January 2011 and Chankhungu Health Center on 11th January 2011).

4.3. Data Analysis

Data analysis is the application of reasoning to understand the data that have been collected (Cooper et al., 2006). This research data analysis process was based on qualitative research tradition and has involved the steps of data reduction, display and conclusion drawing (Miles & Huberman, 1994). The process was iterative, i.e., early data analysis provided insight to shape the collection of further data (Given, 2008); both during and after collecting data, I was engaged in memoing (Birks et al., 2008), i.e., personal, conceptual, or theoretical ideas or reflections that come to my mind were taken as data was analysed (Given, 2008); and involved some form of coding, i.e. data was classified according to specific themes. Some of these themes were developed prior to data collection and others emerged inductively through the data collection and analysis; and were identified based on the review of the literature and early findings of the study. Whenever new data were collected, they were compared and contrasted to old so as to note patterns.

Broadly, two approaches were adopted to perform data analysis in this research. The first was intra-case approach, i.e., data were grouped according to where they were collected. Thereby individual customization site was used as unit of analysis. The unit of analysis in this research is the level of abstraction at which I looked for variability (Guest et al., 2013). This unit of analysis was used to capture the practices applied, for instance, by customizers and those existing on customization artefacts. In other words, with this unit I tried to understand the activity is each site, investigated the experiences of local people of being customizers or *geodata* managers and the supporting infrastructure available at their settings.

Second, throughout the analysis findings from the several sources were cross-walked against each, a process called comparative analysis (Given, 2008). Data belonging to common themes were analysed across sites and time periods; and comparisons performed, for instance, on the customization experiences between sites at the same point in time, as well as within same site at different points in time. Themes, as unit of analysis, were used with the purpose of cross-walk the sites' findings against each other, identify common issues and patterns, the differences and contradictions, and thus refine the understandings. This has been done in all the steps of our data analysis and it helped, for instance, to identify the nature of constraints faced by the customizers of each of the settings during the customization DHIS2. Inter-case approach was applied is these comparisons. Using this approach it was possible to group and analyse *geodata*, as well as to focus on interactions between, for instance, customizers

enrolled in different customization sites, and also people involved in different software activities (development, customization and usage).

Data analysis in this research involved studying both customization extrinsic factors, and those internal which represented the core of the study. The process of how data was analysed in each segment is now discussed.

4.3.1. Analysing customization extrinsic data

The customization extrinsic data collected as part of this research was related to *geodata* (also referred as spatial data). The aim with this was to understand issues related to the creation, processing, storage and the sharing of spatial data. The analysis of this data was performed mainly through thematic analysis.

Thematic analysis is a data reduction and analysis approach, by which data are segmented, categorized, summarized, and reconstructed in a way that captures the important concepts within the data set (Given, 2008). It emphasises on identifying, analysing and reporting patterns within data (Braun & Clarke, 2006). In this research, thematic analysis of the data was guided by the themes present in the interview guide and questionnaire. Themes expressed meaningful patterns, stances of the participants, or concerns (Given, 2008).

Table 4-2 indicates the important research themes. I performed my analysis by classifying the data collected according to four themes which included collection and maintenance, institutional, network and technological issues and human resource.

Table 4-2: Core themes used in this research

	Theme	**Description/Objective**
The *geodata* related themes		
	Geodata collection and maintenance	Assess the process of spatial data creation, data formats, metadata and the mechanism used to process spatial data/information
	Institutional issues	Identify data acquisition, organization, transfer/sharing mechanisms
	Networks and technological issues	Identify the relationships or collaboration between *geodata* institutions, development of skills
	Human resource issues	Identify manpower capacity and their skills
Customization related themes		
	Benefits and challenges	Identify the benefits and challenges of customizing DHIS2 for and by organizations of LMICs

	Work activity	Identify the people involved and the practices adopted during the process of performing the customization tasks
	Capacity-building	Identify the practices adopted and people involved in the building of customization competences
	Requirement-handing	Identify the practices and people involved in the process of requirement gathering and forwarding to developers

4.3.2. Analysing customization intrinsic data

As specified before, the aim of this research was to build understanding of the issues surrounding the activity of software customization. Data collected as part of this process was analysed using a mix of approaches including thematic analysis, activity system and biography of artefacts.

Similar to the previous section, data underwent to a process of reduction via themes, and relating code categories (see Table 4-2). These themes helped to identify the software customization elements. This process began with a mapping of software customization within the activity system framework (Engeström, 1999; Yamagata-Lynch & Haudenschild, 2009). This helped me to understand the activity of software customization, and how they are made up of various components and their inter-linkages. Then I analysed each element and its interrelations which other activities (use and development). This helped to articulate meanings and address multiple perspectives (Akkerman & Bakker, 2011), the division of labour and the organization of work. It also helped to identify disturbances caused by divergences between what was expected and what actually happened.

Moreover, Pollock and Williams (2010) argue for long-term exploration of the interplay between actors and intermediaries in technology adoption. In line with this, I have tried to understand different forms of human experiences that influence or are influenced by the customization activity. The activities of learning (Yamagata-Lynch & Haudenschild, 2009; Karasavvidis, 2009) or capacity-building (Engeström, 1999) and design of information systems (Korpela et al., 2002; Mursu et al., 2007) were analysed. In this regard, DHIS2 customization was considered a result of interactions between community (which is made of user organisations, software customizers and development organization, as well as 'heterogeneous assemblages' encompassing software artefacts, developers, end-users, and work practices) members. The use of biography of artefacts approach (Pollock & Williams, 2010) allowed me to analyse both the content and historical of the artefacts, and this helped me to perform a systematic examination of patterns within the DHIS2 artefact's (e.g., the software application and its documentation), as well as to understand the state of the times in

which these artefacts were developed or lived. Through the use of this approach it was, for instance, possible to document and explain how DHIS2 software, particularly the Tracker module has evolved and gained its maturity, including the ability of customizers and developers bridge customization problems, identify different strategies used, define roles, and to enhance skills and capacity of customizers to solve problems.

4.4. Role of the Researcher

A multiplicity of roles and responsibilities were enacted during this research. My first contact with DHIS was during my Master studies, between August 2003 and June 2005 in Mozambique, with special focus on GIS. It was also during this period that I understood the importance of sharing *geodata* files, as well as the need for collaboration and interaction between organizations. This experience helped initiate my doctoral studies with a survey of organizations dealing with spatial data and GIS. The interviews were taken at the organization setting and during the process I enacted a role of *observer as participant* (Given, 2008), i.e., I observed the setting and had brief interactions with interviewers. This role was also enacted during the DHIS2 workshop academies.

However, in the customization settings I enacted simultaneously the roles of *nonparticipant* (Given, 2008), i.e., I observed form a distance (e.g., the discussions in the mailing list); *complete observer* (Given, 2008), i.e., only listened and observed without interaction (e.g., in meetings) and *participant as observer* (Given, 2008), i.e., I actively participated in a number of activities with the local customizers to the point where I was identified as a consultant, friend or colleague (e.g., in Guinea-Bissau I am affectionately treated by brother or “mano” in Portuguese by the INASA team).

Participant as observer was, in fact, my main role in the customization sites. This was influenced by the way I entered to the fields. The story of my involvement in the sites was as follows. Delays in deciding whether DHIS2 will be used or not in Mozambique forced me to identify other empirical opportunities. After conversations with my supervisors, an opportunity emerged and I went to Malawi and led the process of customization of *DHIS2 OpenHealthMapper*. Likewise, after the customization of *DHIS2 OpenHealthMapper* since it could not be tested unless the customization of the module from where health data could be entered was complete, lead me to join the team working on customizing the DHIS2 Tracker. Moreover, through a casual conversation with a friend of mine in 2010 I became aware about the adoption of DHIS2 by OGUMANIHA project in Mozambique. I then approached the organization, which led to an invitation for me to participate in the customization of the

DHIS2 OpenHealthMapper module. Furthermore, in May 2011 a request to help INASA for strengthening HIS in Guinea-Bissau popped up at the University of Oslo. Since I was the only one speaking Portuguese at the Global Infrastructure Group of the Department of Informatics, I got the opportunity to participate and expand my research on customization. In this project, I acted both as customizer and served as a bridge between the INASA and HISP teams.

Being participant as observer enabled me to have close relationships with key informants who provided introductions to activities, events, and other people in the research settings. This made the access to people and resources to be relatively easy and to have an ongoing connection with people from the settings. Over time, key informants (e.g., from Guinea-Bissau) become friends. This affected the obligations that I had to them and the level of trust demonstrated by them. For instance, during the interviews and reflective sessions, I felt that they have been honest and open in talking about their experiences, expressing their concerns and points for directions that could benefit them in terms of the software system that was being customized, as well as the process of building capacity.

The fact that I did the research by mainly evaluating the actions of individuals from the same organization where I was accepted as PhD student, as well as my own actions as a customizer pose both benefits and limitations. Given (2008) uses the term *insider researcher* to described a research situation where the researcher is a part of the topic being investigated, and asserts that this status may have a considerable effect on the research process. Above I presented some of the benefits of carrying out research as an insider researcher. Other benefits can include, for instance, the fact that the result from the research can affect in positive way the environment being researched.

However, being insider research brings some limitations. Given (2008), for instance, stresses that the shared identity (researcher and customizers in my case) may create tensions and the researcher became aware of cultural practices (e.g., use more appropriate language) and community sensibilities (e.g., being sensitive to material that the investigated community members do not want to disclose publicly). During this research I acknowledged this and kept them in mind.

4.5. Empirical Journey

The section aims to give an overall picture of the empirical experiences and describe how empirical choices were made, and my learning of the activity of software customization in different organizations. The section is divided into four subsections. The first deals with the overall timeline of the research. Then, the empirical settings are presented in subsection two,

focussing on the most relevant experiences. Subsection three presents the people that took part of this research. Finally, the role of the researcher in the customization projects and how empirical choices were made is described in subsection four.

4.5.1. Overview of Timeline

Initial stages of this study were inspired by work performed during my MSc. studies, as well as professional engagements between completion of the study and commencement of the PhD programme. During the master studies my focus was on the implementation of GIS in healthcare organization, after which I taught GIS at University level and supervised both undergraduate and graduate students. These experiences motivated me to do further GIS related research as part of my doctoral studies.

As portrayed in Figure 4.5, the PhD study began in 2009 with a GIS survey in which the aim was to develop a better understanding of the practices behind the production of spatial data. As opportunities of exploring the customization of open source software arose, the GIS study which was supposed to be the core became an exploratory case, however enabling me to gain important insights in the process of customization of generic software that used spatial data.

Between 2009 and 2012, I got opportunities to participate in several DHIS2 customization activities in Malawi, Mozambique and Guinea-Bissau, which was interesting for me given my background as a computer scientist. The activity started in Malawi in 2009, and then in Mozambique (from 2010 to 2011) and Guinea-Bissau (from 2011 to 2012). These customizations are illustrated in Figure 4.5 by the dotted circles.

Furthermore, to gain a more holistic picture on the customization activity, I attended DHIS2 training academies. Similar to the GIS survey that was carried out in the beginning of this research the DHIS2 academies are represented, in the Figure 4.5, by solid circles.

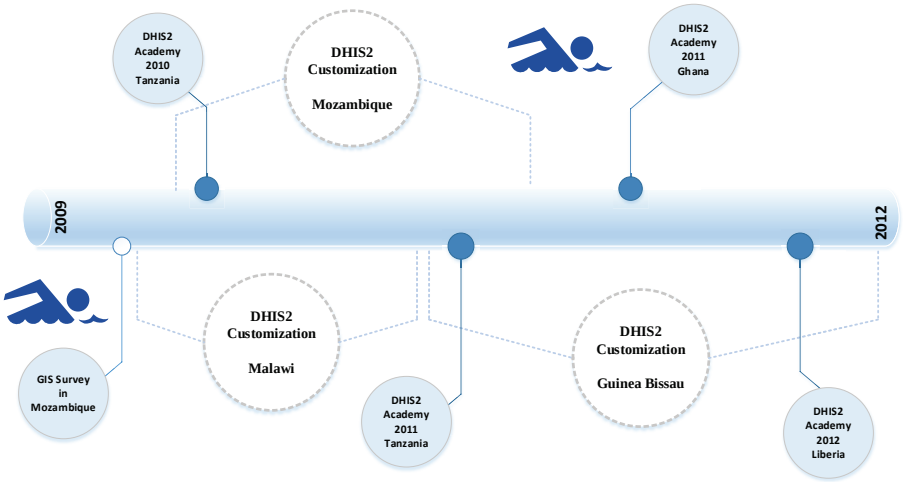

Figure 4-5: Thesis data collection overview timeline

4.5.2. Overview of empirical experiences

The research presented in this thesis has, globally, been performed in the context of HISP project and its software application framework, the DHIS2. Specifically, the thesis is presented as a combination of several related studies centred on how healthcare organizations perform software customization. Next I provide an overview of the empirical insights that were consequently developed through them.

4.5.2.1. The District Health Information Software

HISP is a global south-south-north collaborative network which has contributed to design, development, and implementation of a free and generic tool called DHIS. DHIS is also an open meta-data model and a flexible user interface that allows the user to design the contents of a specific information system without the need for programming. DHIS is designed to support health workers and managers at all administrative levels through a balance between flexibility and standardization, and with a strong emphasis on using information for local action. As consequence, DHIS which was first released in 1997 and used by districts and provinces in South Africa, became a national standard tool for many countries in Africa and Asia, a primary one being South Africa.

Lessons learned from years of intensive collaboration between HISP team and DHIS stakeholders (healthcare providers, researchers, software developers, etc.) in a number of countries triggered the re-engineering of application. Specifically, in 2005 the collaboration

between researchers and developers from Norway, India, South Africa, Ethiopia and Vietnam, resulted in the development of the second version of DHIS, the District Health Information Software 2 (DHIS2).

Developed as an open and globally distributed process, DHIS2 provides the users with its source-code, it is platform independent, can run on both on-line and offline modes and is multi-language enabled. The architecture of DHIS2 can broadly be considered as composed of two layers (see Figure 4.6): first, the DHIS2Core contains the common features used by all the modules, and the second is specifically related to the modules. The main modules include DHIS2 Routine or Aggregated data, DHIS2 Mobile, DHIS2 Tracker and DHIS2 GIS or DHIS2 OpenHealthMapper.

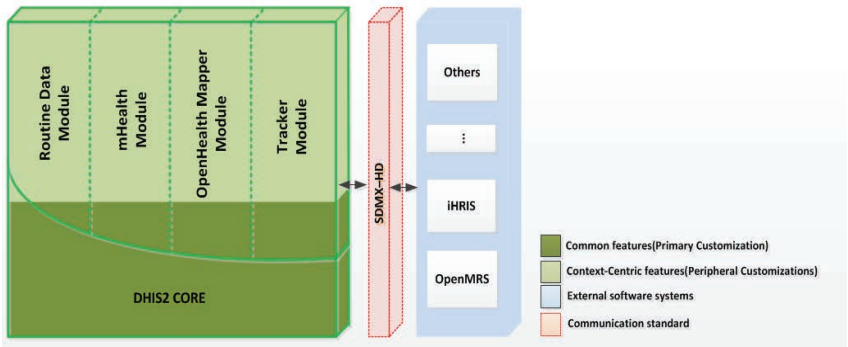

Figure 4-6: DHIS2 Architecture

The DHIS2 Routine allows users to manage aggregate and routine data, i.e., through flexible user interface users can set up data elements, data entry forms, validation rules, indicators and reports and create a fully-fledged system for data management. DHIS2 Tracker module enables users to collect, manage and analyse transactional, case-based data records. It also allows the storage of information about individuals and the tracking of these persons over time. The DHIS2 Mobile covers focus is on the three areas of Java ME applications, browser based mobile solutions and SMS solutions. Through the GIS or OpenHealthMapper module, DHIS2 offer web-based GIS features that allow users to perform thematic mapping of areas and points, view facilities based on classifications, visualize catchment areas for each facility, and design and link legend sets to data elements or indicators and the colours displayed in maps. DHIS2 provides also scalability to accommodate external processes, such as integrating with DXF 2 as well as the SDMX-HD standard to interoperate between patient and aggregate level data.

A key focus of HISP is on capacity building, described through the strategy of Networks of Action (Braa et al., 2004) to support: (i) strengthening the capacity of users to better manage their HIS; (ii) enhancing user understanding of HMIS implementation and management mechanisms; and (iii) developing user capacity to make better and more informed decisions in their respective areas of work. The strategy advocates that learning process and sharing of resources can flow better in situations where sites are connected through networks, rather than when in isolation.

Taking advantage of this approach, I had opportunity to move across countries and working as both customizer and knowledge facilitator. This action has encouraged and assisted in developing of positive attitudes and practices towards customization of DHIS2. Likewise, I attended four DHIS2 academies, some as facilitator and others as a simple participant (see Table 4-3). DHIS2 academies are programs comprising technical and organizational aspects and aim to enable participants to, more effectively, manage their HIS, and strengthen their capacities towards customization and use of DHIS2. During these academy workshops, customizers representing a wide variety of countries come and learn together while engaging in practical customization tasks. Through these academies, participants are informed about new and emerging features and concepts within the DHIS2 framework, and also learn about new requirements from users. Academies, furthermore, help to exchange practices around DHIS2 customization and use across countries.

Table 4-3: An overview of the DHIS2 training workshops or academies

DHIS2 Training Workshops			
Date and place	**Event**	**Description**	**Participants**
Dar-es-Salaam, Tanzania from 7th-11th June 2010	DHIS2 Programmers workshop	Discussion about practical work in country's database	Attended by stakeholders from countries such as Malawi, Kenya, Mozambique and Tanzania
Dar-es-Salaam, Tanzania from 20th-30th June, 2011	East Africa regional DHIS2 Implementers workshop	Develop of participants' capacity to make better and more informed decisions in their respective areas of work; customize DHIS2; diffuse best practices; and inform participants about new features of DHIS2.	Stakeholders from different countries such as Uganda, South Africa, Kenya, Zanzibar, Mozambique, Tanzania, Zambia, Ruanda and Malawi.

Accra, Ghana, 7th-16th November, 2011	West Africa regional DHIS2 Implementers workshop	Global HISP team used this to access and discuss cross-country requirements and to rapidly diffuse best practices through comparisons of performance among the countries; and encouraged countries to improve their databases.	Stakeholders from countries such as Ghana, Kenya, Guinea-Bissau, Sierra Leon, Liberia, Nigeria and Gambia.
Monrovia, Liberia from 16th-23th November, 2012	West Africa regional DHIS2 Implementers workshop	Used to inform participants about new and emerging features and concepts within the DHIS2; address the needs of the participants' country databases; enhance the participants' understanding of HMIS implementation and management mechanisms; and develop practical skills to translate local context requirements into DHIS2 database.	Attended by stakeholders from countries like Ghana, Kenya, Guinea-Bissau, Liberia, Nigeria and Niger.

At the global level I also had opportunity to attend several other ad-hoc meetings, held in Oslo by the DHIS2 developer team. In these meetings various issues were discussed including new features, sharing of experiences from the different DHIS2 implementation/customization sites, among others.

In this section I have introduced my experiences with the DHIS2 developer team and activities at the global level. I presented the main activities and insights that these experiences provide that shape the expectations and assumptions of this thesis. From the next sections until the end of the chapter, I will present an overview of my involvement in different customization sites.

4.5.2.2. Case study on understanding the practices for managing geodata

To understand the practices for *geodata* management I carried out a questionnaire based survey in sixteen organizations using GIS with responsibilities in producing, using and managing *geodata* in Mozambique (see the list of organizations approached in Figure 4.7). Before the questionnaires were sent out to the selected organizations, semi-structured interviews were conducted to understand key practices around *geodata*. The organizations included the National Directorate of Environmental Management (IIAM), Fisheries Research Institute (MIREMI), the National Center for Cartographic and Remote Sensing (CENACARTA), the Municipal Council of Maputo City (CMM), the National Directorate of Territorial Planning (DNOT), National Emergency Operating Center (CENOE), the National Directorate of Planning and Land Management (DINAPOT), and the Regional Water Administration of Southern Mozambique (ARA-SUL), among others.

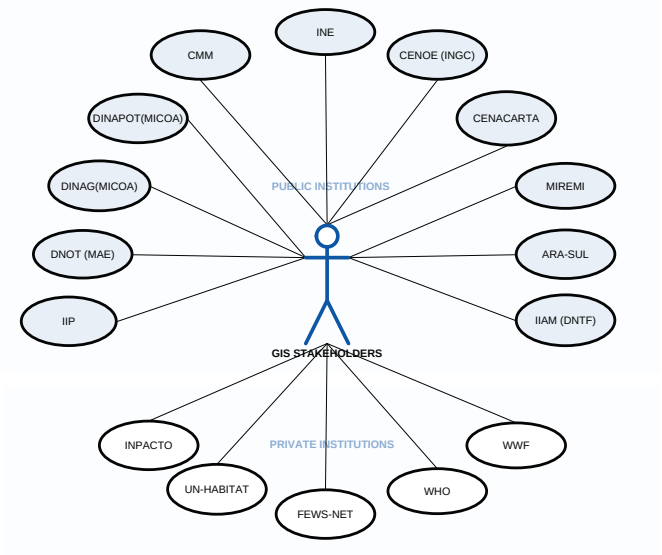

Figure 4-7: Part of the organizations dealing with spatial data in Mozambique

The interviews and questionnaires covered data issues (e.g., data collection and the maintenance), institutional issues (e.g., activities/tasks, human resource, capacity building) and networks and technology issues (e.g., data sharing mechanisms). The responses were further challenged in Malawi and Guinea-Bissau during my studies on customization. Lessons from this case were related to the quality of spatial data, and weak data sharing mechanisms across organizations.

4.5.2.3. The customization projects in Malawi

The customization activity in Malawi started in 2009 and lasted until 2011, and the aim was to understand the practices adopted while customizing DHIS2.

In Malawi I have been involved in two broader action research projects. Firstly, in collaboration with HISP Malawi I worked in the customization of the *DHIS2 OpenHealthMapper*. HISP Malawi is a part and parcel of the Central Monitoring and Evaluation Division and a grouping of a number of organisations, education institution, government agencies and international donors working with the MOH and various stakeholders at the national level in setting-up and supporting various e-Health Information Systems in Malawi (MALAWI, 2013). Central Monitoring and Evaluation Division is a unit under the Planning and Policy Development Department in the MOH in Malawi. The unit is responsible for coordinating routine Health Management Information Systems (HMIS). From 2009 the HISP Malawi has embarked on a number of interventions with a view to revamp the

HIS where one of the core interventions was the customization of DHIS2 to report routine HMIS data.

Secondly, I worked in the customization of the DHIS2 Tracker. This work was performed with fellow researchers as part of a Maternal Health Project. The project was targeting three countries Tanzania, Malawi, the Gambia, all with very poor maternal indicators, and the main goal was to generate knowledge and build capacity around maternal health services, like knowledge about how to improve quality of services. Two specific objectives of the project were to develop tools to monitor quality of maternal health services in health institutions; and to establish functioning problem solving health information systems in institutions, districts and beyond.

As a contribution towards achieving the goals of both projects, I was engaged in a couple of activities such as: collecting spatial data, analysing MCH services, collecting and discussing needs and demands with local customization team and with end-users, performing customization of DHIS2 to fit end-user needs and demands, and share with the global HISP community the outcome of the activities.

From this study I developed knowledge that helped to understand the difficulties in fitting user needs in the software system. Moreover, similar to Mozambique, knowledge was developed related to spatial data quality.

4.5.2.4. The customization project in Guinea-Bissau

Since 1992, after the establishment of the Department of Hygiene and Epidemiology (DHE), the Ministry of Health has been trying to establish a comprehensive National Health Information System (NHIS) that is in the center of the whole chain of decision making. First attempts toward the development of such NHIS emerged with the introduction of a computerized database called 4D. Serious constraints to the implementation of 4D was the political-military conflict of June 1998 that has exacerbated the fragility of government institutions, destroyed infrastructure essential to provide care and support services (PNDS-II, 2008).

Two evaluations made to the NHIS, between 1997 and 2000, found that the information gathered by 4D was turned solely for the epidemiological surveillance and that decision-making authorities did not appeal to them in times of planning and prioritization. It was then clear that a single and integrated system for the collection, analysis and dissemination of health information was needed. This gave a birth to the National Institute of Public Health in Guinea-Bissau, INASA, in 2008.

The mission of INASA was, then, to create, incorporate and disseminate health scientific and technical knowledge with the aim to provide informational, tactic and strategic output needed for decision making in the National Health System. The creation of INASA envisioned also the strengthening of the coordination through the combination of the different databases into a single and integrated NHIS. To INASA were coupled MOH structures that already existed, some of them for over 20 years, and that were working in isolated manner. Such structures included the National School of Health, the National Health Laboratory, the Bandim Health Project, and the Centre for Tropical Medicine, the Department of Information Education and Communication for Health and the Directorate of Hygiene and Epidemiology (PNDS-II, 2008). Given the inexistence of specific budget lines in the national general budget and from various sectors, to allow the proper functioning of HIS, INASA operates as a semi-autonomous institution. Available infrastructure and human resources for HIS is provided by vertical programs or International Aid efforts.

Despite having made progress towards data gathering in a single system, after the evaluation 2000, the NHIS continued to be composed of various databases whose information did not hang together, which was difficult to access and that sometimes led to the existence of indicators with disparate values as the database from which derived. In some cases, there is even duplication in terms of data collection. The recognition of these drawbacks, also the fact that existence of multiple data collection tools creates redundancy and additional workload for the health workers, as well as the struggle of getting data from the fragmented data collection instruments, drove INASA to adopt a new database system that would automate a set of unified and integrated data collection tools.

The database was called SIS_INASA and was developed through a partnership between INASA and a Spanish Non-Governmental Organization (NGO) called Intercanvi, in a Microsoft Access database framework. SIS_INASA was installed on one computer in each of the eleven regions. Monthly, data was sent, via email, from regions are imported into the PC of the data manager at INASA headquarters. However, given that some vertical programmes needed to report to their partners (for instance, HIV/AIDS and TB/Leprosy programs were funded by Global Fund and had monthly and quarterly indicators to be reported, Immunization activities funded by Unicef had also to be reported through specific excel formats, and Nutrition activities funded by a NGO called Vida were also collected using specific paper collection forms) and the data collected by SIS_INASA was condensed and did not satisfy this desire, health programs started to develop their parallel data collection tools. This resulted in a fragmented data management and collection, and in different subsystems,

which increased the difficulties in information sharing and global national analysis. The left side of the Figure 4.8 illustrates such fragmentation.

Recognizing these challenges INASA has assumed, in 2011, the role to lead the integration of information produced by the different health programs, and DHIS2 was the tool selected for that. DHIS2 was adopted as an effort between the INASA, the WAHO and HISP. As portrayed in Figure 4.8, the adoption of DHIS2 intended to provide to the government a sustainable HIS based on an open source platform (right side of Figure 4.8). The customization of DHIS2 started in May 2011 when SIS_INASA was obtained and analysed by the HISP team in Oslo, and had its continuity in Bissau starting from July 2011. Due to financial constraints it was not possible to hire IT personnel that could work as local customizers. Because of that people had to be identified from the available personnel. The difficult in having skilled IT personnel that could take a management role, also led the activity to be done by a 'guest' customizer who were also involved in many other customization activities and was working simultaneously with other customizers on similar activities in other countries.

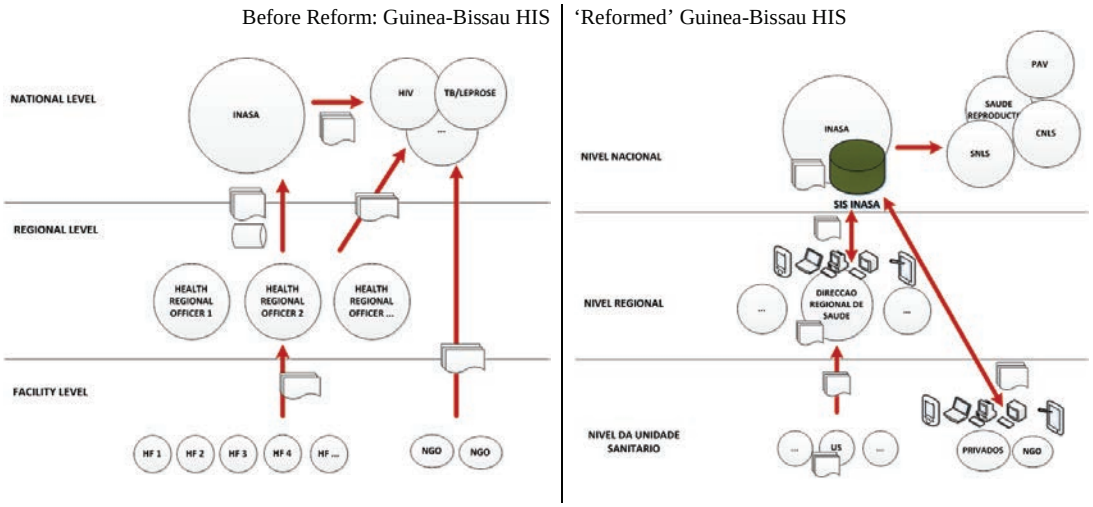

Figure 4-8: Framework for the HIS intervention in Guinea-Bissau

This project examined the national HIS as a whole, with a key focus was on understanding customization practices. Additionally, the study intended to validate the *geodata* problems identified in Mozambique and Malawi. I could also learn the customizing challenges within a political troubled setting which had serious implications on financial dependence. Further, there were other organization challenges related to a reluctant workforce and general

instability. In line with this, it was observed that, when health statisticians and data managers had to leave the customization process to produce the reports, attend meetings and perform supervision work in the regions, customization tasks that were assigned to them was transferred to the 'guest' customizer and sometimes the other participants.

In a project lasting till to-date, various actors were involved including INASA, HISP, Global Fund and others. Assistance provided by these partners helped to fund the participation of local customizers in the DHIS2 academies. For instance, the customization team members were able to attend DHIS2 academies in Ghana in 2011 and Liberia in 2012, because of funds from HISP and WAHO, respectively.

4.5.2.5. The customization project in Mozambique

The customization projects in Malawi and Guinea-Bissau emphasized the importance of partner relationships between software vendors and end-users. For example, partnerships between HISP and the local teams have been important to the customization activity.

An alternative approach towards customization is for the organizations to perform tasks by themselves without relying on the software vendors. An opportunity to study such an arrangement was in OGUMANIHA, Mozambique where the organization did not have a formal contact with the DHIS2 software supplier.

OGUMANIHA is a project proposed by seven NGOs (World Vision, Adventist Development and Relief Agency, ACDI/VOCA, International Relief and Development, Friends in Global Health at the Vanderbilt University, John Hopkins University's Centre for Communication Programs, and Red Cross Mozambique), to improve health and livelihoods of children, women and families in the Province of Zambézia. OGUMANIHA adopted DHIS2 as a framework to develop a software application that could be used to manage data on ninety-two indicators implemented under the auspices of the Ministries of Health, Agriculture, and Public Works and Housing, and in strong coordination with and leadership from the Provincial Health Directorate, the Provincial Agriculture Directorate and the Provincial Directorate of Public Works and Housing (OGUMANIA, 2008).

The software tool was labelled OGUMANIHA Information System (OgIS) and its development resulted from efforts primarily of the local OGUMANIHA team. Members of this team were selected based on a public tender. They had very elaborated job descriptions which included tasks and the tools which were going to be used. This was mainly due to the preliminary work conducted by a consultant hired by OGUMANIHA to conduct a study and suggest the best existing tool that would satisfy the requirements. This work helped

OGUMANIHA managers to have technical specifications and details of the required tasks. For this reason the ads already brought specifications of technical abilities that were expected of competitors.

As portrayed in Figure 4.9 the customization DHIS2 or development of OgIS resulted in an application which was used by sixteen districts. There districts were organized in three regional areas and coordinated from the central office located at the province capital, Quelimane. Data was gathered from communities and health facilities using paper forms and sent to the data managers at district level which was afterwards entered in OgIS database. Monthly reports and backup files were generated in each district and sent to be integrated and stored in the central server located in Quelimane district. While the reports were used by district managers in their regional meetings, the back-up files were sent and stored at project coordination office in Quelimane and afterwards integrated in a single database. The data files received from the district were also kept in a safe place for future use, e.g., recover the district database if any tragedy happens with the computer at district level.

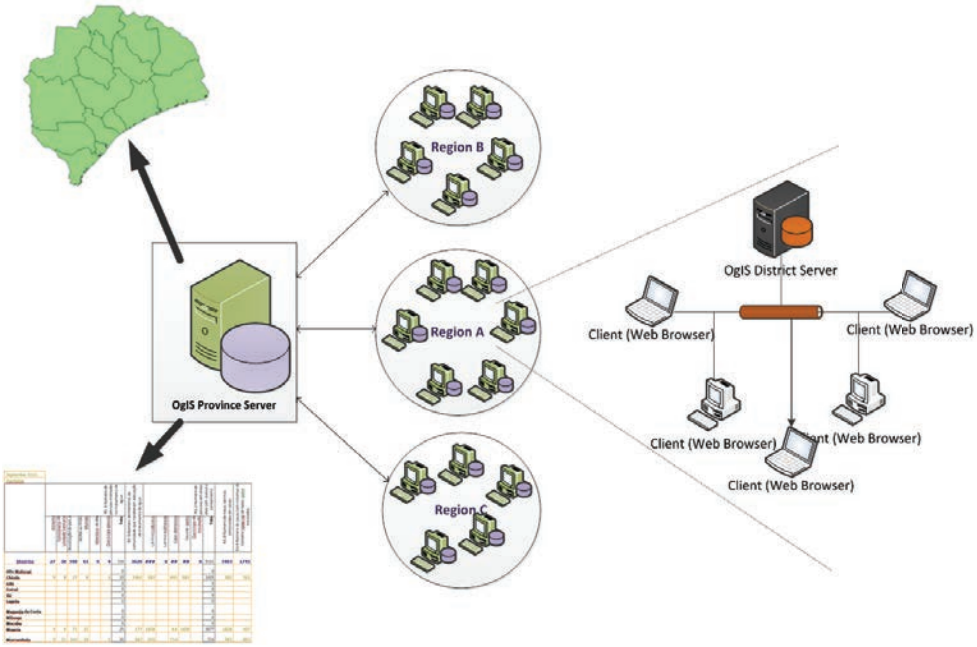

Figure 4-9: Framework for the intervention in Mozambique

From this study I developed knowledge that helped to understand the work-performing and capacity-building practices adopted during software customization. New useful practice: ‘selection of customizers through a public tender approach’ was observed, which helped to formalize the hiring process and issue formal job-description. The alternative to this tendering

process leads to more ad-hoc and unsustainable processes, as was the case in Guinea-Bissau and Malawi.

4.5.2.6. The customization project in Tanzania

A further study was carried within HISP Tanzania. HISP Tanzania is located and coordinated within Department of Computer Science and Engineering of the University of Dar-es-salaam. The HISP Tanzania aims to support the national Ministry of Health and Social Welfare to develop and implement DHIS2. Toward this, HISP Tanzania is supported by the global HISP and partners (or NGOs) such as Clinton Health Access Initiative, Elizabeth Glaser Paediatric AIDS Foundation and Ifakara Health Institute. Each of these partners had its own team responsible for implementing the DHIS2 application in selected areas, including giving training and addressing technical problems.

The study was performed to understand how customization problems were handled. Specific focus was on understanding how local customization teams reacted to the similar challenges faced with DHIS2 Tracker, for instance in Malawi. Moreover, since the division of work, roles and institutions were different from other customization projects a focus was to understand how concerns and knowledge were shared across the two customization levels of HISP Tanzania and the partners.

Table 4.4 present a summary of the potential issues observed in each of the settings.

Table 4-4: Summary of issues observed in the interventions

Study Sites	Approaches		Challenges		Key contribution to the evolution of DHIS2
	People	*Networks*	*People*	*Objects and tasks*	
Malawi	Customizers were pointed or hired with no specific job description; 'Guest' customizers from Mozambique and Togo participated in the customization of the modules;	Two DHIS2 academies; The customization process was facilitated by HISP; GIS community members;	Customizers with lack of skills;	Inexistence of manuals; Districts were not reflected in the existing maps; On-the-fly validation; Sharing of data elements between health programs within DHIS2 Tracker;	DHIS2 Tracker requirement (e.g., sharing of data elements between health programs, aggregation tool, etc.) shared with developers;
Mozambique	Customizers hired based on a public tender; 'Guest' customizer from Mozambique helped with customizations;	One DHIS2 academy; GIS community members;	Lack of skills to perform certain customization tasks;	Providing mechanisms for allowing several partners collecting similar data for same organization unit, period and period type in DHIS2 Routine Data; Managing translation files within OgIS; Creating an embedded export/import feature; Integrating the MS Excel module	Translated DHIS2 interface from English to Portuguese; Shared concerns with DHIS2 developers; The use of DHIS2 to manage non-health related data such as agribusiness and water and sanitation;
Guinea-Bissau	Local customizers selected from the available health personnel; 'Guest' customizer from Mozambique helped and managed the customization process;	Local customizers participated in two DHIS2 academies; The customization process was facilitated by HISP; WAHO and HISP funded the participation of local customizers in DHIS2 trainings;	Inexistence of financial resources that could be used to hire IT personnel; Language problems; Lack of IT expertise;	Language used to develop the objects; Mismatch of administrative boundaries among government institutions; Lack of infrastructure;	TB tracking as a use case for DHIS2 Tracker;

5. Research Findings

The aim of this chapter is to analyse and discuss the major findings of this thesis. The chapter is divided into two main sections. The first section begins with presentation of individual articles that were elaborated as part of this research and their main findings. The second section synthetises the findings of each paper with regard to their contribution to the thesis research questions.

5.1. Synthesis of Research Findings

Six articles were elaborated as part of this research. One of these is a book chapter. Two have been published in conferences and the remaining three are under review in relevant journals. Each is summarized as follows.

Paper I: **The Challenge of Customizing Global Open Source Software to Local Country Contexts: The Case of DHIS GIS for Health Management**

Zeferino Saugene and Sundeep Sahay. IFIP WG 9.4: Social Implications of Computers in Developing Countries. Kathmandu, Nepal, 2011

This paper focuses on the interaction between the local and global streams of generic software system, and presents the results of an attempt to customize OpenHealthMapper in two different sites. The experiences from each of the cases were compared with each other. The research was carried out using action research approach adopting mainly the technique of participant observation. This technique was applied during the period that the researcher took part of the teams that were customizing DHIS2 in Malawi and Mozambique.

This paper illustrates several challenges affecting the activity of customizing generic software systems in the healthcare sector of LMICs, which included mainly spatial data problems, the handling emerging technical problems and limitations of the tool. As part of the technical limitations, for instance, customization team failed to generate the GeoJSON and GML files from the *shapefiles*. With regard to spatial data it was observed that districts were not represented in the existing maps and organizational units were part of the same spatial administrative district boundary. As several of these problems became visible to the project, efforts were taken to combat them via improvisation. However, in some cases the lack of skills appeared as a problem to improvisation.

The lesson learnt in this paper reinforces the critique of the technology transfer approach which treats technology as a black box that can be un-problematically moved to different

settings. Instead a sensitive process involving mutual adaptation between the global and local is required.

The outputs of this paper are the basis of the research presented in the subsequent papers. For instance, in Paper II we use the customization of OpenHealthMapper in Guinea-Bissau and the case study performed in Mozambique, where organizations dealing with spatial data were researched with the aim of understanding procedures of data management, to confirm finds of this paper. In Paper III we use the lack of technical skills identified in this paper and compare with other settings. Also, in Paper V the issue of limitation of the generic tool is further investigated.

Paper II: **Factors affecting Geographic Information Systems implementation and use in Healthcare Sector: the Case of OpenHealthMapper in Developing Countries**

Zeferino Saugene, Márcia Juvane and Inalda Ernesto. In: Rajabifad, A. & Coleman, D. (eds.) Spatially Enabling Government, Industry and Citizens: Research and Development Perspectives. USA: GSDI Association Press, 2012

In Paper I, a number of problems were presented as related to the customization of OpenHealthMapper and one of those problems was related to *geodata*. Adopting the notion of 'boundary objects' to denote *geodata* files, this paper analyses the role of these artefacts to the customization process and how their quality is influenced by the tensions between the people or organizations managing them. Specifically, the article investigates factors surrounding *geodata* production and sharing; and proposes mechanisms that may be used to address *geodata* tensions.

Data used to elaborate this article was collected through interviews and questionnaires and was administrated to sixteen institutions in Mozambique. To further test the findings of Paper I, we looked at the customization of the OpenHealthMapper module in Guinea-Bissau.

Findings reveal that, the different *geodata* layers are created by individual agencies to meet their specific needs, and usually with very little coordination. Moreover, it is also illustrated that, in Guinea-Bissau the administrative regions in the maps or *geodata* files did not correspond with the health regions; and the sectors and health facilities of some regions were split and aggregated under two other regions which were not in the maps. Due to these deficiencies, the adoption of technologies such as OpenHealthMapper face challenges of not being able to provide accurate results or even not being fully customized. Hence, even if GIS institutions and agencies interact to reduce data collection efforts, problems (in quality,

standard, and format) found in the data files, forces them to (i) engage in data capturing and (ii) not be confident in using data collected by unknown individuals.

Considering 'boundary objects' as supportive artefacts that enable efficient customization of OpenHealthMapper and also because they are devices that maintain relationships and also create tensions, the article suggests the adoption of Carliles' knowledge integration framework as a mechanism that may be used to alleviate these boundary tensions. Through this approach, we suggest adopting the processes of *transfer*, *translation* and *transformation*, as well as the strengthening of coordination among community members.

Paper III: **Extending System Capacity in Low Resource Environments through 'Flexible' Competency Building in Open Source Applications Customization**

Zeferino Saugene and Jens Kaasbøll, Int. J. of Healthcare Technology and Management, Special Issue on: "Extensible Electronic Health Records" (in review)

The objective of this paper was to build an understanding of how software stakeholders interact in order to develop customization competence. To perform the study a cross-case perspective was adopted and applied in four customization projects in Mozambique, Malawi, Tanzania and Guinea-Bissau.

Important aspect verified in this article show that, contrary to the traditional conceptualization of software customization where the activity is performed by vendors' representatives or the modern where the task is left to end-users, the activity is performed by a group of technical middle-men which are referred as boundary spanners. These individuals were not end-users but, in some cases belonged to the users' setting and, in others, were guests. The activity also benefits from software artefacts. In fact this has already been highlighted in Paper II, but in this paper the focus has been on the objects that describe the features of software being customized and include manuals, physical documents and official webpage, database system, emails and mailing lists.

The paper argues that customization competence emerge when there is interaction of software stakeholders as well as software artefacts, a process known as boundary crossing or spanning. Often, the people doing the job received support from an inter-disciplinary team where each individual represents a different community (e.g., developers, users and customizers). Although members of this team have disparate perspectives and cultures, having them in a joint team with common overall objectives help to develop a shared understanding of each other's domain.

The main lesson learned in the paper is that in generic software customization it is vital to have people from different disciplines interacting. However, the process of spanning comes with different types of tensions, one of them is competence. The paper suggest that the four dialogical mechanisms of identification, coordination, reflection and transformation suggested by Akkerman and Bakker (2011), can help to understand these tensions and guide their adjustments. Identification entails a questioning of the core identity of each of the intersecting sites that leads to renewed insight into what the diverse practices concern. Coordination assumes that learning at the boundary involves establishing dialogue between boundary crossers. Reflection emphasizes the need for boundary crossers to realize and explain the differences between practices, as precondition to enrich their knowledge with something new about their own and others' practices. Transformation involves investigating the effects of working at the boundary.

Paper IV: **The Influence of Community Structures in the Development of Software Customization Capacity**

Zeferino Saugene, Journal of Community Informatics: Southern Africa Special Edition (in review)

This paper aimed at highlighting the important role of communities in the development of capacity. To do that, the paper explored the evolution of the DHIS2 application and its support to business cases that were previously outside of its scope. The paper illustrated further how a group of NGOs operating in Zambézia province, Mozambique were able to customize DHIS2 to handle agribusiness, water and sanitation and health indicators.

The study found that, the when customizers adapt the software to their own needs together with getting access to DHIS2 source-code, they access knowledge held on software frameworks which in turn will improve their IT and programming skills. Moreover, it is illustrated that although developers provided the software with its source-code, i.e., indirectly giving local customizers the freedom to change as they wanted; customizers were not able to perform some changes. This is in part due to the impossibility of entirely planning and controlling software customization and also because of shortage of time and skills.

In order to address these challenges the paper highlights the role of local customizers and concentrates on their attitudes and actions. To analyse those actions, work-around practices of *bricolage* and improvisation were evaluated.

Findings have illustrated that improvisation takes place thanks to skills and knowledge which in turn result from face-to-face conversations during learning-by-doing session as well as training workshops. With regard to this, the paper emphasises the importance of communities of practice, which refers to the group of people coming together in search of common aims or shared practices. Likewise, together with community of practice, clusters are suggested as strategies that enable capacity-building across boundaries. Their need comes from the fact that, today, people often work in geographically distributed groups or cooperate across organizational boundaries.

Furthermore, experiences from this paper reveals, for instance, that after attending the workshop trainings and having face-to-face conversation with developers and other customizers, the work of the local customizers was high visible to the global community, and appeared to be a pleasing experience to both local and global teams. As result of these activities local customizers shared their work with the global community; as well as participated in community activities by translating the language of the software from English to Portuguese. It was also observed that for having carried out customization work with little support of the DHIS2 developers, local people developed a sense of ownership, i.e., local customizers easily took charge of their organization choices or decisions.

Paper V: **Leveraging from customization to inform Generic Software Systems development: DHIS tracker and its introduction in healthcare**

Zeferino Saugene, IFIP WG 9.4: Social Implications of Computers in Developing Countries. Montego Bay, Jamaica, 2013

Development of generic software systems is the focus of this article. In this paper I analyse the process that lead to generification of DHIS2 Tracker and the circumstances under which this process occurred during software customization. Here the concepts of generification, standardization and customizability are used interchangeable to refer to the process that leads to the development of generic software systems. The paper builds on Paper IV and is also attempting to investigate issues that emerged from research work illustrated in Paper I. To perform this study I adopted a cross-case approach as data collecting strategy. Towards that, data was collected from interventions during the customization of DHIS2 Tracker in Malawi and Guinea-Bissau.

By evaluating boundaries being spanned during software customization, together with the tension between encouraging or restricting the growth of practices in IT-artefacts (Levina &

Vaast, 2005), the paper provides important contributions to the process of software customization and is particularly relevant for institutions that will seek to enhance customizability of generic IT-artefacts through the mechanism of customization. As example the paper revealed that the adoption of generic IT-artefacts by different healthcare service providers has resulted in a large pool of customization instances. This was motivated mainly by the lack of skills to perform changes, as well as the changes made at the local contexts which were not aligned with the global standards. The fragmentation has posed challenge both to developers in harmonizing and satisfying user needs, and to the local customizers in their continuation of benefiting from the improvements being added to new the versions of the generic tool. With regard to this, the paper asserts that there is a need to create balance between assigning the flexibility and controlling inclusion of new practices, i.e., developers need to encourage local development with some restrictions on the tasks to be performed.

Additionally, customization is used as a mode through which boundaries and spanning activities are analysed. Software customizability which was defined, in Chapter Three, as a combination of the principles of modularity - ensuring that complex and larger IT-artefacts are divided into simpler and more manageable modules, standardization - allowing multiple customizations to be performed on the same line without major changes, and predictability - predicting what the software will and is needed to do, is in this case an outcome of a sequence of boundary spanning activities, i.e., customizability is seen to emerge as materialization of lessons learned after spanning domains, settings, and customizations sites. Thereby, the paper portrays the importance and the role of boundary spanners that span customization sites by showing how experiences from one site are transferred and beneficial to other sites. The transporting of these lessons provides a ground for mutual understanding between diverse software customization stakeholders, helps to build an understanding and enable customizers to get prepared to act if similar problems are experienced. And, their understanding of the multiple cultures is imperative when features of the generic tools were discussed.

Paper VI: **Software customization in healthcare domain of low-resource settings: a model for building capacity**

Zeferino Saugene, Jens Kaasbøll and Sundeep Sahay, Journal of Information Technology for Development (in review)

This paper introduces a model for making sense of the process of capacity-building toward the customization of generic IT-artefacts. Specifically, the paper provides an appraisal of

practices adopted in the customization of DHIS2 in Malawi, Mozambique and Guinea-Bissau toward the development of capacity. The study uses as point of departure the fact that, because of its dynamic landscape, adoption of generic software systems in healthcare is covered by a number of problems. In response to these problems, the various actions performed toward the effectiveness of customization activity, were identified and used to address the research aim. Special focus is paid to the roles of the different stakeholders in the process.

Furthermore, the paper describes how DHIS2 academies helped local context people to learn how to make better customization of DHIS2 as well as be able to better share thoughts and concerns about the system to others. Papers III, IV and V provide the basis from which the model is developed.

Particular insights developed in this study are threefold. First, given that emergent problems characterize the customization of generic software systems, customizers' tacit knowledge and skills appear to be very important. Second, due to constant changes that generic IT-artefacts suffer, software customization activity is more effective when combining the individual skills and knowledge with the approaches of *situatedness*, mediation and clustering. While the individual skills and knowledge are expressed by work-around practices of improvisation and *bricolage* (illustrated in paper IV); *situatedness*, mediation and clustering is articulated by four practices including requesting for help, cross-site interaction, tailored training and co-located learning.

As portrayed in Figure 5.1 capacity requires an on-going process through which customization practice is converted into knowledge. The combination of *situatedness* - revealing the realities of the practice through exposure to the domain complexity; mediation - having guest people supporting the customization while promoting team practice and collaborative problem solving; and clustering - helping customizers to appreciate the balance between their perspectives and others as they develop a broader view of practice trough inter-professional collaboration, will enable customization stakeholders to recognize the complex practices and appreciate their benefits. Third, in order to maintain commitment of local customizers and manage customization support apparatus, projects require effective governance mechanisms.

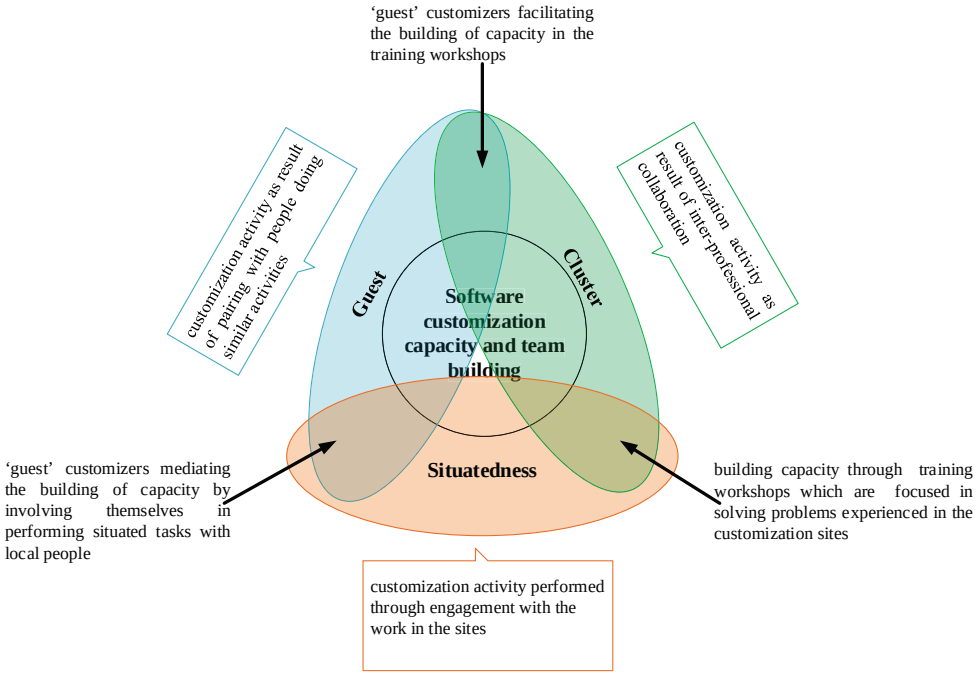

Figure 5-1: Model for capacity-building in software customization

5.2. Summary of findings

The following table summarizes the papers in terms of objective and their contribution to the answering of the thesis research questions, thereby contributing to the understanding of the software customization activity.

Table 5-1: Overview of the included research papers

Paper details		Objective of the paper	Contribution to thesis research questions
Paper I	The Challenge of Customizing Global Open Source Software to Local Country Contexts: The Case of DHIS GIS for Health Management	The paper aims at understanding the nature of customization challenges in tailoring GIS applications; as well as understanding the approaches used to deal with challenges	The paper describes how a given generic software system was customized in healthcare organizations of LMICs. This article considers software misfit, skills and competence as the reason for the difficulties faced during customization. The paper shows also that work-around as a supportive tool that will enable efficiency while performing the activity of software customization.

Paper II	Factors affecting Geographic Information Systems implementation and use in Healthcare Sector: the Case of OpenHealthMapper in Developing Countries	The paper aim at investigating the factors surrounding *geodata* production and sharing; as well as discussing the approach to address *geodata* tensions and problems.	The paper describes the role of *geodata* and organisations producing them; and considers the absence of coordination as the main problem behind the existence of several fragmented spatial datasets spread across different institutions. To address these problems, the article suggests the adoption of Carlile's knowledge integration framework through its processes of transfer, translation and transformation.
Paper III	Extending System Capacity in Low Resource Environments through 'Flexible' Competency Building in Open Source Applications Customization	This article evaluates competency development in multidisciplinary workgroups.	The paper illustrates the customization practices with special focus on the crucial role played by both boundary spanners and boundary objects toward the development of customization competence. It also shows the complexity of the relationship between the different software customization stakeholders, which leads to challenges. In this regard, the paper suggests that the dialogical mechanisms of identification, coordination, reflection and transformation may help to address those challenges.
Paper IV	The Influence of Community Structures in the Development of Software Customization Capacity	The paper aims at discussing the influence of communities in the customization of GSS applications, especially regarded to the issue of capacity building.	This paper shows how customization problems can be overcome. Accordingly, the article shows that prior skills, knowledge or experience can lead to positive outcomes. Work-around practices of improvisation and *bricolage* are pointed as strategies that enable that short-term solution to occur. The article emphasise, however, the importance of relationships and collaboration between stakeholders. Practices of requesting for help and learning-by-doing have an effect on the successful outcome of this process.
Paper V	"Leveraging from customization to inform Generic Software Systems development: DHIS tracker and its introduction in healthcare"	The paper discusses cross-country software customization and highlights its importance in informing software evolution or maturity.	This paper shows the benefit of generic software systems, as well as how the problem of software misfit can be overcome. According to the research, the solutions to this problem can arise from working across customization sites. This paper emphasises the approach of several customizers that influence the design of generic software systems. That collaboration has an effect on the successful customizability of generic software systems. The practice of interactions across sites is pointed to influence this outcome.

Paper VI	Software customization in healthcare domain of low-resource settings: a model for building capacity	Taking a cross-site perspective the paper attempts to answer the following research question: how different software stakeholders interact to shape customization capacity?	The paper introduces a model for capacity development toward software customization. This model suggest combining the customizers knowledge with exposures to (i) the complexity of the customization sites and the domains where the software will be applied, (ii) guests that support and help with the customization work; and (iii) environments where customizers can develop a broader view of their activity through inter-professional collaborations. The model combines several practices including learning-by-doing, requesting for help, cross-site interaction, co-located learning, and tailored training. The paper demonstrated how including these practices in the customization of generic software systems can significantly improve the performance of the activity.

6. Discussion and Implications

This chapter builds on the research findings presented in the previous chapter to elaborate on the major contributions to knowledge and practice that have emerged in this thesis. The chapter starts with discussion on how the thesis has addressed the research questions. Following, an abstraction from the analysis of the findings is made to develop broader theoretical implications. The chapter ends with presentation of the implications for practice.

6.1. Analysis and Discussion

As stated in Chapter One, the main goal of this thesis is to improve our understanding of the practice of software customization from the perspective of healthcare organizations of LMICs. As such, following I revisit the research questions defined in this thesis and summarize the answers the research provided to each of them.

6.1.1. What potentials and constraints exist in customizing open source software systems for and by healthcare organizations in LMICs?

In this thesis, I report on several studies that customized OSS for healthcare organizations of LMICs. The focus was on the customization of DHIS2, mainly in three different settings. The research found that organizations may have different approaches to customization of OSS, as well as different relationship with the OSS communities (developers and users); but there are common benefits and challenges. Apart from the overall characteristics of generic OSS presented in Chapter Two (Section 2.2), major benefits for healthcare organizations when customizing OSS are threefold.

First, generic OSS offer to organizations access to widely used tools containing features that are developed, tested and maintained by technologically and healthcare skilled professionals. Findings illustrate that DHIS2 allows healthcare organizations of LMICs to access to (a) a wide range of health informatics practices; (b) organizational practices embedded in generic packages; and (c) innovations with regard to the treatment and processing of healthcare data. According to the literature, DHIS2 has been adopted as a national standard for health information management in several countries in Africa and Asia. Its development has been an effort of more than fifteen years of cross national action research where lessons were collected and used to build the DHIS2 software (see e.g. Braa et al. (2004), Braa et al. (2007), Titlestad et al. (2009) and Braa and Sahay (2012)). Within this study I have observed countries like Guinea-Bissau adopting features embedded within

DHIS2 Tracker to track their TB patients, and Mozambique and Malawi being able with a single click to link health data with *geodata* and thus perform spatial analysis.

Second, generic OSS offers to organizations the ability to enable functionalities as required. The characteristics of generic OSS specified in Chapter Three (of modularity, predictability and standardization) enable software features to be accessed and modified by users to fit their needs and demands. The modular and standardized structure of the framework used as a foundation for building HIS investigated in this thesis, allow features to be enabled as required. For instance, while the definition of data elements and indicators is required to the entire systems, non-critical elements such as layouts for data entry, and modules for *geodata* visualization (e.g., DHIS2 OpenHealthMapper), and chart and table visualization (e.g., Data Visualizer) may be enabled when required. Similarly, modules such as DHIS2 Tracker and integration standard specification (e.g., SDMX-HD and XDF) may also be enabled when needed. Moreover, the pre-existence of core elements in the tools provides an opportunity to speed-up the process of development.

Finally, the fact that OSS customisation is informed by boundaries of people and practices (see Figure 3.1, Chapter Three) leads to more knowledgeable stakeholders. As presented in the findings, the customization of DHIS2 was situated at the users' organizations. By being involved in software customization activities, users gain valuable knowledge and insight, both related to DHIS2 as well insight to the healthcare domain. This is due to the fact that several communities are observed during the customization work. These communities are made of professionals with different backgrounds and performing different type of service. Besides having similar interests, members of each community have different cultures and practices. For instance, while the developers are responsible in providing guidance related to the design and development of the OSS, the customizers are responsible in fitting local context requirements on it and delivering user needs and demands to developers, and end-users validate and examine the customized application.

Thereby, effective customization of OSS requires the spanning of boundaries between communities. As illustrated in Figure 3.1, software customization requires spanning at least two communities, i.e. developer and user communities. In this research I observed that when boundaries are spanned, knowledge held by the dispersed boundary members is negotiated and shared. This releases a potential for creating new knowledge. For instance, in this research both customization sites and DHIS2 academies were places where boundaries were spanned. In these places local context people were able to learn how to make better and more efficient use of DHIS2, as well as be able to better share thoughts and concerns about the

system to others. In addition, the fact that users are invited to adapt the software to their own needs together with the possibility of getting access to DHIS2 source-code, allows them to access knowledge held on the DHIS2 framework and by the software community, which in turn will improve users' IT and customizers' programming skills.

It was, however, observed that for having carried out customization work with little support of the DHIS2 developers, a sense of empowerment and ownership has been instilled on local people. The thesis illustrates also that knowledge gained from users during customization was used by the developers to improve the functionalities of DHIS2. For instance, DHIS2 Tracker gained its maturity thanks to experiences gathered from the users in the different context where it was customized. In this regard, users' involvement influences the direction as well as ensures the future of the IT-artefact.

There is, as shown above and in Chapter Two, a significant potential for healthcare organizations in adopting and customizing generic OSS. All OSS may have these potentials regardless to their application domain. However, the customization of OSS is not without pitfalls. Central findings of this research point to a wide range of factors that affect the extent to which customization of OSS is achieved by and in health organizations of LMICs. The reported challenges derive from:

(a) Poor skills and competence. When executing customization of OSS tasks, skills and experiences play a role. The difficulty of having local people, who are technological skilled, to perform software customization was the major challenge in the sites. While customizers of OSS are not expected to have the same technical levels as the development team, they are required to have knowledge and expertise that will allow them to perform customization work. The research has found that not all customizers were technologically literate enough, i.e., had experience with customizing IT-artefacts similar to DHIS2. This made the customization process more difficult. Difficulties deriving from this were verified in the customization process in Guinea-Bissau. Likewise, technologically literate customizers faced another kind of difficulties. Illustrations showed that although developers provided the software with its source code, i.e., indirectly giving customizers the 'freedom' to change as they wanted; several customizers were not able to perform such changes. OGUMANIHA customizers, for instance, had problems in integrating by themselves a module that was available in earlier versions and removed from the last versions. In Malawi customizers were not able to align DHIS2 Tracker module with their user requirements by changing the source-code. Technical limitations were also verified with the team failing to generate the GeoJSON and GML files from the *shapefiles*.

Furthermore, the research has shown that some of these problems were related to the criterion used to designate individuals as customizers. In line with that, it was observed that becoming a customizer does not necessarily require proven customization experience or skills. For instance, while software customizers in Malawi and Guinea-Bissau were elected by the coordination team, in Mozambique they were selected based on a public tender. The latter had an extensive job description which included description of the tasks, and the tools which were going to be used. For the case of Guinea-Bissau customizers were selected based on their willingness to join the team.

(b) Software misfit. The inability of OSS to respond to user needs and demands also impeded the activity of customization. The research illustrates examples where a generic OSS (the DHIS2 framework in this case) had an impact on the effectiveness of the customization activity. Major software problems were related to non-availability of features, as well as mismatch between the health information and software process flows. Users in Malawi, for instance, wanted on-the-fly validations while entering data into the application which could not be included because of limitations of web-based applications not affording sending requests to the server every time a field is filled with data. Other problems were experienced with the creation of logic expressions used by data aggregation queries, inability to export the data entered into the database that made the customization to be redone from scratch each time a new version of *DHIS2 Tracker* was released, and also the impossibility of sharing data between health programs. Moreover, the study findings indicate that, when DHIS2 Tracker could not be aligned with local business processes, customizers in Tanzanian chose to perform changes at the source-code level. However, since the process was not coordinated with DHIS2 developers the decision led to additional challenges. For instance, they could not benefit from the enhancements of the generic DHIS Tracker.

(c) Poor supporting infrastructure. OSS literature suggests that boundary objects (e.g., online tutorials, mailing lists and discussion forums) may mediate the process of knowledge building during the customization activity. The study found problems with the artefacts used to support the customization activity. For example, in Malawi during the customization of DHIS2 OpenHealthMapper, customizers observed that two new districts Likoma and Neno were not represented in the existing maps and two DHIS2 organizational units (Mzimba South and Mzimba North) were part of the same spatial administrative district boundary. Similarly, in Guinea-Bissau the country administrative regions did not correspond with the health regions; and the sectors and health facilities of

Oio region were split and aggregated under two regions, Farim and Oio which were not in the maps. Problems were also found in manuals and tutorials, i.e., DHIS2 manuals may have been given less priority mainly when there were few users of the modules. One problem faced by customizers during the customization of DHIS2 Tracker in Malawi, was the unavailability of documentation that could be used to guide the process. Moreover, other document related problems were faced during the customization of other modules as well. Most of them were due to the constant change of the software which was not followed by updated manuals. This need for more updated documentation was felt keenly in the customization sites. Furthermore, the research reported situations of lack of communication infrastructure. In Guinea-Bissau, for instance, customizers' limited access to internet in combination with unfamiliarity with English has restricted them from following the online discussions. Additionally, other customizers who have had access to the DHIS2 online universe faced constraints in having face-to-face interactions with developers or other customizers (e.g., OGUMANIHA customizers).

Even though OSS is described as a special and different member of the software systems family (see Chapter Two), I see clear parallels in relation to their adoption challenges with other kind of software systems that have been adopted in LMICs, specifically by healthcare organizations. However, due to the characteristics of the healthcare sector of LMICs (specified in the Chapter One, Section 1.1.2 and in Chapter Two) the effects of these challenges are much more noticeable in this sector than in others. It is therefore timely to understand how healthcare organizations manage to effectively customize OSS, and to establish a platform for future OSS customization activities. This leads to my following research question.

6.1.2. What are effective approaches to deal with software customization processes?

To answer my second research question, it becomes worthwhile to explore the practice entity (of the Figure 6.1). I found that several practices were adopted to effectively perform the customization activity. These practices include *bricolage*, improvisation, querying for artefacts, requesting for help, tailored training, co-located learning, and cross-site interactions. The practices are associated with and were adopted mainly for work performing, building competence and delivering requirement to developers. A summary of them is presented in Table 6-2 together with their influence to the effectiveness of the customization process.

Table 6-1: Summary of practices and their influence to software customization

Group	Practice	Influence the effectiveness of the customization activity
Work-performing	Work-around practices of improvisation and *bricolage*	Quick response to software misfits
	Requesting for help	Get assistance from developers and 'guest' customizers
	Querying for software documentation	Self-development of knowledge about the activity of software customization
Competence-building	Tailored training	Train local customizers in addressing current and future problems.
	Co-located learning	Develop mutual learning during customization
	Cross-site interaction	Learn from the practices adopted by other countries or sites
Requirement-delivering	Cross-site interaction	Coming up with more customizable features

6.1.2.1. Work-performing practices

The customization activity, which is the focus of this thesis, involves taking a generic OSS and tailoring it to the needs of the local contexts. The execution of this work has been considered as complex and problematic (see Gasser (1986), Pozzebon and Heck (2006), Levina and Vaast (2005), and Suchman (2007)). Similarly to Suchman (2007) 'plans and situated actions' argument, lessons from this research illustrate the existence, in the local contexts, of several factors that inhibit customization work to flow easily. Three practices were observed in this research as mechanisms that helped customizers to address most of customization difficulties. These are:

Work-around practices of bricolage and improvisation	
Definition:	*Bricolage* and improvisation were defined in Chapter Three as practices used to deal with the unexpected problems. While *bricolage* is used to make do with resources at hand (Ferneley & Bell, 2006; Ciborra, 2002; Lanzara, 1999); improvisation consists of using both prior experience and resources at hand (Tan & Hallo, 2008). Differently from *bricolage*, improvisation is adopted when there is a possibility of seeking for resources.
Example:	Findings from this research illustrate examples where customizers were flooded by unexpected problems. Actions taken to deal with these problems included for instance, deploying two versions of the same application, using

	special characters (e.g. hyphen, colon and dot) to differentiate one organization unit from other, entering data manually, among others. Details of these actions can be found in papers I and IV.
How the practice influence the effectiveness of customization	
Delays in customization projects can occur when people spend time on finding and reaching the correct person in a given role. Moreover, misfits are inevitable in generic software systems; especially when it comes to new use domains, new software features etc. Sometime fixing problems may take weeks, months or years. Thus, being able to improvise either by getting someone to change the code (as in Tanzania) or running two parallel versions (as in Mozambique) may be the only way to beat that time pressure.	

Requesting for help	
Definition:	The practice of *requesting for help* is similar to *urgent request* defined as a mechanism for requesting urgent information from a group with specific knowledge (Bass et al., 2007). This practice is motivated by fact that the expectation of people roles does not coincide with what they actually do in practice (Levina & Vaast, 2005), and is intended to quickly address customization problems.
Example:	It was observed, in this research, that when customizers faced challenges they requested help from the developer community. Detailed examples can be found in papers III and IV, where the ability to have support from both the developers and 'guest' customizers is highlighted as an approach that helped to speed the customization work.
How the practice influence the effectiveness of customization	
An alternative approach to quickly address customization challenges (e.g., software misfit) is to request help from the community of people already familiar with the software. This practice helped customizers to, at a given moment in time, collect information on a specific topic and proceed with the customization process. The practice allowed also customizers to benefit from experiences of 'guest' customizers. By obtaining quick responses from community, it helped them to keep the customization activities up to speed.	

Querying for software documentation	
Definition:	The practice of *querying for customization artifacts* refers to a process leading to the exploration of documents that keep customization knowledge.
Example:	Examples of the use of documentation, and boundary objects or artefacts in general can be found in papers I, II, III and IV.

How the practice influence the effectiveness of customization

In OSS not every user has direct contact with the developer community. Moreover, it might be difficulty to have access to people (as observed in some customization sites). Face-to-face contact (with experienced customizers or developers on the sites helping or teaching how to customize a software system) is expensive. Because of that, customizers can gain valuable knowledge about the activity of software customization at a very cheap cost by downloading software documentation. By accessing these documents customizers expected to obtain a common understanding of practices and experiences with customization of the different sites.

Considering software documentation as boundary objects, it is stated that they help participants to focus their attention to the development of local knowledge (Yanow, 2004). This is mainly due to the shared nature of the problem of healthcare strengthening. In other words, the effective support of boundary objects toward the development of customization capacity is due to the existence of a shared problem in the sites, e.g., the healthcare strengthening. Because of that, boundary objects are able to align customization work by enabling customizers to clarify knowledge embedded within tools. This enables clarified knowledge to emerge (Lee, 2007; Carlile, 2006), lead to shared understanding (Koskinen & Mäkinen, 2009) and a cross-boundary mutual agreement on common knowledge (Carlile, 2004).

6.1.2.2. Competence-building practices

The customization of IT-artefacts, as presented in Chapter Five, is influenced by customizers' skills and competence. As portrayed by Figure 6.1, customization competence rely on individuals, the boundary spanners, that facilitate the sharing of expertise by linking two or more groups of people; and on organic arrangements, artefacts or boundary objects that allow the boundary spanners to work together (Star, 2010). While examining the ability of customizers to deal with the disturbances, the research found that customizers' ability was shaped by two broader practices including: *learning-by-doing* and *cross-site interaction*. The

practice of *learning-by-doing* verified in this thesis is part of the network of action approach by Braa et al. (2004), an mechanism which is believed to create knowledge in an efficient way. The mechanism is characterized by team members from the user site meeting those of developer site and jointly developing an understanding of the functional specification. Learning-by-doing practice verified in this thesis combines the practices of *tailored training* and *co-located learning* by Bass et al. (2007).

Tailored training	
Definition:	Bass et al. (2007) define tailored training as a competence building mechanism that is designed to teach the application of standard training contents to specific projects.
Example:	It was observed in the research that in situations where customization site was not sufficiently familiar with the technology requested involvement of member of more advanced customization sites. Details can be found in papers III, IV, V and VI.
How the practice influence the effectiveness of customization	
The execution of the practice of requesting for help, as observed in this study, resulted in 'guest' customizers being exposed to specific work in the customization sites. While in the sites, the focus of these guests is both the help addressing the challenges and to train local customizers in order to be able to address future problems. This training most of the times take into account the specific characteristics of the domain. Moreover, findings show that the collaborative arrangements observed during the spanning of boundary, besides helping customizers to effectively perform their work and thus build HISs that meet the needs of end-users, permits the development of knowledge.	

Co-located learning	
Definition:	Bass et al. (2007) define co-location as a process of bringing together teams that have not previously worked together. The practice of co-located learning borrow these characteristics to refer to the process whereby inter-professional from both customizer and developer sites are co-located and jointly engage in customization of software systems.
Example:	Findings from this thesis has illustrated examples where local customizers were visited by people involved in similar projects in other contexts referred as

	'guest' customizers. The research illustrates also examples of DHIS2 academies that were attended by teams of several customization sites, as well as by the developers. Details can be found in papers IV, V and V, as well as in Table 4-3 in Chapter Four.
How the practice influence the effectiveness of customization	
The fact that the people were shared between interventions provided a common ground for mutual understanding between local and guest customizers. It was observed that during the tailored trainings, while local customizers learned how to perform the software customization activity, the 'guest' customizers gained knowledge about local particularities, as well as delivered to the local people the experiences from other settings. In other words, together the teams (local and guests) developed a common understanding on how the technology would be customized.	

Cross-site interaction	
Definition:	The *cross-site interaction* practice behaves similarly as the cross-site delegation which Bass et al. (2007) defines as the delegation of individuals from a central site to a remote site. In this research cross-site interaction express the way knowledge is developed by combining views of teams from different customization sites.
Example:	Findings from this study show that knowledge was created as result of interactions that occurred in DHIS2 academies. For instance through academies while cooperating together to realize individual and country learning goals, customizers shared experiences between each other. In papers IV and VI, I present details of the interactions between delegations from different customization site (composed of customizers and users) and the development team during DHIS2 workshop academies.
How the practice influence the effectiveness of customization	
Often, it is not the case that information is not available; rather, the information is not shared with the right individuals. This practice helps to establish communication across sites that can be useful if information is needed at any point in the project (Bass et al., 2007). The possibility of having people who were involved in the customization of the same software in other sites, domains and settings, to help with the customization is beneficial both the local people and to 'guest' customizers. This ability to view peers' work and have a direct	

interaction can lead to learning opportunities that extend customizers competence. While local customizers use this opportunity to access and learn from the practices adopted by other countries or sites, for 'guest' customizers it is one more source that enriches their knowledge and competence. By being exposed to peers' work, local customizers come across a range of experiences and perspectives which helped them to for instance address customization challenges. The practice is, in this regard, a strategy helping the extraction of knowledge existing in the heads of customization community members. Applying cross-site interaction helps in achieving a shared understanding of problems that needs to be solved (Clerc et al., 2007).

6.1.2.3. Requirement-delivering practices

Given that most OSSs are developed based on 'generic' principles, one of the problems identified in this thesis was the issue of customizability. Customizability, as defined in Chapter Three, depends on three principles: modularity, standardization and predictability. From these principles predictability and standardization are the principles allowing multiple customizations to be performed on the same line without major changes. Predictability as defined in Chapter Three refers to the degree to which OSS what will and is needed to do. This definition may even be valid to those adopting mature OSS, but has its limitations. In this regard if we wanted to understand how developers come up with such standard software or reach such maturity it would lead us to study the biography of the artefact (Pollock & Williams, 2010) or the standardization process. From this thesis, standardization appears to be an outcome of materialization of lessons learned after spanning domains, settings, and customizations sites. In other words, OSS is made customizable through an on-going problem-solving process taking place as individuals are engaged in customization activities.

With regard to this, the practice of *cross-site interaction* was observed.

Definition:	The practice of *cross-site interaction* refers to a mechanism that focuses on cross-cultural contexts to foster the collection of requirements. The practice builds on (Damian & Zowghi, 2002) argument that due to distance interaction with customers is challenging and may be done through mediators. In this research the interaction with practitioners from different customization sites was possible due to the practice of *co-located learning* where customizers from the 'guest' customizers were sent to sites and during the joint customization work they collected requirements, as well as through face-to-

<table>
<tr><td></td><td>face meetings with ‘guest’ customizers organized the developer community to align expectations of users from all customization sites.</td></tr>
<tr><td>Example:</td><td>Findings from this research show that customization sites were settings prone to disturbances. Example of disturbances included DHIS2 not allowing mimicking business processes workflow, difficulties to share data elements between different health programmes, and non-availability of offline data-entry and import/export features. These and other user needs and demands that could not addressed by DHIS2 were in the majority of the times forwarded to developers in some cases by local customizers and in others by ‘guest’ customizers.

The research has illustrated that the process of making DHIS2 customizable resulted from a sequence of interactions between domains, settings, and customization sites (see details in Paper V). For instance, it was observed that after customization problems being identified in Malawi and reported to the developers, the DHIS features were enhanced. Results of this effort was observed in Guinea-Bissau were customizers did not face similar challenges as those in Malawi and Tanzania, as well as with the emergence of new features within DHIS2 that could enable customizers to perform better their work (e.g., the possibility of exporting data from DHIS2 Tracker).</td></tr>
<tr><td colspan="2">How the practice influence the effectiveness of customization</td></tr>
<tr><td colspan="2">The interactions allow accumulating expertise that is used to improve the software features. By interacting with practitioners from different customization sites, customizers and developers are able to come up with features that will be more customizable. In other words, this practice helped people (from different backgrounds, institutions or organizations collaborate in the production of the tool) to build trust as well as to share the ownership of the technology (Kamensky et al., 2004).

Moreover, the understanding of the multiple cultures is imperative for ‘guest’ customizers when features of the generic tools are discussed. Experiences with a certain feature or user needs and demands can be compared across sites in a way that developers can provide a design or model that addresses the needs of all the users.</td></tr>
</table>

6.1.3. How can customization sites be organized to strengthen their capacity for carrying out customization?

This research shows that the development of the capacity to perform software customization work goes through several stages from exposure to domain complexity to inter-professional collaboration. A model developed in this research (presented in Figure 5.1) illustrates this process, and suggests that customization activity is most effective when combining work-performing and competence-building practices. The model illustrates also how important a network and its community of members are to the software customization activity, particularly to capacity-building. In this research, networks and communities were established between different groups of users of DHIS2, which convers the perspectives of several roles including developer, customizer, implementer and end-user.

The developer, customizers and user roles, were manifested in this research exactly as described in Chapter Three, Section 3.1. However, difference was only on the emergence of the implementers role which was used to refer to the expert users were, those having the task to work closely with the users, collect requirements, analyse and if possible address through customization. These implementers were mainly NGOs which worked as partners of the customization team, and included organizations such as Clinton Health Access Initiative, Elizabeth Glaser Pediatric AIDS Foundation and Ifakara Health Institute. It was also observed these implementer institutions, producing new kind of practices (e.g., users performing customization). Their participation in the joint field became the basis upon which they were distinguished from those in their local fields who were not participating in a similar activities (e.g. those taking the end-user role). Each of these partners had its own team responsible for implementing the application, training the end-users and addressing the technical problems faced by end-users.

However, due to factors expressed in chapters one and two which characterize healthcare organizations of LMICs, the practices of requesting help, tailored training, co-located learning and cross-site interaction, can be impracticable. In other words, the limited access to infrastructure, financial barriers, and cultural factors (e.g., language) can hinder the realization of these practices. In this thesis most of the available communities were initiated and maintained by ‘champions’ with a different cultural background (e.g., domain knowledge, languages, technologically literate levels, etc.) as compared to those members of the three groups of users highlighted above. This somehow prevents customizers, especially those experiencing huge cultural gaps, to join the communities and request help or share concerns.

Building upon these insights, I suggest the need of cultivating knowledge sharing within the communities made by individuals with similar cultures, skills and practices. This can benefit from the existence of common goals among the stakeholders within their countries or regions. Example of such communities can be what some countries call ‘HIS forum’, used by HIS stakeholders within countries to periodically discuss HIS related issues. Since these stakeholders live and work in the same setting it is easy to identify and acknowledge the differences among them, as well as seeks out the sameness. These communities can gradually through the networks, communicate with other communities, and make the result of this interaction beneficial to all members. Thereby, if there is a new member (who shares characteristics with the community), will have a space where to place and meet the most basic concerns related to the technology.

This can also help the work of regional or funding organizations such as the WAHO, the Global Fund and HISP to effectively address both healthcare and customization problems in a given country or region. These local and semi-local communities can help to reduce the divide between, for instance, the North and South given that it might be easier for a customizer from Guinea-Bissau to work together with a person from the same country or with a person from a Portuguese speaking country like Mozambique than with customizers from Tanzania, Norway or India.

6.1.4. Summary

The empirical studies have shown that software customization is a complex activity which is influenced by many factors. On the one hand, we find that software customization relies on boundary spanners. The boundary spanners are mainly customizers. They develop their skills and knowledge by engaging with practice as well as by accessing knowledge embedded in boundary objects. Boundary objects are generally artefacts drawing attention to knowledge dispersed across boundary spanners and at the same time clarifying the knowledge of local people. On the other hand, especially in situations where support is needed, boundary spanners act on behalf of others and in the research they have been moving across customization sites. The cross-site perspective enabled also boundary spanners to act on behalf of others, as well as influenced the content of boundary objects. Our results also reveal that networks and clusters are important mediators in the software customization work.

An overview of the major elements characterizing this complexity, obtained during this research, is abstracted in Figure 6.1 in form of entities and relationships between entities. In this figure the boxes represent the entities and the connecting lines are the relationships or the

association between entities. The direction of the arrow represents the influence of one entity over another.

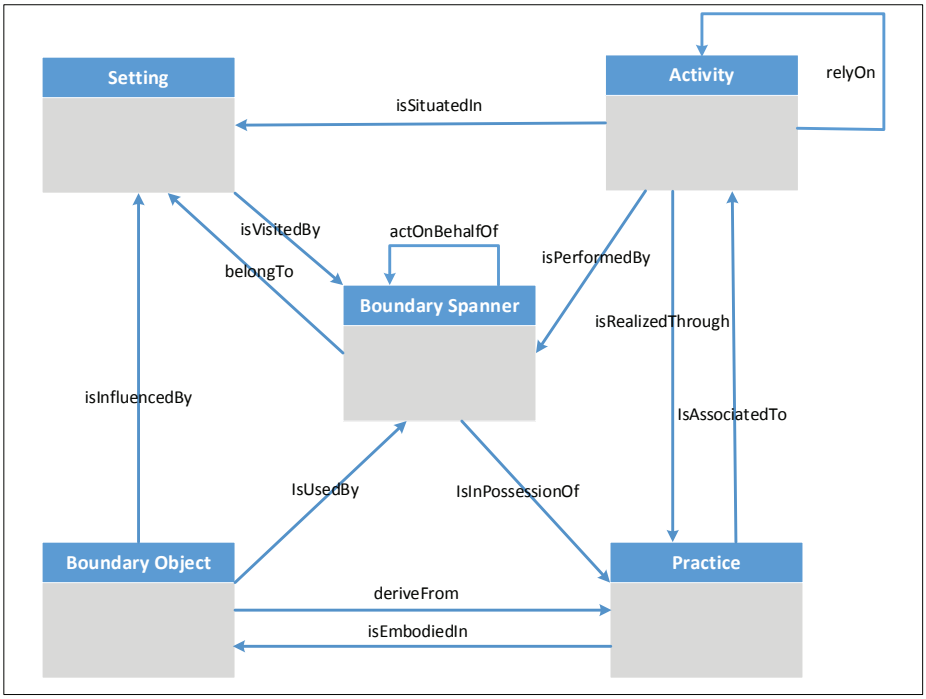

Figure 6.1: Types of customization entities and their relationships

I will, in the next two sections, provide a discussion on how this thesis contributes to our knowledge in terms of implications for theory and practice.

6.2. Theoretical Implications

As presented in Chapter Three, my approach to meet the objectives of this research has been to bring together a number of related theories and concepts that can inform the understanding of IT-artifact customization. Observed by Bräuchler and Postill (2010), theories of practice are conceptualizations of work that "takes the human body to be the nexus of arrays of activities, or practices, that agents perform with a greater or lesser commitment, dexterity and grace" (pg.11). Theorists have also embraced theories of practice to investigate the dynamics between technology and use contexts, especially the activities performed to accomplish adoption of technology (Nicolini, 2013; Orlikowski, 2010). In this manner, I may broadly propose implications relevant to the practice-based literature. Furthermore, my intention is to apply the findings and thoughts back to the conceptualization of IT-artifact customization so that contribution is also made to the current literature on the IT-artifact customization matter. I, in turn, discuss the five broad contribution areas.

6.2.1. Human-centred improvisation

Technology transfer projects such as the one investigated in this thesis are susceptible to disturbances. Due to complexity of the public health domain, there are a multiplicity of emergent activities which leads to increasing rates of requirement change, multiplicity of components (e.g., numbers and types of stakeholders), and unpredictability and increasing size of the system, and different types of breakdowns. Addressing these breakdowns is a matter of both time and skills. Given that time to conceive and implement projects is often short, improvisation becomes an important strategy to address emerging disturbances.

One of the primary implications of the results from this research is for the field of improvisation. Improvisation involves a set of actions emerging in response to the need of managing unexpected opportunities or breakdowns while implementing changes in organizations (Orlikowski & Hoffman, 1997; Pina e Cunha et al., 1999). For instance, as reported in this research when OGUMANIHA customizers found themselves in a dilemma on whether to upgrade to a new DHIS version, to have the OpenHealthMapper and loose the excel module, or keep the current version thereby losing the possibility of benefiting from the potentialities of the OpenHealthMapper, they had to improvise. Because many of these actions are related to tasks, the practice of improvisation has systematically been related to the performing of tasks differently. Orlikowski (1996), for instance, considers that new technologies is given meaning or adapted to particular settings through unintended tasks. While Ciborra (1996) considers improvisation as a combination of resources, routines and structures which are able to match the present, turbulent circumstances; Barrett (1998) describes improvisation as novel responses without a prescribed plan and certainty of outcomes; and Vera and Crossan (2005) describe it as a spontaneous and creative process of attempting to achieve an objective in a new way. A key element of these descriptions of improvisation is the issue of task execution, especially dealing with breakdowns.

While such features of improvisation have also been seen in this thesis, an additional type was also seen which I term as *the human centred improvisation*. This perspective considers the emergent actions performed by *people on people*, especially relevant given the characteristics of healthcare organizations of LMICs as related to the workforce crisis (Liese et al., 2003; Huddart & Picazo, 2003), budget shortages, poor motivation, the high rate of exodus of qualified professionals due to the availability of greener pastures in the private sector, in international NGOs or abroad (Unger & Criel, 1995), and the high dependencies on foreign assistance (Kimaro & Nhampossa, 2007; Baskaran, 2001). Trying to carry out the

customization work in the light of these inherent and systemic human resources related challenges, calls for improvisations, especially related to people.

This thesis has described several human related actions adopted during the process of carrying out customization work. For example, when the HISP Tanzania customizer team faced challenges in inscribing user requirements within the DHIS2 Tracker module, they decided to hire a local developer to perform the changes at the source-code level since those capacities were not available internally. Similarly, given that the local OgIS customizers could not adapt the DHIS2 OpenHealthMapper module by themselves, a customizer who had been involved in several other projects at the global level was asked to help in adapting the module to their context. In Guinea-Bissau, when health statisticians and data managers had to leave the customization process to produce the reports, or attend meetings and perform supervision work in the regions, the customization tasks that were assigned to them were transferred to the 'guest' customizer and sometimes the other participants so as to fill the gap.

Further, the decision of trusting NGOs to mediate the link between end-user and customizers of DHIS2 in Tanzania created a new role, the implementers. This was an improvisation action performed by HISP Tanzania due to their financial constraints. The adoption of this practice was later considered in other countries such as Malawi. These examples show different models of improvisation to select customizers, when internal capacity – financial and person related – was inadequate. Moreover, while some project managers hired customizers based on formal job descriptions, other projects such as in Guinea-Bissau and Malawi made their selections informally and based on social networks, also to deal with their financial constraints which did not allow formal advertisements and selection processes.

Consequently, there is a potential of considering software customization in a LMIC as a process of human centred improvisation for the following reasons: (a) the failure of various projects in the past has been the lack or shortage of individuals with abilities or skills to perform specific type of tasks; (b) in some cases it has been the lack of capacity (material and financial) in the institutions to keep the most qualified personnel for the tasks; and finally, (c) even if individuals have the required skills at the moment, they do not get adequate opportunities to upgrade and enhance their skills in line with the evolving technologies and organizational needs. For example, the DHIS2 software that started to be developed in MS Access in 1994 has evolved over time to be Java and OSS based in 2005. Since its introduction until now (August 2013) the software has also undergone several significant revisions to the point where today we find features and execution logics quite different from

those that had existed. Individuals who were hired during the first versions of the software would be inadequate to deal with the new versions without adequate upgrading of technical skills.

Human centred improvisation is relevant when different members have their own obligations and competences, and when necessary, they can swap tasks and support each other as the exigencies of the situation demands. Examples include work by Mosse (2005) arguing that the vibrant tradition of resource sharing existing in the healthcare systems of LMICs creates potential for strengthening collaborative linkages and of joint problem solving. Moreover, drawing from the existing bones of communities and friendships, I extend the sharing of objects (printers and cars in Mosse (2005)) to human beings or social actors (the customizers). This sharing process allows the strengthening of linkages, but importantly enables the delivering of the software that meets uses needs.

An important issue to consider is the sustainability of collective responsibility toward software customization, which refers to the "condition in which responsibility for the success of an … [activity] is distributed across all the [community] members" (Scardamalia, 2002, pg. 68). This collectiveness goes beyond awareness and complementarity, and requires that members are engaged in the execution of tasks (Zhang et al., 2009), and have the responsibility and commitment to deliver (Scardamalia, 2002). In the next section, I discuss how collectives can be made stable and functional.

6.2.2. Customization through networks of practice

Most existing literature on generic open source software systems, especially those that focus on the healthcare sector of LMICs, describes software customization work as being offloaded to 'local people'. Although the model is not dead yet, it is often inadequate to meet with the complexities of healthcare organizations in LMICs, and requires various models of support, which I argue can be supported by 'networks of practice'. I see this network as being dynamic and plastic that expand and contract depending on the problem at hand, and where the members do the work for and with each other.

This approach offers several benefits including: (1) flexibility: because members of Networks-of-Practice (NoP) confront, discuss, modify, and learn practices with their pairs who belong to different organizations (Tagliaventi & Mattarelli, 2006), they can leverage the skills of a range of providers; (2) innovation: the recurrent use of networks provides a pool of practices and tools, and, through this, they can support alignment of practices beyond local settings; (3) by leveraging the expertise of 'customization mediators', network approaches

enforce customization as a shared activity, with a focus towards problem solving and (4) the decentralized form of a network linked to the ability to rapidly access information from local and global actors, to help improve the speed and efficiency of the customization activity.

The customization process is situated in a context, referring to the environment/setting where the software should be used. Authors such as Vaast (2004) claim that only members who share the same setting, face the same kinds of concerns, and interact directly may actually share practices. This is similar to the *Community-of-Practice* (CoP) notion described by Wenger (1998) as emerging from recurrent face-to-face interactions taking place in materially and historically bounded contexts. This refers to the arena in which the people act (Nardi, 1996). In this thesis the arena was beyond the environment where the software was to be used to encompass both the DHIS2 academies and the experiences brought from other settings where the 'customization mediators' had previously worked. The adoption of networks allowed software customization to be extended from being performed in the user setting and by local people, to being a result of collaborative work performed with support of customization mediators at global and regional levels. Such interactions allowed the sharing of practices that were once 'restricted' to specific settings, by creating a sense of proximity beyond geographical distance and national boundaries. Therefore I find that the thesis contributes to the extension of the notion of 'situated context' by going beyond the country or site level CoPs to include NoP.

While the idea of networks has been important in studying organizations, and also technology transfer processes, it has not explicitly been applied to study processes of customization, and how they enable for instance work-around practices of improvisation and competence-building practices. This extension arguably helps to enrich both our understanding of how improvisation takes place, and also the nature of action within networks of action. Various authors (Orlikowski & Hoffman, 1997; Pina e Cunha et al., 1999) have emphasized the critical role played by improvisation in increasing competencies. I argue that the notion of networks of practice helps to further understand the circumstances and conditions in which those competencies are developed during the process of software customization. With regards to networks of action, Braa et al. (2004) have stressed that organizational learning flows better in situations where sites are connected through networks, rather than as individuals in isolation. The kinds of action they describe as flowing in the network included the sharing of resources, software products and implementation resources. I add to this by describing how customization can be carried out and learnt in these networks, to support local work.

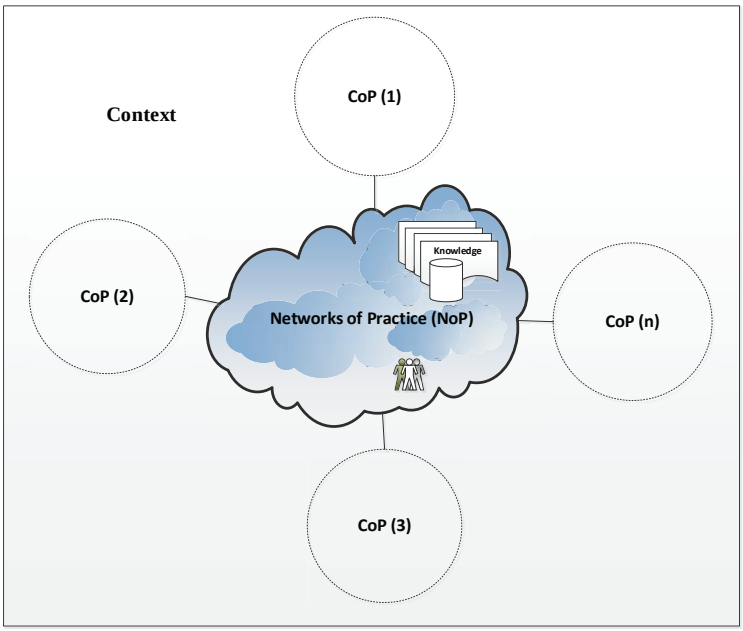

Figure 6.2: Constructing NoP by linking multiple CoPs

As portrayed by Figure 6.2, successful network dynamics is based on the principle of actors having equal access to resources in the network. Such networking allows for cost reductions in the adoption of a technology, as it allows leveraging upon the capacities and experiences of the members of a pre-established community. As Metcalfe's Law (Metcalfe, 1995) argues that the value of a network grows in proportion to the number of users of that network. Taking the example of social networks like Twitter or Facebook, the value of being a member of these networks depends on how many of your friends are part of that network, which directly contributes to the value of participating in the network. When different CoPs link with each other, they can enable a NoP which transcend geographical boundaries. This thesis emphasizes the value of these networks, and the sharing of a web of practices, often enabled through visits of mediators to the local customization sites. Since network members have been engaged in similar work practices and experiences, there is an emergent complementarity between the CoP and the NoP (Vaast, 2004). For instance, the fact that the participants in the DHIS2 academies are usually focused on understanding and addressing individual country problems provides a sharing of responsibility and flexibility in addressing unexpected difficulties.

6.2.3. Reconceptualising the notions of boundary spanner and boundary object as customization mediators

Traditionally, software customizations in healthcare organizations of LMICs are performed by boundary spanners. This thesis provides an alternative model for the same. First, customization of generic IT-artefact involves boundary spanning work, with its various complexities. Boundary spanners are regarded as individuals that engage in collective knowledge generation to support local users' needs and demands. In our story, the developers and customizers were two key boundary spanners. While developers were responsible in providing guidance across boundaries related to the design and development of DHIS2, the customizers were responsible for fitting local context specific requirements in the DHIS2, and validating it to user needs. The software developers help to enrich customizers' knowledge, and mutually support problem solving. However, given the human resources challenges LMICs face, a key issue concerns of understanding the roles, difficulties and strategies used during the course of boundary spanning work. Levina and Vaast (2005) have asked the question of *should boundary spanners be formally nominated or emerge from practice?* Our examples were of both nominated and emergent boundary spanners. For instance, while in Guinea-Bissau individuals were selected from available health staff; in Mozambique a public tender was used to select them. I also observed boundary spanners turning themselves into developers in Tanzania, and mediating agencies (implementer institutions) emerging to foster software customization and the implementation process also in Tanzania. In this regard, both types of boundary spanners are needed for effective software customization.

The need for handling both nominated and emergent boundary spanners in the course of the software customization activity demonstrates how complex is the boundary spanning work. This complexity is also demonstrated when looking at the role played by boundary spanners and boundary objects. In this study I verified several situations where boundary spanners failed to fulfill their roles. For instance, OSS assumes that local context customizers are technically equipped to handle the customization activity, i.e., they are able to perform any kind of change, required meet local needs and demands, in the system. When that is not possible it can be considered a failure. In this research failures has been observed, for example, in Malawi with local customizers not being able to perform changes to meet their end-users' needs and demands, and in Guinea-Bissau where it was not possible to find individuals to exercise the customizer role. This analysis allowed going beyond perceptions of what people aspire to do, to what people do in practice. In this way, the thesis supports Levina and Vaast (2005) suggestion of using the notion of *boundary spanner-in-practice* instead of

just boundary spanner. Similar situation was observed with respect to the boundary objects. I also found artefacts (physical documents and webpages, emails and mailing lists and databases) failed to address such boundary spanning purposes, and raises the need to study *boundary-object-in-use* (Levina & Vaast, 2005). In this regard, the research observed that in Malawi customizers could not have access to DHIS2 Tracker documentation because it did not exist and used PowerPoint documents provided by a researcher who was in India, a setting where DHIS2 Tracker was in use. And in the Portuguese speaking countries, because the documentation containing DHIS2 customization practices was in English, local customizers faced difficulties in follow up and studying by themselves, thus becoming a barrier to the customization activity.

Both boundary-spanner-in-practice and boundary-object-in-use exerts the function of mediators; hence I consider them as *customization mediators*. These customization mediators, in some cases, belong to the users' setting and, in others do not belong to neither of the settings (user or vendor). In general they are individual or artefact whose understanding/translation of the multiple cultures is sufficient to lower the gaps, as well as provide better understanding of both the domain and the generic tools.

With regard to their role, literature talks about them mostly in projects where their focus is to link two domains with overlapping agendas. The customization work investigated in this thesis is rather about multi-domain and multisite spanning activity performed with support of networks. Levina and Vaast (2005) asked the question of *which boundaries should be spanned in building organization competence?* Through the network perspective, this research describes software customization as an activity that spans customization settings, which in turn spans domains (e.g., health and IT). Thereby, I find myself contributing to the enrichment of the pool of concepts providing a theoretical lens to analyse the production of what Puri (2007) called hybridized knowledge. Hybridized knowledge refers to knowledge that is acknowledged by a multiplicity of knowledge systems (e.g., software developers, healthcare manager and end-users). Puri (2007) stresses that creating this knowledge is challenging and requires a focused analysis of the different communities that hold and apply such knowledge. He suggests that such analysis can be facilitated by the notions of CoP, boundary object and participation.

In this thesis, 'customization mediators' were seen moving from one site to another with the aim, not only to share knowledge but to participate in the customization activity. In Puri's language each of these customization sites is a CoP. Through mediators different CoPs are able to communicate and together contribute to the generation of hybridized knowledge. That

knowledge flows within a NoP which is represented in Figure 6.2 by a cloud. Similar to Puri (2007) mediators inhabit several CoPs and satisfy needs and demands of each of them. Through participation in different settings 'customization mediators' they spread practices across sites, as well as bring local requirements to the knowledge of the community. This has happened, for instance with *DHIS2 Tracker*, where lessons from Malawi were later applied during the customization in Guinea-Bissau; and with *DHIS2 OpenHealthMapper* with lessons from Malawi being applied in Mozambique.

6.2.4. Participatory design through customization

One important area of research when considering software customization as a situated activity is the understanding of the level of involvement of individuals, who reside or live the day-to-day life of the context where the activity of software customization take place, into the design of the technology. It was toward this aim that the Participatory Design (PD) approach started to be used and throughout the years has often been treated as user involvement in the system design.

According to Puri (2007) and Damtew (2013), there has been very little analysis on the conditions and also limited discussion in the IS literature of the involvement of local people in expressing their domain knowledge towards the development of the technology. However, the complexity of the domain where this technology is being inserted, especially in LMICs, challenges the PD process. In the healthcare sector, for instance, those challenges are due to (a) the complexity of setting and its subsequent lack of skilled personnel, (b) the lack of financial resources that lead to very shallow salaries, (c) the involvement of donors in healthcare that forces these organizations to follow their procedures (d) lack of infrastructure (e.g., internet), and (e) cultural discrepancies (e.g., language). Thereby we cannot expect a straight forward and active participation of local users.

Involvement in PD is characterized primarily by developers discussing with users and collecting their perceptions about the tool in form of requirements. In this study I verified that this activity happened during the customization process. While some of these requirements were provided by the end-users, most of them came from indirect users such as donors and NGOs. Example of requirements that came from end-users includes the need to continue entering data while the server is offline, the sharing of data elements between programs and the possibility of navigating on the data that was entered in offline mode. I have also seen requirements being provided by donors and NGOs. NGOs such as WAHO, Population Service Information (PSI), OGUMANIHA and Center for Disease Control and Prevention

(CDC), pushed the boundaries of what was required, by bringing new use cases such as agribusiness, water and sanitation, management of lab specimens, among others. These new use cases pushed what the developers needed to do. PSI, for instance, wanted to use DHIS2 for food security in a global scale; but due to the fact that DHIS2 interface language was hardcoded they could not do it easily. So, developers were then prompted to make language feature in DHIS2 more dynamic. Similarly, requirements came also from WAHO who had a different organization hierarchy and wanted to have DHIS2 to handle data from the fifteen countries and CDC that wanted to track lab specimens.

Moreover, some of these donors (e.g., WAHO, HISP and Global Fund) are giving opportunity for different actors to become part of the network; bringing new requirements in the picture; providing new requirements to the software systems; pushing to incorporate new requirements; force the integration with other software systems. For example, customizers in Malawi and Guinea-Bissau were able to participate in the DHIS2 academies because HISP and WAHO funded their participation. Malawian and Bissau-Guinean customizers were, through HISP funds, able to have 'guest' customizers working with them for a long period of time and they used this opportunity to hand their needs and demands. Through funding provided by a group of NGOs, OGUMANIHA customizers had opportunity to become part of the network of practice, otherwise could have been difficult to do. With participation to NoP being part of customization culture, knowledge is 'freely' available and there is also opportunity for other knowledge to flow in. This is more advantageous compared to traditional customization cultures that rely only on CoPs.

In this thesis, PD which could mean that end-users participate in the design of the software systems was seen gaining a new guise. Two mechanisms, customization mediators and DHIS2 academies, were used to enable participation of local people. Given their involvement with customization in the sites, mediators were responsible for forwarding end-users' needs and demands to the developers. The use of mediators in PD is not new in the IS field, authors such as Iivari (2006), Tuovila and Iivari (2007) and Titlestad et al. (2009) have studied the process of representing user in the design of IT-artefacts. However, special characteristics were observed in this study that although similar to some of these previous works differs to most of them. Mediators from this study did not belong to the development contexts, but rather belonged-to the customization contexts. They lived the everyday challenges of the users as related to the lack of specific features on the software and received day-to-day pressure from end-users about such features. Some of them have been moving from one CoP

to another, and beyond extracting needs and demands from users, they were actively engaged in the process of customization.

Moreover, it was observed that developers used the DHIS2 academies to present new features of the system, and through them received inputs. Pollock et al. (2007) have demonstrated the benefits of clusters, which is also expressed in this thesis. However, differently from Pollock et al. (2007) clusters from this thesis were not segregated. They operated as networks connecting myriads of professionals and customizers involved in customizations in various sites and with many different knowledge levels and technology literacy levels. Their existence opens space for local context customizers, as well as end-users to participate in the design of the software. By allowing participation to happen at the network level we will be reducing, for instance, the divide between the North and South, where people can work at local and semi-local communities.

6.2.5. Learning-by-doing through clustering approach

Learning is a process through which people develop knowledge. This process usually involves sharing and transferring of practices across individuals, a process which often take place during the execution of activities (Arrow, 1962). Literature on capacity development talks a lot about this process, but little is written about how it can be enabled. Similarly, literature on technology transfer says that technology can be taken from country A and put in country B, and after giving little training users can go on. (Bondarouk and Ruël (2003)), for instance, state that the introduction of new information technology enables individuals from different domains, settings and professional skills to interact. These interactions allow people to share knowledge, express their attitudes towards the system, exchange experience while interacting with the system, and even collectively plan for further improvement and implementation. In settings where people are technologically literate, this can be possible. But, in LMICs and healthcare settings dominated by problems such as lack of skills, lack of infrastructure and language, we cannot expect local people to perform these tasks (e.g., assess to documents and mailing lists, follow them and successful perform customization) by themselves.

To complement this, through findings of this thesis I argue that software ‘learning-by-doing’ must adopt approaches that will work in their entire life cycle. The clustering approach is proposed as a way of addressing such longevity and is characterized by regional DHIS2 workshop trainings organized and run every year in Southern and Western regions of Africa. The goal of these workshops is to provide the participants with training that will enable

effective management of their country customization processes. Each of these programs is designed to meet customization needs of healthcare organizations of LMICs and provides to the participants an on-the-job practical training that enables them to subsequently translate their knowledge into practical actions. These clusters enable mediators, who have been concentrated in specific country customizations or CoPs, to learn from other customizers. This also permits lessons from one site to be transferred to others, helps to disseminates best practices, and to deal with customization challenges. For instance, through advice received during these cluster trainings OGUMANIHA customizers were able to strengthen their HIS by replacing the two parallel versions of the OgIS application that was run for a couple of weeks with only one instance run and used by all OgIS stakeholders. They also shared their work with the rest of the community and participate in community activities by, for instance, translating the language of the software from English to Portuguese. For these customizers, clusters were the only places where they could have face-to-face interaction with developers.

This thesis illustrates also the critical role played by mediators in enabling the development of capacity both in clusters and in the customization sites. Various examples were provided whereby challenges faced in the customization sites were addressed thanks to the learning-by-doing approach. Under the guidance of mediators, several tasks were performed following a step-by-step on-the-job customization at the same time the different software features were explored. The approach was also used by customizers on their own effort during the building of understanding and subsequent mastering of DHIS2 customization. The learning-by-doing approach transformed software customization from being an activity practiced only by technologically literate people into a practical reality which everyone with basic computer skills can perform. We have seen examples of Guinea-Bissau where statisticians without IT background were able to perform customization of DHIS2.

6.2.6. Summary: Linking the contributions to theoretical discourses

When the results of the research presented in this thesis are put in a broader perspective, can be related to the practice-based theory, as identified in the information systems' literature (e.g., Orlikowski (2000), Suchman (2007) and Nicolini (2013)). As stated in Chapter One and Three, practice-based theory has the special capacity to understand how organizational action is enabled and constrained by prevailing organizational and societal practices. Scholars adopted this perspective to access: actions in specific places and times, and develop generalizable principles of how action might unfold in other settings; people's situated behaviour and explore how problems are solved or how competence is constructed in

practice; and tools and artefacts that people use in doing customization work. Its basic unit of analysis is practice, and refers to "routine bodily activities made possible by the active contribution of an array of material resources" (Nicolini, 2013, pg. 4).

Though there are many ways that the perspective is associated with technology adoption, this thesis contribute to several areas of the debates within the practice-based theory. Firstly, software customization is conceptualized as socially situated (Suchman, 2007). As a situated work, software customization is considered as embedded in contexts whose meaning is constituted by people, their actions, and interrelated objects. Second, software customization is abstracted a 'boundary spanning' work (Akkerman & Bakker, 2011), i.e., the actions, interactions and the attitudes and practices of people that enter onto territory in which they are unfamiliar and, to some extent unqualified (Suchman, 1994) are theorized using the boundary spanning perspective. The approach have the potential of conceptualizing the introduction of elements of one practice into the other (Fisher & Atkinson-Grosjean, 2002) and based on fresh look at the long-standing practices and assumptions, create deep learning (Tsui & Law, 2007). The research supports and details further the views on boundary spanning put forward by Levina and Vaast (2005) and provide a series of practices that focus on customization mediators, the individuals and objects that facilitate the sharing of expertise between groups of people.

In both conceptualizations, software customization entails a flow of activities which incorporates among others the content and process, intent and emergence, and thinking and acting (Draxler & Stevens, 2011; Zachman, 1999; Dittrich et al., 2009; Kimaro & Nhampossa, 2007). Applying practice-based perspective into these activities, means seeking an understanding of how the dichotomies elide in the on-going shaping of the practice (Jarzabkowski, 2005). The research has provided the practices of improvisation, networks, participation and clusters to better explain the shaping of software customization. Farther, not only are the findings compatible with Brown and Duguid (2000) argument that practice "both shapes and support learning" (pg. 129), but they also provide evidence for learning-by-doing theory.

6.3. Practical Contributions

The practical contribution of the thesis consists of a framework that highlights the main building blocks of OSS customization, especially when it is performed in and by healthcare organizations of LMICs. As portrayed by Figure 6.3, these building blocks include performing customization work, building capacity and contributing to the customizability of

the generic software system. Each of these building blocks is influenced by several variables including *what*, *when*, *how*, *who*, and *where* is customization being performed.

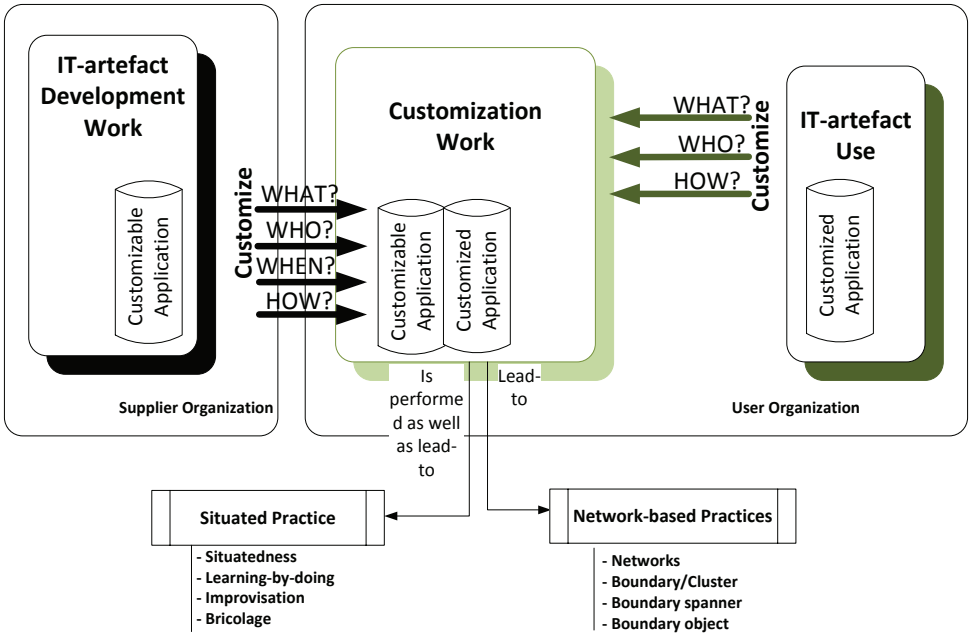

Figure 6.3: IT-artefact customizing framework

As framed by Michaud (1999) customization consists of performing changes at the data, visual appearance and control or behaviour (*the what*). This activity can be performed during the software development, the system refinement and when the system is in active usage *(the when)*. For its performance individuals can access the source-code or benefit from the interaction styles (*the how)*. Experiences from this study have shown that instructions of, *what to customize*, come both from developers through the software and from the end-users through their needs and demands. When these needs do not 'marry' to software features, disturbances, work disrupt or tensions emerge. Despite the activity having to be performed by customizers, the process usually starts with developers creating the customizable features and is extended to end-users by allowing them to adjust basic software appearances (*the who*). Hereafter, lessons from the study also shows that software customization is influenced by the setting where the process in being performed. At the sites the activity is affected by for instance the availability of skilled personnel, supporting infrastructure and the leadership style. The variable *where* emerge and is attached to the model to highlight such issues. Therefore, performing software customization is about combining the variables together, as well as relating and evaluating them with each other.

With regard to capacity-building building block, the thesis contributes with a practical model that may be used to enhance the customization capacity in LMICs. The model was presented in Figure 5.1, and the logic behind it is that if adopting OSS is to contribute to the building of capacity, then there is a need of combining *situatedness* with guest and cluster approaches. In other words, the model is described by the following two arguments. First, given that existence of emergent glitches characterize OSS customization, customizers' knowledge and skills appear to be very important. Second, due to the constant changes that OSS artefacts suffer, customization practice is most effective when combines the team skills and knowledge with the approaches of *situatedness*, mediation and clustering.

As we know, this model has been developed taking into account the actions and interactions between customizers and sites that are part from the same community. Thereby an effective way to benefit from this model is to cultivate the notion of community. The following five principles by Wenger et al. (2002) may be applied for cultivating such communities:

Invite different levels of participation: This principle link the success of a community to the existence of many different levels of participation. The existence of a heterogeneous team with diverse skills, and cultural and technological experiences demand for different levels of participation. Having a multiplicity of individuals and levels of participation in the customization, e.g., healthcare managers, developers, NGOs and GIS managers have shown to be beneficial to the development of customization competence. An example was the involvement of GIS experts which helped to address some *geodata* problems.

Open a dialogue between inside and outside perspective: According to Wenger et al. (2002), good community design requires an understanding of the community's potential to develop and steward knowledge, but it often takes an outside perspective to help members see the possibilities. While developing communities, this strategy can help foster members to focus not only on their communities but also on what is happening on other communities. An example could be to open the customizer communities to cooperate with people from other countries and regions so that they can learn from their experiences. For instance, once community members have developed sufficiency skills and taken charge of their choices, they can be connected to broader communities or networks. This can be materialized by networks of practices, referred in this research as cluster DHIS2 academies. These networks of practice allow lessons from one customization site to be transported to other (Brown & Duguid, 2001). This provides a room for enhancing customization competence.

Combine familiarity and excitement: Successful communities offer comforts of the site or domain, but they also have enough interesting and varied events to keep new ideas and new people cycling into the community (Wenger et al., 2002). This principle fortify even more the competence-building thoughts addressed by the previous two principles related to the need for have a cross-community and multi-level interactions.

Develop both public and private communities' spaces: Wenger et al. (2002) argues that dynamic communities become rich if there is connection between public and private spaces. It was observed, in this research, that local customizers were trained and shared their experience with people from other countries (e.g., during the DHIS2 academies) because donors have supported them by providing both travel and accommodation funds. Moreover, because healthcare sector is composed by members from public and private institutions, competence building within the field is guided by public (e.g., meetings and websites) as well as private means (e.g., one-on-one networking).

Create a rhythm for the community: According to Wenger et al. (2002), at the heart of a community is a web of enduring relationships among members, but the tempo of their integrations is greatly influenced by the rhythm of community events. This principle suggests that community need to be well organized and maintain its rigor in relation to execution of its activities. As noted OSSs are constantly changing, e.g., four versions of DHIS2 are released annually; while new features are added some are improved and others removed. On the other hand, the complexity and problems of healthcare sector require constant monitoring of the evolution of the systems under penalty of being frozen in time. This requires that customizers are in constant training. However, as was seen in this thesis the academies take place once a year in each region. This means that the academies are not enough for competence building. Therefore, the four principles above should be well articulated.

Customization sites that adhere to these principles can perform better through increased collaboration effectiveness. I then think that while cultivating these communities, members will be familiarized with both the technology and domain being addressed by the OSS and once this is created they will be able to present their concerns and contribute in effective way to the discussions both in the communities and in the networks of practice.

7. Concluding Remarks

This thesis has adopted a multiple interpretive case study strategy to investigate generic OSS customization in LMICs. The overall goal of the thesis has been to increase the understanding of customization of generic OSS, the kinds of challenges faced, and the approaches adopted to make customization processes to work in practice. This was done, mainly, by studying software customization in and by healthcare organizations of three LMICs, namely Guinea-Bissau, Malawi and Mozambique. Each of these customization settings is considered a case study. In this chapter, I present the conclusions of the thesis. Furthermore, I point out limitations and directions for future research based upon this work.

7.1. Conclusions

The research presented in this thesis had three main aims. First, explore how software customization is performed, and the different interactions involved; second, investigate the challenges involved in performing customization tasks; and finally, formulate a model that can help to guide customization of generic software systems in the public health domain of LMICs. From these aims the following questions were defined:

RQ1: What potential and constraints exist in customizing open source software systems for and by healthcare organizations in LMICs?

RQ2: What are effective approaches to deal with software customization processes?

RQ3: How can customization sites be organized to strengthen their capacity for carrying out customization?

In addressing these research questions, the thesis has provided an empirical description of how generic OSS are customized in and by healthcare organizations of LMICs. Results from the studies addressing the first research question show that these software systems offer to organizations access to widely used tools containing features that are developed, tested and maintained by technologically and healthcare skilled professionals. They offer also the ability to enable functionalities as required, and the fact that their customisation is informed by diverse groups of people with different background leads to more knowledgeable stakeholders. However, due to several factors the customization activity is very difficult to achieve by many LMICs healthcare organizations. The research points to software misfit, poor skills and competence, and poor supporting infrastructure as core reasons to these problems.

The studies addressing the second research question provide evidence that successful customization is heavily influenced by customizers' previous experience (their current skills), as well as by people from outside the organization through face-to-face communication and networks. But because of the existence of a variety of cultures (e.g., habits, language, technological skills), additional barriers were observed during their participation in the networks. For instance, language and financial constraints prevented countries from being represented in these networks. For that reason the thesis suggests the creation or strengthening of 'communities of practice' within the specific countries. I therefore, think that while cultivating these communities, members will be familiarized with both the technology and domain being addressed by the OSS and once this is created they will be able to present their concerns and contribute in effective way to the discussions both in the communities and in the networks of practice.

This thesis, furthermore, provides a framework for customizing OSS. Specifically, the framework conceptualizes software customization as both a situated practice as well as a network-based practice. In addressing the third research question, the research suggests taking a differentiated view of capacity building by combining individual customizers' skills and knowledge with three overlapping approaches: guest - having guest people supporting the customization while promoting team practice and collaborative problem solving; cluster - helping customizers to appreciate the balance between their perspectives and others as they develop a broader view of practice trough inter-professional collaboration; and *situatedness* - revealing the realities of the practice through exposure to the domain complexity. I believe that understanding software customization through these lines will help researchers, managers and other practitioners especially from LMICs, to strengthen their customization projects.

Table 7-1 summarizes how this thesis has responded to these research questions.

Table 6-1: Summary of responses to the research questions

Research Question	**Summary of the responses**
RQ1: What potentials and constraints exist in customizing open source software systems for and by healthcare organizations in LMICs?	Potentials: - *Tools contain functionalities that are developed, tested and maintained by skilled professionals and experts of the domain* - *Functionalities are enabled as required* - *Tools lead to more knowledgeable users* Challenges: - *Healthcare organizations of LMICs are characterized by lack of skills and competence* - *There is a high probability of software misfit* - *Infrastructure that is expected to be used as a supporting apparatus (e.g., artefacts, local people, software supporting manuals and IT) is poor*

Research Question	Summary of the responses
RQ2: What are effective approaches to deal with software customization processes?	IT-artefact customization is both a situated practice as well as a network-based practice. The approaches to deal with this activity include: Situated practice - *Learning-by-doing practice with emphasis on side-by-side work involving 'experts' and 'novices'* - *Tailored training* - *Work-around practices of improvisation and bricolage* Networks of Practice - *Requesting for help* - *Cross-site interactions* - *Co-located learning* - *Clear organizational structures* - *Querying for customization artefacts*
RQ3: How can customization sites be organized to strengthen their capacity for carrying out customization?	Two strategies are proposed in this thesis: Clusters - *Cultivating regional training workshops* - *Replicating/scaling these approaches to the country levels. For example, by creating forums where issues are discussed within countries or organizations.* Communities of Practice - *Formalizing the networks of practices* - *Creating networks between organization or countries that share similar cultures or challenges*

In conclusion, this thesis contributes to the practice-base theory. Specially, five broad contribution lines were developed. Firstly, an alternative paradigm to study improvisation, which I termed *human-centred improvisation*, was developed (see Section 6.2.1). Building on the understanding of software customization as socially situated, the second contribution took a network perspective to discuss the *situatedness* of software customization (see Section 6.2.2). Third, an understanding of whether boundary spanners should be formally nominated or emerges from practice, as well as understanding of boundaries that are spanned to building organization competence was developed (see Section 6.2.3). The fourth contribution discussed the process of participatory design during the customization of generic software systems (see Section 6.2.4). To end with, contribution to the literature on learning-by-doing was discussed by conceptualizing software customization capacity-building as situated and clustered (see Section 6.2.5).

7.2. Limitation and Future Research

The focus of the research presented in this thesis has been on understanding the customization of generic software systems. I aimed to use empirically based research techniques in order to investigate the challenges faced and the approaches adopted to make customization processes to work in practice. Although such inductive research is beneficial in understanding the

dynamics in organization settings, it is not without its shortcomings. In this section I describe those shortcomings and I split them into generic and specific.

With regard to generic limitations, three main are highlighted. First, the focus of this research has been only on open source software, and as such could not get a contrasting picture in relation to commercial products. However, it has been written in literature (see for instance, Bacal (1987), Perens (1999), Jones et al. (2000), Karels (2003), Shah (2006) and Corio and Sayana (2008)), that because of license restrictions, users do not have a possibility to customize the software, and thus there is continued dependence on the vendors. Second, given that I did not have the possibility to study commercial organizations with my focus being primarily on universities, NGOs, healthcare departments and freelance customizers, I acknowledge this as limitation. Finally, I acknowledge the existence of paid consultants that work as customizers. In my thesis I could not empirically study this, but I know that dependence on paid consultants means that the possibility of building sustainability decreases.

Furthermore, while I have learned a lot from this research process, I have also been exposed to customization related questions which I did not dig out on trying to find answers. These are now described. First, this research was conducted mainly through participatory observation which was characterized by my involvement in conducting software customization work in the researched organizations and also with a closer collaboration with the developers. Future studies could benefit from researcher being less involved with work performance. I think that increased depth with customization projects such as the OGUMANIHA, where the researcher was less involved could provide very good insights to the process of customization. Remember that this project was performed outside of the HISP network and with no formal link or contact with developers. Moreover, if this intervention could be evaluated by someone who was not closer to the developers and not involved with customization work could provide different outcomes.

Second, the fact that I have been moving across customization sites to both participate in the customization process and carry out comparative studies, did not help me to observe the effects that the networks of practice had in the capacity of local customizers throughout time, in each setting and compare them. This would have somehow enriched the findings of this thesis. Thus, future research could examine the dynamics of networks of practice with especial focus on how individuals' benefiting from them enhances their competence over time.

Third, one of the arguments presented in this thesis to support the need for customization sites to organize themselves into CoP that share cultures, habits and technological skill level

before embarking to NoP, it was because of the existence of a good chance of network members not to benefit from each other when there is a considerable gap (e.g., on cultures, habits and technological skill level) among them. Nevertheless, while arguing that DHIS2 academies were cluster meetings for sharing knowledge only the benefits were taken into account, challenges and constraints were left aside. I know of the existence of several problems in these clusters. For example, many times, if not all, it has been difficult to bring together people who have the same knowledge level about the DHIS2; sometimes policies implemented in participants organizations, e.g., rotating participation approach used by some countries which does not allow the same individual to consecutively attend these events, create several problems to training moderators who need to unfold themselves in order to accommodate the diversity of training needs; almost always there are new people to the DHIS2 attending the academies. Thus, a research that focuses on these aspects could help to validate the benefits of networks of practice that I present here and also present the challenges they are associated with.

Fourth, another limitation of this study was the fact that I did not have time to follow closely the actions that have been sparked in Tanzania when they found that DHIS2 Tracker was not satisfying all their needs and decided to hire someone to make it work by changing the source-code. Because of this they got limitations and were unable to benefit from the new versions of DHIS2 Tracker. In this thesis I merely speak of the existence of those difficulties without expressing in detail their impact on the ground. Still on the software generalizability mood I believe that requirement-delivering practices, proposed in this thesis, for software systems that developers have no formal contract with the users are challenging. In other words, the fact that in OSS requirements can come from everywhere poses challenge to their management processes. I believe that the process of identification and assignment of these requirements to software releases will be hard. Furthermore, I have concluded that the cross-site work helps in delivering requirement that will contribute to the maturity of the software, but I did not research on the process that these requisites go through from when they are delivered to the developers until they are inscribed and released as software features. There were situations when the time span between receiving requirements and the developers started to talk about them was very long (e.g., the sharing of data between programs which was highlighted during the customization of DHIS2 Tracker in Malawi). I think this could be an important area to be researched. Questions could be, for example, given that developers receive requirements from a large and evolving network of distributed stakeholders, requirements may overlap; in such situations how do developers address these overlaps?

Since mediators are the one interacting directly with developers, are users involved when there is a need of fitting the different views, i.e., in the negotiation process?

Fifth, from this thesis I developed a model for building capacity during software customization activity. Despite the strengths of this model, I should also note its limitations. First, in the model I only describe the approaches and the processes; procedures for successful cross-cultural interactions need to be investigated further. Additionally, in order to establish this model as a best practice, further research should focus in testing the applicability of the model.

Finally, networks of practice have been identified in this thesis as elements that play a key role to software customization. The research investigated how members of this network share practices, and found that they are made to work primarily through sharing of network members across the customization settings, as well as during the cluster training workshops. However, there is a very important component of this process which was overlooked, because it was not intended to be part of this research, but it was found to impact on the possibility of having the network to perform its role. I am talking about issues such as governance mechanism, funding sources, agreements between organizations, among others. Although I have mentioned some of them in thesis, there is need for thorough research in order to provide insights that will enable healthcare managers embarking on this journey, to be prepared to deal wisely with the issue of capacity-building.

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Appendixes

I

THE CHALLENGE OF CUSTOMIZING GLOBAL OPEN SOURCE SOFTWARE TO LOCAL COUNTRY CONTEXTS: THE CASE OF DHIS GIS FOR HEALTH MANAGEMENT

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Abstract: A **s**oftware systems that supports wide range of user needs is difficult to customize. Most of the challenges are related to limitation of the tools as well as the skills needed to adapt them to fit local needs. In most cases the business workflow procedure inscribed into these global software systems may not directly map into the practices of the organizations adopting it. In whatever case, there is always a need to develop and apply methods that can help to rapidly integrate them on the business processes and perspectives of the organizations. This paper reports on an action research study that aims at understanding the tensions of adopting global software system for health care management in developing countries. The work was conducted in Mozambique and Malawi and aimed at customizing the spatial analysis module of the district health information software to the local context. The findings of the study reveal that the process is prone for challenges and addressing those challenges require competent and skilled team that may be plunged not only into adaptations but also contributing in the evolution of the tool.

Keywords: Global Open Source Software, Local adaptations, Geographic Information System, Developing Countries.

THE CHALLENGE OF CUSTOMIZING GLOBAL OPEN SOURCE SOFTWARE TO LOCAL COUNTRY CONTEXTS: THE CASE OF DHIS GIS FOR HEALTH MANAGEMENT

1. INTRODUCTION

Computer systems are rarely developed from scratch, and typically require 'adapting' existing elements to new institutional contents (Pollock and Cornford 2002). Global Software Systems (GSS) are part of this important trend as they are expected to provide benefits from increased economies of scale and access to accumulated knowledge about organizational practices 'embedded' in these software packages (Pozzebon and Pinsonneault 2005). Further, they offer the possibility that the system functionalities can adapt to the user's changing needs and requirements over time and thus remain relevant (Dourish 1995). However, this process of adaptation is a challenging task, whether they are moving across the boundary from a commercial organizational context to a public sector setting, or from a general to a specific setting (Pollock and Cornford 2002).

This paper reports on an action research study that aims at understanding the tensions that come into play during the customization of a Global Open Source Geographic Information System (GIS) to the local contexts of health care management in Mozambique and Malawi. The process involves taking an existing software product and tailoring it to suit the needs of a group of users as well as translating and building the appropriate database, creating local reports, and creating other additions or deletions in the functionalities as required. In this process, significant and subtle changes needed to be made by the local users in order to fit with the generic GIS developed for global use.

The challenges of customizing GSS to local contexts have been well documented in Information Systems (IS) literature, including domains of global software outsourcing (Sahay et al. 2003), implementing of global applications in multi-national corporations to their various country offices (Rolland and Monteiro 2002), and also in the transfer of technology to developing country contexts (Nhampossa 2005). Bada (2002) has studied the challenges of adapting a GSS within a Nigerian bank, and (Pozzebon and Heck 2006) have likewise studied such adaptation in a Brazilian cooperative. These studies have concluded the need for global-local negotiations to help inscribe local organization business into the generic application system.

In the context of this study, it is also important to note particular challenges that come with GIS in developing countries, including the availability of maps that are adequately geo-referenced (Nuckols et al. 2004; Tanser and le Sueur 2002) while studying the adoption of GIS to address public health problems (such has HIV, malaria and tuberculosis) in Africa, have argued that accessibility to spatial data, fundamental to any GIS application, continues to be difficult and expensive. Further to the technology, there are additional particularities that come with public health settings particularly weak technical capacity (Braa et al. 2007; Heeks 2002; Tanser and le Sueur 2002) which impedes effective in-house customization. In studying the problem of scaling of health information systems in India, Sahay and Walsham have highlighted the problems of increasing technological complexity, human resources capacity, waning political support, and unanticipated effects as challenges to local customizations (Sahay and Walsham 2006). Human capacity to address contextual characteristics in order to better implement and manage generic IT projects is a continuing challenge (Avgerou and Walsham 2000).

Given the particularities of our study context – GIS technology, public health setting, developing country contexts, the customization challenges are relatively unknown, and even less is our understanding of how to deal with them. The aim of the paper is therefore twofold:

1. To understand the nature of customization challenges in tailoring a global open source GIS tool for local use in the public health sector in developing country contexts;
2. Understanding ways and approaches of dealing with these challenges by engaging in addressing them in practice.

The nature of the research aims called for an action research approach which was carried out within the framework of the Health Information Systems Project (HISP), a global action research programme from the University of Oslo (Braa et al. 2007). This study was located in the Mozambique and Malawi chapters on the global HISP network.

The paper proceeds as follows. In Section 2, we describe the theoretical foundation which serves as the basis for our analysis. Then, in Section 3, we describe the research setting and the research approach. In Section 4, details regarding the empirical study are presented. The paper ends with analysis and discussion in Section 5.

2. THEORETICAL FRAMEWORK: ADAPTING GLOBAL SOFTWARE SYSTEMS TO LOCAL CONTEXTS – TENSIONS AND APPROACHES

There are many drivers to the globalization of software development including skill shortages in industrialized economies, increasing distributed modes of development and spread of ICTs to less developed economies, where skilled labor is available at lower costs (Abbott 2004). A current trend is for technologies that have been developed in the West to satisfy the socioeconomic needs and the context of developing countries (Bada 2002). This process of transfer has been proved to be rather complex given the significant differences in organizational, economic, social, political, and cultural conditions.

Even though developers seek to reduce the uncertainty inherent in the innovation process by technical iterations and prototyping, "as soon as [the technology] gets into the hands of the... production department the complexity will increase again" (Leonard-Barton 1988). This "complexity," takes the form of misalignments (poor fits) between the technology and its technical and institutional requirements. Caution thus has to be exercised against a process of "mechanistic" transfer and of instead adopting a subtle and sensitive approach to customization. Such an approach involves a dynamic process of negotiation due to differences between local work practices and those 'imposed' by the generic application system (Pozzebon and Heck 2006).

Institutional differences cause persistent heterogeneity among organizations across countries, even if they operate in the same industry and are subject to similar external influences (Woywode 2002). Various authors have suggested 'local adaptations' to help support GSS adoption, particularly those located in developing regions (Avgerou and Walsham 2000). These local modifications will try to ensure that the technology is workable and fits with the needs and demands of the different contexts of implementation (Bada 2002).

Since cultures will engage differently with local adaptations, the challenge resides in how best to support diversity, which requires a greater sensitivity to local norms, values, and ways of doing things (Pozzebon and Heck 2006). Roland and Monteiro, for example, argue "how the development and use of IT is interwoven with social and strategic issues of the organization" (Rolland and Monteiro 2002). They suggest a strategy of a "pragmatic balance" for how a generic IT can be localized in practice, where the focus is to try and distinguish between context dependent and independent components, seeking to globalize the independent parts

and focus on the dependent parts for local customization. The notion of a design-reality gap (Heeks 2002) helps to focus on understanding the mismatch between current requirements and characteristics of a local organization and the embedded system design conceptions of a generic technology. This gap occurs because the contexts of the 'designer' and 'user' are often distant in physical, cultural, economic dimensions and as a result certain design assumptions gets inscribed which do not reflect local realities. Understanding this gap helps to focus on the extent and nature of customization required. The greater we are able to plug the design-reality gaps (Heeks 2002), the larger is the possibility of success.

However, most of the times "when individuals face emergent but not necessarily dramatic situations" (Magni et al. 2009) improvised behaviors will result. Improvisation or "walk-arounds" are described as the occurrence of spontaneous and creative behaviors (Bada 2002; Rolland and Monteiro 2002) to address everyday problems. Such behavior has been studied in various domains including organizational learning, technology implementation (Orlikowski and Baroudi 1991), and new product development (Magni et al. 2009). Since not all required changes are concentrated in the local dimension, these adaptations also refer to significant or subtle changes local entities make in features crafted into the generic application system (Pozzebon and Heck 2006). Thus customization of technical innovations is best viewed as a process of mutual adaptation i.e., the re-invention of the technology and the simultaneous adaptation of the organization (Leonard-Barton 1988).

3. RESEARCH SETTING AND APPROACH

3.1.Research Setting

The research was conducted in Mozambique and Malawi, two developing countries in Sub-Saharan Africa in collaboration with the Ministry of Health (MOH). HISP teams in both countries are engaged in ongoing customization activities of the District Health Information Software (DHIS), to assist the management of health care data. The DHIS is a customizable free and open-source software (FOSS) for management of health information within the framework of a data warehouse. DHIS supports the collection, validation, analysis, and presentation of aggregate statistical data. This application has been adapted in various countries including South Africa, India, Mozambique, Botswana, Tanzania, Malawi, and Zambia.

The early versions of DHIS application (1.3 and 1.4) released from 1997, were developed on Microsoft Office platform, and distributed for free. In 2005, the University of Oslo in collaboration with students and researchers from India, South Africa, Ethiopia and Vietnam, initiated the development of Version 2 as an evolution of DHIS 1.x., using open-source Java frameworks and tools, such as the Spring Framework, Hibernate, Struts2, Maven, and JUnit. The application it is now platform independent, can run on both on-line and offline modes, and is multi-language enabled.

Due to its modular approach of design, a variety of software modules are gradually being included within DHIS2 including the *DHIS Community Data Management (DHIS2 Tracking)* that aims at collecting and processing the community based data, the *DHIS Mobile Health Data Management (DHIS2 mHealth)* that allows the collection and processing of community based data using mobile device, and the *DHIS Spatial Data Management (DHIS2 GIS)* which is a focus of this study (see Figure 1 below). The DHIS2 GIS module allows for the display of map based information collected and processed by DHIS Core. It can also provide visual representation of baseline geographic, demographic and health information, including the location of communities, health facilities, and accessibility by road, among others.

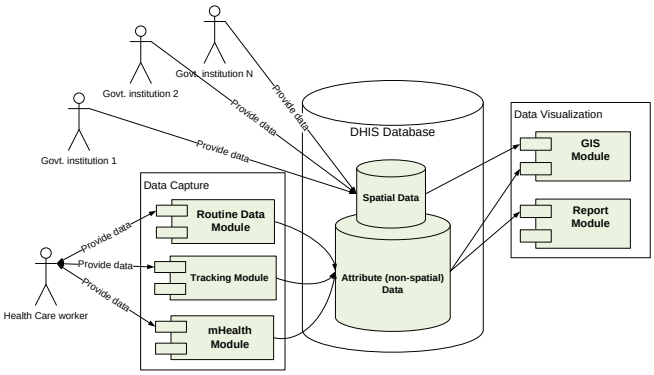

Figure 1: The DHIS ecosystem

3.2.Research Design

This study was conducted within an action research framework. The approach is based on the belief that the best experts of what needs to be done in any situation are the people already experiencing the situation (Hilsen and Ennals 2005). The study embedded a partnership between researchers, health care members, software developers and customizers in the period between January 2009 to June 2010. During this period, the action researchers apart from getting involved in the customization process, have worked as "participant observers" (Hansson 2006) and together with other members of the team has been involved in reasoning, action formulation, and action taking, leading to joint learning. This interaction has capitalized on learning by both researchers, software developers and customizers, and practitioners within the context of the practitioners' social system (Baskerville and Myers 2004).

The research has relied on the qualitative research tradition that is based on a situated activity that locates the observer in the world (Iivari 2010). Data collection has involved observation, interviews and document analysis. Documents and research articles were accessed and used as source of knowledge about the past history and current context of GSS in Africa and World and more specifically about DHIS and GIS. Two types of observations were applied: formal observations performed during the GIS users' interviews, and informal observations performed within the DHIS customizers' environments. Three types of interview were applied: face-to-face, phone, and e-mail. Interviews by phone and by e-mail were carried out with a considerable number of stakeholders including two DHIS2 developers, seven customizers and seventeen GIS users. Face-to-face interviews were conducted mostly within the sixteen spatial data user institutions in Mozambique.

4. EMPIRICAL INSIGHTS: CUSTOMIZATION OF DHIS GIS

This study considers specifically the DHIS2 GIS module and its customization to fit the health care contexts in Malawi and Mozambique, process that we describe below.

4.1. The GIS Module

Soon after the release of DHIS2 in 2006, the HISP team began exploring the possibility to integrate in it a GIS module starting in 2006 when a group of Master students from University of Oslo developed a Java based prototype named HISP GIS, which was integrated within the version of DHIS2 application working in India. HISP GIS was supposed to work closely with DHIS2 by providing map visualization of health indicators (Vik and Andersen 2005).

Subsequently, the HISP team explored Key Indicator Data System and CartoWeb. Due to limitations originating from the programming language and its limitations in supporting polygonal entities, the OpenHealth project emerged in 2007. This was operationalized through a MOU between WHO and HISP to enable developers from Geneva and Oslo to create an improved and web based version of the earlier HealthMapper of WHO.

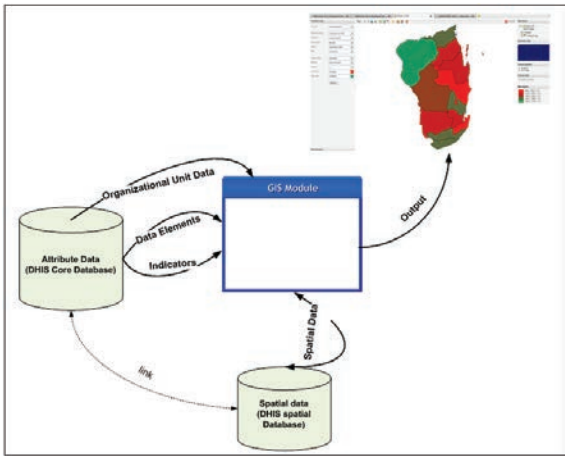

Figure 2: The generic view of the DHIS2 GIS Module

The module (see Figure 2) is a client-server application integrated within DHIS2. The three layers architecture of the module is handled by the store and service layers. The store layer provides communication with the database through Hibernate Framework while the service layer handles the objects and the service functionality (logic) manipulated at the application programming interface (Øverland 2010). The client side of the module is developed using JavaScript frameworks such as MapFish, OpenLayers, Ext JS and GeoExt, and it reads JavaScript Object Notation as a data-interchange format, Geometry JavaScript Object Notation (GeoJSON) is the format for encoding a variety of geographic data structures and Scalable Vector Graphics in XML. The server is purely based on Java.

4.2. DHIS GIS in Mozambique: process of customization

Based on experiences from the adoption of GIS in developing countries, and the challenges faced during the introduction of those system into the health care sector (Melnick 2002), (Saugene and Macome 2008; Tanser and le Sueur 2002), the customization started with GIS user institutions' assessment. The aim was to understand spatial data issues including creation, processing and data storage as well as the supporting infrastructure, sharing and exchange issues, and human capacity. Key inferences were:

- **Data Issues:** Data collection and maintenance is expensive and time consuming. While earlier, spatial data was derived from digitizing analogue maps, currently processes used include manual digitizing and scanning of analogue maps, image data input and conversion to a GIS, direct data entry including Global Positioning Systems (GPS), and transfer of data from existing digital sources. GIS was relatively new in most of institutions studied, and users were still learning its potentialities, learned primarily through the vendors of spatial data and GIS software. As a result independent capacity was limited, for example the data formats they used could not be customized for broader range of users.

- **Institutional issues:** All institutions studied were involved with collecting and maintaining their own spatial data using their own digitalizing equipment. While information related to spatial data was registered during its collection, but the same was not done while digitalization. The data was usually organized in different ways leading to multiple standalone versions of the same data themes in each institution, making it difficult to identify which institution to approach for specific type of spatial data.
- **Networking issues:** There was limited networking, technological or institutional, connecting the various institutions, but there were internal networks of professionals from different institutions providing some form of technical advise. Interviewees stressed the need to belong to multiple networks to gain technical help. Additionally, there were limited mechanisms to enable sharing of data, forcing users to contact producers directly for their needs. Again, the informal networks also helped in this regard.
- **Human resources issues:** Human capacity in most cases was inadequate for the institutional needs in terms of experience and skills, and further there were inequities across the institutions. As a result, the staff was forced to perform multiple roles. Limited capacity impeded institutions from integrating their spatial data with that from other institutions. Internal capacity development plans were fragmented, uncoordinated and impeded due to limited funds. The onus then was on the individual rather than the institution to upgrade their skills.

Our customization process had two focus areas – one customizing DHIS2 for the Ministry of Health (MOH), and the on the management of HIV data as well as related resources like finance and water. The second area was based on reports of indicators cross-cutting the two types of data. While DHIS2 customization was the responsibility of the HISP team,the other case was handled by a NGO assisting the MOH in scaling-up of HIV/AIDS care in Zambézia Province. Both groups were responsible to ensure security and integrity of the databases, develop new forms, reports, and modules, and integrate them in the DHIS2 application.

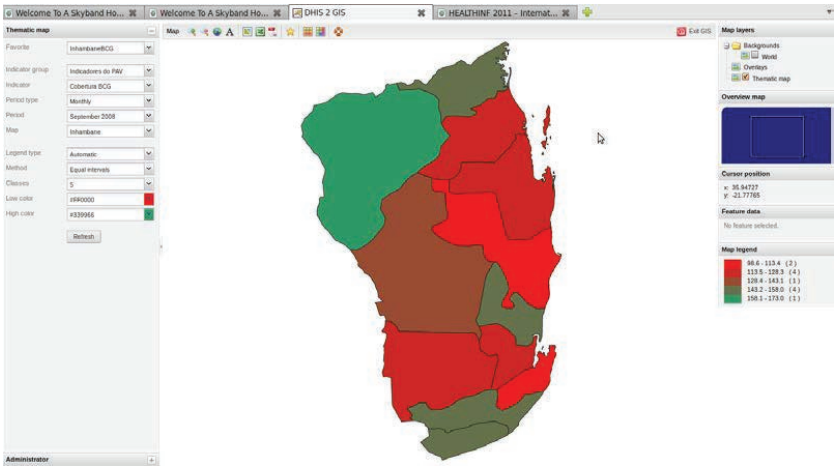

Figure 3: The Main DHIS GIS Module Interface for Mozambique

The DHIS2 GIS was successfully customized for the first user group (see outcome in Figure 3). During the customization challenges were faced, which contributed to the "unsuccessful" customization for the second user group. Key challenges related to the need for the NGO users to perform spatial analysis based on data elements, while the GIS was customized for indicators. However, technical problems prevailed, with the non-spatial database requiring customization such that the DHIS2 GIS would need to be done from scratch.

4.3.DHIS GIS in Malawi: process of customization

In 2009, Malawi decided to embrace DHIS2 and with it the GIS. First, the modules used to capture data that feeds the system were customized in a gradual manner and then subsequently integrated with DHIS2 based on requirements or requests from the users. Soon after the spatial information requirements were gathered and the first assessment was carried out in February 2010, leading to the initiation of the DHIS2 GIS customization.

GIS requires not only spatial information but data from the non-spatial database such as organization unit name and level, data elements, and indicators for display on the maps. These required database customizations including the definition of both spatial and non spatial data. Obtaining the spatial information from external sources required negotiations with the spatial information producers as well as the MOH users. Our analysis revealed:

- Existing district boundaries and health facilities were represented in the respective maps. Two new districts *Likoma* and *Neno,* which were previously part of other districts, were not reflected in the existing maps, and so also new health facilities that had been recently constructed. These new additions needed to be customized and the database updated.

This customization required the generation of *GeoJSON* file format from the *shapefiles* collected in the first step, which was then imported to the DHIS software and invoked in the mapping client. However, this process did not show the expected results, the reasons for which we could not diagnose because of our own technical limitations. Support was gained then from global HISP, to diagnose and solve the problem. After then the *GeoJSON* files were correctly generated, imported and configured and displayed in the DHIS application, the user interface customization was started. The following problems were identified:

- The database had administrative information which did not match the reality, reflecting a mismatch between the MOH administrative data with that of data from other government institutions system. Figure 5 illustrates this problem where the Mzimba non-spatial data of the MOH stored in the DHIS2 database under two organizational units (Mzimba South and Mzimba North), which were actually part of the same administrative district.

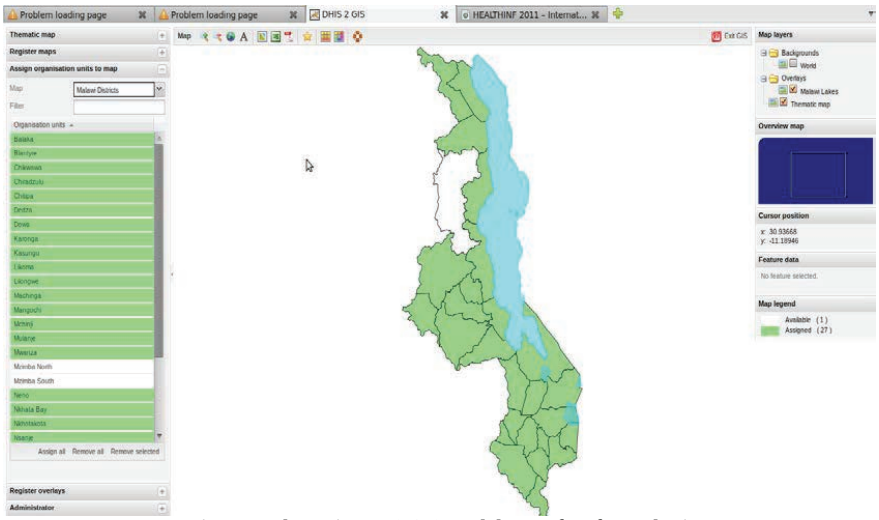

Figure 5: The Main DHIS GIS Module Interface for Malawi

To overcome this problem, two alternatives were tried: first, to link the two districts to the same district on the map polygon; second, to create one district called Mzimba and assign the

two as sub-districts. The second option was selected, with the consequence that it would not be possible for the health officers to perform spatial analysis on each of the sub-districts.

Since DHIS2 GIS is part of the DHIS2 data visualization modules, it would be booted only when the data entry module was completed or at least the basic features of DHIS2 had been customized. The team customizing the routine data systems in the DHIS2 had to collectively work with the GIS group to complete tasks of identification of data elements and indicators. However, since version 2.0.4 of DHIS2 required that spatial analysis must be performed only through indicators, the following additional problems were experienced:

- Indicators had not yet been included in the DHIS2 database, and this process was delayed because data from the older versions of DHIS was not yet imported. The existing priority there was on completing data entry forms and report design.

To overcome this issue, the customization team defined basic indicators for demonstration purposes of the mapping client to a selected group of stakeholders.

4.4.From specific to general development – The requirements

Successful implementation and usage of a GSS like DHIS2 is posited to be influenced by the perceived fit between the organization and the characteristics of the innovation. This requires flexibility both in the technology and for the organizational processes to adapt to the changes. During customization in both domains, requirements could not be always met because of the limitations of the technology. These incomplete requirements then became salient inputs for the global team to take forward in their road map. Some of these new requirements were:

- The possibility of performing analysis based on data elements, for example, to understand malaria causes, managers preferred to use data elements rather than indicators.
- There was the need to provide more detailed description of the spatial data stored in the database. Such information helps the user in using the right data required for their needs.
- There was the additional need to include community data such as related to households. Such data might allow for example an ambulance driver to transport a pregnant woman due for delivery to the nearest facility.

5. DISCUSSION AND CONCLUSIONS

After developing in-house solutions and/or embracing non-tailorable packages expected to match organizational requirements and needs (Pozzebon and Pinsonneault 2005) for decades, organizations are increasingly relying on using GSS. This in itself has been proved not to be a trivial task and fraught with huge challenges. This paper has tried to unpack some of these challenges by actually engaging in trying to address them through action. Our analysis has helped to identify three major challenges related to: (1) customizing of the spatial and attribute (non-spatial) databases, (2) handling emerging technical problems, and (3) having viable strategies for accommodating user requirements.

The customization process, which is the focus of this study, involved taking an existing software product and tailoring it for the local users in Mozambique and Malawi, including building the appropriate database, configuring the users' interfaces, and providing other required additions or deletions. In this process, changes were made by customizers in the local processes and rules in order to fit with the generic application system (Pozzebon and Heck 2006). Some examples of feedback to improve the GSS are provided, such as in understanding new requirements. Engaging in this mutual learning process has implications beyond GIS GSS adoption in Mozambique and Malawi.

In both cases, we identified similar database related challenges which slowed the process of creation of the *databases*. There were challenges identified in the non-spatial database creation as well as those related to the spatial database such as the acquisition of maps and the dependency on external providers. Similar problems had earlier been reported in research (Melnick 2002), problems not directly controlled by local customization teams. Dealing with these issues, required "improvised" actions such as the creation of indicators that was not in the database, definition of administrative unit only to accommodate the differences identified between data from the MOH and other institutions as well as the conversion of the *shapefiles* into *GeoJSON* performed by external expertise.

The customization process was also plagued by *technical problems*, especially in dealing with the very advanced JavaScript frameworks (such as MapFish, OpenLayers, Ext JS and GeoExt) and the mapping client which relied relied on *GeoJSON* file format. The struggles faced by the team while generating the *GeoJSON* files from the *shapefiles* as well as the conversion of spatial data between coordinate systems during the spatial database creation in Malawi, are examples of these problems. Regarding non-spatial data, two examples are pertinent: First, the creation of indicators was not a priority of the team which adversely influenced customization, contributing to improvised solutions. For example, in Malawi the team created indicators by themselves, risking in creating gaps in the databases or errors in the definition of such indicators. Secondly, during the interface customization, we found the way in which the MOH had organized their administrative system differed from that of other institutions. This led to problems in importing the spatial data in the DHIS2 application.

Absence of required technical skills locally adversely influenced the customization process, and required the intervention of the global team that often took time and was challenging to communicate. There were also inherent *limitations of the tool*, which required local hacks such as to address the administrative levels differences the team created a new administrative level and attached to this two data collection levels. The creation of indicators was similarly a local improvisation resulting from the inability of the tool to display data-elements on maps. This process of identifying limitations through action, and finding global or local solutions emphasizes that addressing design-use gaps (Heeks 2002) is mutually-influenced (Pozzebon and Heck 2006).

The study builds on earlier research on global-local software issues from both the context of developing (Avgerou and Walsham 2000; Bada 2002; Sahay et al. 2003) and developed countries (Bada 2002). The action approach that has sought to identify and address challenges is a dimension in which this study extends upon earlier research. The study reinforces the critique of the technology transfer approach which treats technology like a black box that can be unproblematically moved to different settings. Instead a sensitive process involving mutual adaptation between the global and local is required. The additional particularities in this process because of the GIS and public health context have been highlighted in this paper, which arguably are additional contributions to the research field.

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II

CHAPTER 13

Factors Affecting Geographic Information Systems Implementation and Use in Healthcare Sector: The Case of OpenHealthMapper in Developing Countries

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Abstract

Geographic Information Systems are one of the most widely used information technologies to assist governments in the management of spatial related problems such as those of healthcare practitioners in developing countries. As a follow-up of the challenges faced while customising *OpenHealthMapper* in Malawi and Guinea Bissau, this paper uses the case of Mozambique to highlight significant differences between the ways geospatial stakeholders approach the issue of *geodata*. Empirical data illustrates that boundary complexity and weak coordination are behind the problems encountered in the *geodata*. With an emphasis on *geodata* needed to perform healthcare analysis, the article analyzes the role of boundary objects and how their quality is influenced by the tensions between the communities managing them. The analysis demonstrates how boundary objects are devices that maintain relationships and also creates tensions. Based on Carlile's knowledge integration framework, the development of an integrated *geodata* management approach is discussed, i.e., the paper suggests a management mechanism focused on the notion of *transfer*, *translation* and *transformation* which is used to conceptualize the role of boundary objects as elements that helps to reduce the boundary complexity and strengthen community members' coordination.

KEYWORDS: Geographic information systems, healthcare sector, boundary interaction, boundary objects, geodata management, developing countries.

1. Introduction

One of the most interesting developments in recent years has been the increased adoption of spatial enabled applications to assist government to manage its information and processes using spatial concepts and technologies: a process that has come to be known as spatially enabled government (Masser *et al.,* 2008). The vision of this process is to establish enabling infrastructure that facilitates the provision of the place or where or location to all human activities, and government actions, decisions and policies (Holland *et al.,* 2010; Masser *et al.,* 2008). Realising this vision is dependent on the development of appropriate mechanisms to facilitate the delivery of data and services. Among others these mechanisms embody efficient management of geodata.

Health Information Systems Programme (HISP), for instance, has been for many years assisting healthcare managers of developing countries through a Geographical Information Systems (GIS) tool called OpenHealthMapper. The primary function of this tool is to graphically display aggregated data managed by District Health Information Software (DHIS2) application as maps with layers of information. However, its use for supporting decision-making is not only limited by combining the different datasets, but to efficiently access, retrieve and apply health data and indicators without substantial effort to rummage around map storages or visiting sources or, conducting many diverse queries, merging different data and bringing all the data into the same map view. However, despite its benefits the implementation has been proved as complex, for both technical and institutional reasons: see some examples in Saugene and Sahay (2011). Technically, the complexity is caused by difficulty in handling emerging problems, the ability to deal with the advanced JavaScript frameworks such as MapFish, OpenLayers, Ext JS and GeoExt, and the conversion of geodata between coordinate systems and formats. Institutionally, tensions arise from various sources including the need for consensus on standards and the inclusion of users in the standardization activities.

Recognizing that management and use of geodata is the responsibility of every institution dealing with geodata, this paper examines those factors affecting the implementation of GIS applications in healthcare settings of developing countries. Based on OpenHealthMapper customization achievements in Malawi and Guinea-Bissau and the prospects of the Mozambican experience toward management of geodata, issues of developing countries are discussed. Two questions guide our research: first we investigate the factors surrounding geodata production and sharing; and secondly, we discuss the approach that may be used to address geodata tensions and problems.

Our empirical work highlights the existence of geodata related problems originated mostly from lack of trained manpower and un-coordinated effort among the GIS user institutions, as well as financial concerns. Hence, we borrow the concepts of boundary interaction and boundary objects to study what happens between and across the GIS community in Mozambique, the interfaces or translation devices, and the practices

used to make such translations happen. Through Carlile's cross-border knowledge integration framework (2004), the development of an integrated geodata management approach is discussed whereby mechanisms focused on the notion of transfer, translation and transformation are discussed together with syntactic, semantic and pragmatic processes. These processes overlap iteratively between each other.

The article proceeds as follows: section 2 describes a theoretical framework by discussing the complexity of GIS boundaries. Then, we will describe the approach used to gather data for this paper in section 3. Section 4 presents and explores our empirical work. Then, in section 5 we return to our main research question and through analysis of empirical findings we discuss and present the concluding remarks of the paper.

2. The Complexity of GIS Boundaries

GIS is one of several geographic information technologies that have evolved rapidly in recent years (Goodchild, 2001), and are becoming a standard tool for information management, storage and data interpretation (Hoffman, 1998) in most developing countries. In the healthcare sector, for instance, GIS is used to predict the outbreak and spread of disease (Montana, 2008) and to display and analyze statistics on health services and social programs such as immunization compliance and maternal/high-risk infant programs (Hall, 2004).

However, implementation of these applications is context sensitive (Martin, 1998), i.e., given that most are imported from the developed world, their adoption require careful evaluation and analysis of cultural differences, institutional context and organizational arrangements. In this section we examine social negotiations taking place within the GIS community through the concepts of boundary interaction and boundary objects. Since the negotiation between different groups is fundamental to the construction of GIS, the Carlile (2004) framework on cross-boundary knowledge management opens new ways to address the challenges faced because of the relationships between the technology and the people.

2.1. Boundary Interaction and Boundary Objects

Kerosuo (2001) defines boundaries as places of division between what is familiar and what is unknown. Considering that effective adoption and use of GIS requires commitments on data from different users, its implementation can be conceptualized as a boundary interaction whereby each individual/user institution besides being a member of a GIS community has a (specific) culture related to its own workplace. These cultural differences define their boundaries. Crossing them means connecting both sides; however, since each of the sides has its own people, objects and practices, joining them will create some kind of complexity which according to Akkerman and Bakker (2011) may cause a sandwich effect for objects located between the sites.

Through the concept of boundary interaction scholars have studied how people at work enter onto territory in which they are unfamiliar and, to some extent unqualified (Suchman, 1994) and based on their fresh look at the long-standing practices and assumptions, create deep learning (Tsui and Law, 2007).

These interactions help to reveal the real story of GIS implementation and its functionality (Martin, 1998). For instance, being boundary objects (e.g. data with low quality) one of the most challenging implementation problems affecting the implementation of OpenHealthMapper in developing countries, unpacking its complexity require investigating the objects that are shared during the boundary crossing activities. Thus, concentrating on the interactions mean paying attention to the process of negotiation and combination of data from different contexts (Akkerman and Bakker, 2011; Engeström *et al.,* 1995).

The boundary object concept was used by Huvila (2011) and Bowker and Star (1999) to refer to abstract or physical artefacts (including tools, techniques and ideas, stories and memories) residing in the interface between communities that are capable of bridging assumed and experienced differences. By building on re-conceptualization of the relations between humans and non-humans, boundary objects are used in studying how multiple groups engage each other in the construction and use of technology. They form crucial intersections and translation between different worlds (Harvey, 1999).

Geodata are examples of these boundary artefacts which besides being objects function as mediating artefacts and represent varying viewpoints and interests. Because of that, they can support the adoption of GIS, and its effective usage require communication and collaboration (Hunter, 2008), as well as management (Akkerman and Bakker, 2011) mechanisms. However, they can also fail to address their purposes. If, for example, the artefacts do not capture the meanings and perspectives needed to address specific problem, they will not be able to help the decision makers. Akkerman and Bakker (2011) presented a case where message boxes with system-related information about a medical technology failed to be supportive because the concerns and interpretations of users were not accounted for. Problems may also be experienced if geodata do not represent a consensus of the various stakeholders or if "... changes occurring in boundary crossings do not occur within the limits of the boundaries, thus, destroying existing boundary objects" (Huvila, 2011). In this regard, the challenges involved in producing, archiving, and sharing the boundary objects, more specifically, the poor availability of spatial information in developing countries (Bishop *et al.,* 2000) require proper consideration and management.

2.2. Managing GIS Objects across Boundaries

The potential of GIS when combined with other information technologies is clear and means much more than data visualization. It is in fact, a collection of knowledge archived as single geodata objects. Due to factors like resources (human and financial), single institution cannot provide geodata on a continuing basis. In this regard sharing might be considered. Darr and Kurtzberg (2000) define sharing in context of knowledge as a process whereby people acquire knowledge by learning other's experience. This process demand proper management, which consequently will require understanding the mechanisms of transfer, translation and transformation of data objects. Carlile's (2004) cross-boundary knowledge integration framework deals with the above three mechanisms as well as the syntactic, semantic and pragmatic boundary perspectives.

According to Edenius *et al.* (2010) the syntactic approach refers to the information processing perspective, where organizational members are seen as instrumental in their knowledge sharing behaviours, i.e., is conceived as the process of sending and receiving messages, and is useful in conditions of low novelty and highly shared context. Breakdowns and difficulties in knowledge sharing arise from incompatible codes, lack of information, routines and/or protocols. Semantic perspective builds on syntactic, but also recognizes the importance of interpretation and meaning that can vary across knowledge communities (Lervik *et al.,* 2007). However, Edenius et al. (2010) stresses that differences in meanings, assumptions and contexts are not easily tackled. Even if different ways of knowledge sharing are adopted, such as the use of shared language, meanings or collective stories, many occurrences make it difficult to share. Hence, a pragmatic perspective that incorporates syntactic and semantic approaches was introduced to pay special attention to recognising that new knowledge in one domain may have costs in other domains, requiring joint problem-solving and negotiations of interests and trade-offs (Lervik *et al.,* 2007).

As depicted in Carlile's framework in an effective cross-border management, knowledge on the syntactic level might be fairly well-known to the actors. When the common lexicon (language) sufficiently specifies the differences and dependencies among actors, the boundary is experienced as unproblematic and the focus of boundary management is "simply" to transfer knowledge. The translation from a syntactic to a semantic boundary occurs when the degree of novelty of an innovation is increased, and makes knowledge differences and dependencies unclear or the meaning ambiguous. The transition from a semantic to a pragmatic boundary arises when the further increasing novelty of the innovation results in the emergence of different interests among actors in the social system (Edenius *et al.,* 2010). Finally, the forth element focus on progressive development of common understanding and alignment of interests, i.e., the iterative cycling process that permits executing the above three steps over and over again as long it is required with special emphasis on negotiation and consensus building.

3. Research Approach and Methods

The research takes the form of case study and the epistemological stance is interpretive (Walsham, 1995; Walsham, 2006). The research relies also on the qualitative research tradition which, according to Iivari (2010), is characterized as a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible. This study is based on a series of events that occurred over a period comprehended from January 2009 to August 2011 toward the adoption of OpenHealthMapper in a couple of developing countries. The results are drawn from empirical work performed in Guinea-Bissau, Malawi and Mozambique; three developing countries located the first in west and the last two in southern region of Africa.

3.1 Background

DHIS2 is a customizable Free/Libre Open Source Software (FLOSS) application and data warehouse framework that supports the collection, validation, analysis, and presentation of healthcare data. The features of DHIS2 application are organized in modules which include DHIS2 Routine, used for the management of routine data, DHIS2 Tracking, used to manage community data, DHIS2 mHealth, for management of health data using mobile devices, and DHIS2 GIS or OpenHealthMapper, a mapping client used as data display and analysis based on aggregated data.

OpenHealthMapper is developed as web-based client-server tool inspired on HISP_SpA (module working in versions 1.3 and 1.4 of DHIS application in India) and HealthMapper (WHO tool used by many countries to perform spatial analysis in healthcare sector). Both its client and server sides are integrated within DHIS2 (Øverland, 2010). The client side is developed using JavaScript frameworks which comes with Mapfish, OpenLayers, Ext JS and GeoExt; and it reads JavaScript Object Notation (JSON) as a data-interchange format, GeoJSON as a format for encoding a variety of geographic data structures and Scalable Vector Graphics (SVG) as a language for describing graphical applications in XML (Saugene and Sahay, 2011). The server is Java based. The three layers architecture of the module are handled by the store layer where the communication with the database is made through Hibernate and the service layer where the objects, service functionalities (logic) and application programming interface (API) are implemented.

The tool has embedded the basic features of any GIS application. Additionally the tool has user interface with ability to add new WMS layers to the map, possibility of running DHIS2 datamart automatically when indicator, period and level are selected, organization unit level drill down when a polygon is clicked, ability to display data elements (“raw data”) as well as indicators, capability of filtering map extent: the map showing only a limited area such as a province or district, an interface suitable for all international users, organization unit profiles as pop-ups which show values for all

indicators in an indicator group and ability to export map, legend and comments as external file.

3.2 Data Collection and Analysis

Concerning data collection and analysis, the research relies on the qualitative research tradition (Iivari, 2010), considered as an activity that locates the observer in the world, supported by mixed methods including interviews, observations, and reflective discussion. Data was also collected from conversations (email, person-to-person, etc), documents and papers, and operational procedures. A total of sixteen (16) institutions dealing with spatial data were approached. The interviews followed a semi-structured manner, and the questions had been made available for the interviewees beforehand. Throughout the entire study reflective discussion was performed together with the interviewers.

Data transformation mechanisms applied in this study follows interpretive philosophy and its deductive process was possible through data reduction, data display and conclusion and verification steps of a data analysis framework (Miles and Huberman, 1994). Data was then organized, and compressed in a manner that permitted drawing conclusions easily in forms of text and diagrams.

4. Empirical Insights and Analysis

4.1 Introduction

The DHIS2 mapping client evaluated in the current study relies on GeoJSON files and GML file formats. These files are usually created from coordinates (latitude and longitude) stored within shapefiles. These files in most developing countries such as Mozambique, Malawi and Guinea-Bissau are produced by different institutions. The customization of *OpenHealthMapper* in these countries has presented many challenges. For example, Saugene and Sahay (2011) mentioned problems faced in Malawi and Mozambique which included among others:

(a) Districts not being reflected in the existing maps: e.g. in Malawi two new districts Likoma and Neno were not represented, yet in the existing maps and two DHIS2 organizational units (Mzimba South and Mzimba North) were part of the same spatial administrative district boundary. Figure 1 below illustrates these problems with the Malawian *geodata*.

(b) Existence of technical limitations in manipulating *geodata*: for instance, we have identified problems in generating GeoJSON and GML files from the shapefiles. Addressing this issues required support from external experts.

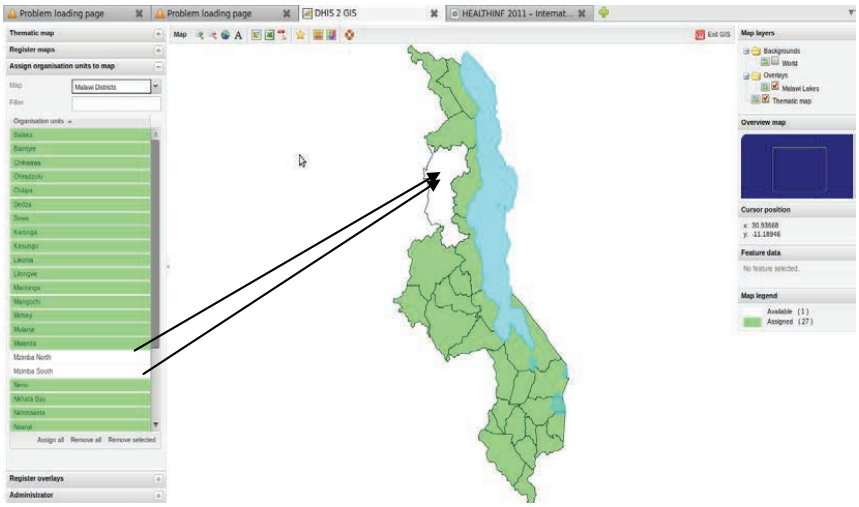

Figure 1: Example of problems identified with geodata while customizing OpenHealthMapper in Malawi

During the customization of the DHIS2 mapping client in the settings including Malawi and Guinea-Bissau, observed recurrent problems included:

Mismatch of administrative boundaries among government institutions. Figure 2 illustrate problems with the Guinea Bissau *geodata*, i.e., administratively the country is divided into 9 regions but the Ministry of Health has split some of the regions and in total has 11 regions. For example, sectors and health facilities from Oio region were split and aggregated under two regions, Farim and Oio. However, the administrative shapefiles presenting the 9 regions were not updated to reflect this new situation and as a consequence some of the DHIS2 data collected in the missing regions cannot be displayed in the maps.

As highlighted before, the reasons for the above problems are associated to technical as well as organizational issues. Aiming at understanding these reasons the next sections present and discusses lessons from our findings.

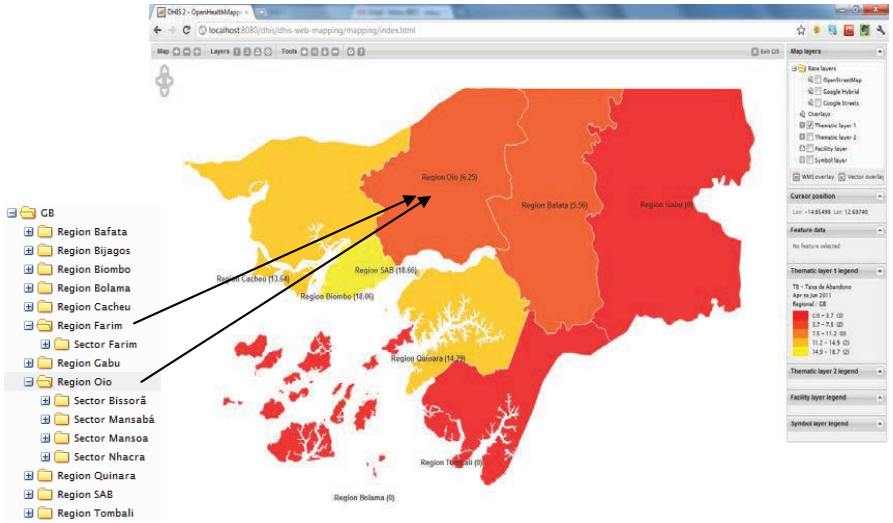

Figure 2: OpenHealthMapper map displaying dropout rate for TB patients with Bk+ in the regions of Guinea Bissau in the second quarter of 2011 and the challenges with geodata

4.2. The major GIS opportunities and constraints

Adoption of GIS applications in Mozambique has increased in the last years. Many of these initiatives have been taken in isolation and without necessary synchronization and cooperation. Thereat institutions adopting them, for instance healthcare sector, face various types of challenges. These challenges are summarized in the following two bullets:

Despite the existence of a government institution responsible for handling *geodata*, its availability is fragmented amongst different institutions. There is lack of data collection coordination and networking between users which results in duplication of data (Ernesto 2010; Juvane 2009). Institutions with shortage of resources (human, material and financial) are doomed to rely on base maps which are outdated, compiled by different agencies with different map scales. Most of the users are still learning GIS potentialities and the absence of guidelines makes users to employ data format, practices, etc, defined by the *geodata* holders and GIS processing software vendors. In some situations the data formats are specific to the needs of particular institutions; and not intended to meet the needs of a broader range of users. Although large amount of data is now available in digital formats, most is derived from analogue maps produced by CENACARTA(Juvane 2009). Even though accessing such data is not difficult, its use has been limited by lack of metadata. In fact, metadata of *geodata* is

collected together with the data while in field; however, its organization varies between institutions. Usually paper forms are compiled with details of the *geodata*, but only the information requested by GIS applications is recorded. The paper forms are kept but not shared along with the digital files.

Institutions	DNGA	IIP	INE	CENACARTA	CMM	DINOT	CENOE	DINAPOT	ARA-SUL
Total workforce	2	4	12	20	4	2	2	5	10
Fulltime workforce	1	0	12	12	4	2	2	3	10

Table 1. Number of GIS professionals working in some of the visited institutions[1]

(ii) Since GIS is still new for most institutions, it is difficult to say with certainty whether the workforce is appropriate or not to institutional needs. However, we have found discrepancies in the number of available human resources within staffing groups in the institutions. For instance, even though CENACARTA, INE and ARA-SUL have considerable GIS personnel for their activities, most of the staff does not participate in data collection and the percentage of time spent for carrying GIS activities is very low. Table 1 presents this observation across selected institutions. Further, besides being comprized of recently graduated staff lacking experience to conduct specific activities, the available staff do not continuously update their skills and knowledge. Continuing education for the GIS personnel is fragmented and uncoordinated explaining why institutions such as CENACARTA do not repose confidence in *geodata* collected by other institutions. Some institutions have capacity building plans, however their implementation is slow resulting in personnel not being up-to-date with the latest GIS technologies. Users in some institutions have benefited from capacity building activities. Mostly these activities are funded by ONGs, concentrated on their areas of interest and not integrated with the overall capacity building plans within the institutions.

4.3 Institutional Interactions

Since obtaining the most current *geodata* is a question of resources, a single agency may not be able to provide that on a continuing basis. Almost every institution using GIS is involved in data collection activities. Similar data is repeatedly collected, resulting in multiple standalone versions of "the same" data themes. This is caused by

[1] National Directorate of Environmental Management(DNGA), Fisheries Research Institute (IIP), National Center for Cartographic and Remote Sensing(CENACARTA), Municipal Council of Maputo City(CMM), National Directorate of Territorial Planning(DINOT), National Emergency Operating Center (CENOE), National Directorate of Planning and Land Management(DINAPOT), and Regional Water Administration of Southern Mozambique(ARA-SUL).

a lack of 'strong' leadership. Institutions such as CENACARTA, INE and CMM, which have specific units or departments responsible for GIS activities, are not committed to establishing standards. In fact, in 1998 a document that could be used as a guideline while creating, processing, handling or storing *geodata* was drafted. This document did not successfully attract the GIS community members and enough professionals to contribute to its implementation and adoption with the consequence that the document has not been finalized and the effects of its absence is visible and expressed through the quality of data available. Because the successful application of GIS technology is largely dependent on how well the data from different sources can 'talk' or communicate, absence of such standards hamper information sharing, communication and improvement of *geodata*.

Furthermore, there is no single network, either technological or social, that connects all institutions, but several 'social' networks which are constructed and dissolved as needed. Most of them were boosted during interactions while taking courses, for example, at faculty or in the cross-disciplinary meetings. To easily perform their activities users need to belong to multiple networks. Through this, they can 'always' find someone who can assist to address their problems, either technology-related or data-related. These partnerships also work as 'bridges' for gaining access to geodata. For instance, NGOs that funded capacity building activities or having a common pool of interests have used this linkage to access data produced or managed by non-related institutions, i.e., since free access to data is unavailable where the institution does not have an agreement, some institutions have requested data on behalf of others.

Institutions seem to understand geodata sharing differently; very few see data sharing as a mechanism for improving its quality and availability. This results in stakeholders operating in isolation from one another and is exacerbated because of the absence of a coordinated GIS strategy. For instance, while some institutions still do not share their data, others such as the national mapping body, CENACARTA, have undergone a shift where digital data is provided online and free of charge for the public. This might maximize its reuse and minimize the need for collecting similar data themes.

5. Discussion and Conclusion

GIS can reform government and societal functions by uniting disparate information sets and displaying them as a simple mechanism for people to understand. Developing an integrated computer system that ties, for instance, healthcare data with GIS assets can simplify tasks, assist with planning and management, and lead to more efficient decision-making (Melnick, 2002). To enable governments to perform spatial analysis of, for instance, healthcare data, their applications draw geodata from GIS databases. However, geodata has been reported, by scholars and also through our own experience in customizing OpenHealthMapper in developing countries, as the major problem limiting the effective adoption and use of GIS.

Efforts to deal with this problem have made governments rethink their roles with respect to the availability of geographic information. Spatial Data Infrastructures (Masser *et al.,* 2008; Silapathong, 2004), for instance, have emerged as a result of this government process. With this paper we sought to contribute to this field by providing insight into what happens at the interaction between GIS boundaries and the tensions of geodata sharing. For that two research questions were formulated, whereby the first aimed at investigating the factors surrounding geodata production and sharing; and the second directed towards the approach that may be used to address the tensions identified by the first question.

In relation to the first question, our findings reveal that geodata have been created by individual agencies to meet their specific needs, and usually with very little coordination among them. Due to this lack of coordination, the adoption of healthcare management technologies such as the OpenHealthMapper application face challenges of not being able to provide accurate results or even not being fully customized. Hence, even if institutions and agencies interact to reduce data collection efforts, problems (in quality, standard, and format) found in the data files, forces them to (i) engage in data collection activities, and (ii) lack confidence in using data collected by unknown individuals.

Moreover, since GIS users (public and private institutions) represent one single community which share identities represented by and in the boundary objects, they were supposed to "allow the definition of consensual sharing of data" (Harvey, 1999). However, each user has a different culture which represents the boundary between them and is manifested through the 'hidden' impediments of geodata sharing. From our empirical work these impediments are presented as results of absence of metadata, technical expertise in providing the necessary quality, and infrastructure that enables the transfer of data, all originating from the absence of coordination and the high costs associated with production of data and different data units and reference systems. In short, based on their own needs each institution manages geodata using its own approach, i.e., geodata is encoded in an uncoordinated way, without consideration of compatibility and interoperability with other utility systems.

Much like geographic boundaries these boundary objects separate different social groups while at the same time delineating important points of reference between them (Akkerman and Bakker, 2011). Thus, given that sharing and capacity to integrate geodata across boundaries is vital for effective use of GIS, our second research question concentrates on discussing how the principles behind Carlile's cross-boundary knowledge integration framework can help to address the impediments or factors that impact on the adoption of GIS for healthcare management. Through this iterative framework we join with scholars such as Lervik *et al.* (2007) who support the idea that GIS adoption does not only depend on making explicit information available in repositories across institutions or agencies, but, in efficiently facilitating the access through sharing and integration across domains and/or institutions. Since many institutions and agencies have already invested in GIS technologies, establishing a link that builds upon them may be possible through syntactic, semantic and pragmatic

processes, i.e., an approach for removing geodata conflicts need to be characterized by the following features:

(a) Since *geodata* is managed (collected, stored and managed) differently, its effective exchange (send and receive) must boost the development of a common dictionary or standards among the institutions and agencies and also avoid duplications through the emphasis on the syntactic process. Syntactic process, according to Sheth (1999), refers to the difference in data type and format. Initiatives such as that by CENACARTA related to the provision of data and its metadata free of charge and electronically, and the development of guidelines, if taken seriously can syntactically help to make data more exchangeable.

(b) Access to timely and accurate data is vital for proper reporting and monitoring of healthcare activities. However, accessing by and of itself is insufficient; there is a need for developing mechanisms for analysing *geodata*, checking the inconsistencies and duplications, i.e., perform semantic checking. The semantic aspect of *geodata* refers to differences in naming conventions and conceptual groupings in different organizations (Harvey, 1999). Since *geodata* captured by each institution take into consideration its own specific needs, a standardization process that considers the varying interpretation and meanings across these institutions and agencies needs to be recognized and supported by all. For example, our findings have illustrated that institutions collect the 'same' data themes in an uncoordinated way, whereby semantically identical data items are named differently or semantically different data items are named identically; through access to metadata and documentation to assist integration work, techniques like Ontology mapping (Buccella *et al.,* 2011; Stoimenov and Djordjević-Kajan, 2005) while helping to define a common vocabulary can assist to reconcile heterogeneous cognitive issues reducing in this regard semantic problems. However, problems with availability of metadata may hinder this process.

(c) These features do not incorporate the fact that partnerships between the GIS users also involve interests. Through our findings we have presented examples whereby partnerships created by funding training were used as channels toward access to *geodata*. Lessons also illustrate that the keys to successfully permit the 'communication between *geodata*' do not only result in high-quality and accurate data or well-designed processes that recognize the differences across the data providers, but also the recognition that *geodata* capture requires huge investments in resources (material, human and financial), i.e., recognition that '*geodata* is power' (Lervik *et al.,* 2007). Through this perspective we argue that, instead of every institution being involved in capturing the 'same' data themes, investments should be made in strengthening the partnerships and negotiation of interests.

(d) Since the integration of multiple spatial datasets managed by different institutions in different utility domains raises a number of conflicts, their recognition is an

important step, but special attention needs to be directed to providing a 'good' approach. In this regard, execution of the above processes must be iterative whereby negotiation activities overlap syntactic, semantic and pragmatic processes, i.e., *geodata* is checked for consistent geometry and the appropriate projection. The encountered problems being automatically corrected; each *geodata* extended with metadata fields, which are then populated along with the data. These boundary objects are expected to stabilize the relationships and the negotiation of differences may be crucial in providing flexibility and dynamic coherences (Harvey and Chrisman, 1998). Hereafter, since institutions are in different adoption levels, as presented in our findings, negotiations which involve the three features above must be seen as an ongoing process where users are aware about the need for interacting between each other in order to arrive at a standardized data which all the institutions will accept and recognize.

Given the existence of a vast number of geodata producers, decision-making activities often rely on geodata from distributed GIS sources. However, distributed data sources and their heterogeneity are the main problems for institutions adopting GIS. The social constructivist framework concentrated on an interactive process towards the production of qualitative boundary objects is one reasonable approach. By deepening and extending our understanding of geodata problems and proposing Carlile's framework as a strategy for addressing geodata conflicts, we have brought a theoretical understanding of what happens within the GIS world and how a theoretical approach may be applied to guide future adoption and paths regarding GIS application adoption.

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III

Extending System Capacity in Low Resource Environments through 'Flexible' Competency Building in Open Source Applications Customization

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Abstract. The adoption of software systems in low resource countries is generally viewed as a mechanism to improve service delivery. However, given that many of these applications are generic systems, one of the commonly recounted challenges is the lack of the necessary competences to adapt them to local county contexts. Drawing its material from four customization projects, the article evaluate the issue of competency building through the concepts of *identification*, *coordination*, *reflection* and *transformation*. The research is based on a qualitative multi-case approach and the epistemological stance is interpretive. The study findings illustrate different types of tensions generated at the *boundary crossing area*. Furthermore, in the course of resolving these tensions, *boundary objects* and *boundary crossers* are seen as source of, in some projects, and a barrier to customization in others. The paper concludes that, since software customization process crosses many boundaries, the four dialogical mechanisms for learning from where this article draws its analysis can help to understand customization tensions and guide their adjustments.

Key words: healthcare management, open source software customization, boundary crossing, boundary object, competence building.

Introduction

Health Information Systems Programme (HISP) has been, for more than a decade, supporting developing countries' healthcare reform processes. One of the important moments of this journey was the introduction of a Free/Libre Open Source Software (FLOSS) application labelled District Health Information Software (DHIS2).

However, developing countries' ability to implement generic software tools has been reported several times as a major concern for most healthcare managers. Sahay and Walsham (2006), for instance, while studying the scaling of Health Management Information Systems (HMIS) in India have pointed to issues of increasing technological complexity, human resources capacity, waning political support, and unanticipated

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effects as factors affecting the customization process. These issues have been discussed by other Information System (IS) scholars, and a common finding is that usually there are tensions between local needs and the capability of the generic software (see Avgerou (2008), Bada (2002), Pozzebon and Pinsonneault (2005), Nhampossa (2005) and Pozzebon and Heck (2006)). However, few studies have concentrated on the issue of competence building taking place during the customization of generic FLOSS applications to fit local needs. Customization, in this context, would be carried out by a local team, which has to learn both user requirements and the affordances and constraints of the generic software.

Given that software customization involves working in a multidisciplinary community, our broader research question now is: "how competency should be developed in this kind of environment?"

Whereas the main challenge in the multidisciplinary community interacting during customization is bridging the gaps between the local customizer team and the software provider on one side and the users at the other, we borrow the concepts of *boundary crossing* and *boundary objects* to refer to, respectively, the interaction between the sides during the process and the artefacts (translation devices and practices) traded by them. Furthermore, since the existence of tensions within and between boundaries and objects that crosses is inevitable (see for instance, Tsui and Law (2007) and Fisher and Atkinson-Grosjean (2002)), addressing them is a matter of competence.

Based on lessons from four DHIS2 customization projects, the paper first, investigates the actors and tools interacting at the boundary crossing area; and secondly, discusses how cross-border learning helps to identify sources of tensions and ways of addressing them.

The article is structured as follows. First we describe a theoretical framework based on concepts of *boundary*, *boundary crossing*, *boundary objects*, and the four mechanisms of cross-border learning. Then the customization projects and the way data for this paper was gathered are described. In the next sections empirically exploration of the meaning of software customization and how learning occurs in this environment is performed.

Theoretical Framework

By exposing its functionalities and implementation details, the emergence of FLOSS brought the possibility of seeing software as open objects. This openness enables end-users to control the software as they want, thus, leading the learning process. The learning usually occurs during the period in which a generic application is changed to achieve a goal that the

original design did not fully support(Watson et al. 2004), i.e., a process in which a software as a black-box object is opened up and its content studied, negotiated and understood by the practitioners. This process is considered as socio-technical activity taking place at a region that crosses developer and user *boundaries* and is labelled customization.

Kerosuo (2001) define *boundaries* as places of division between what is familiar and what is unknown. However, since each of the boundary sides has its own people, objects and practices, crossing them will create some kind of complexity (Akkerman and Bakker 2011). Managing this complexity is a matter of 'boundary-crossing competence' (Fortuin and Bush 2010; Walker and Nocon 2007). Obtaining such competence, especially in software customization environment, is a matter of meeting the right people to dialogue with, exchange experiences and practices, and also ease access to the software related artefacts.

To study attitudes and practices of people that enter onto territory in which they are unfamiliar and, to some extent unqualified (Suchman 1994) and based on their fresh look at the long-standing practices and assumptions, create deep learning (Tsui and Law 2007), scholars have used *boundary crosser* concept. Fisher and Atkinson-Grosjean (2002) argues that boundary crossers have a very rich and valuable position by introducing elements of one practice into the other. The approach helps also to identify problems. Fisher and Atkinson-Grosjean (2002) highlighted these problems arguing that while boundary crossers face a difficult position by being easily seen as member at the periphery with the risk of never fully belonging to or being acknowledged as a participant in any practice. Thus, studying them requires paying attention to the process of negotiation and combination of ingredients from different contexts (Akkerman and Bakker 2011; Engeström et al. 1995).

On the other hand, the investigation of artefacts shared during the boundary crossing activities, has been done through the *boundary object* concept. Bowker and Star (1999), for instance, used *boundary object* to refer to tools, techniques, ideas, stories and memories exchanged between sides sharing the same boundary. The perspective proved to be supportive to the customization process by acting as tools for communication and collaboration (Hunter 2008), and management (Akkerman and Bakker 2011). Conversely, it can also fail to address customization process, i.e., if artefacts do not fully or rightfully capture multiple meanings and perspectives needed to address specific customization problem they will not be able to help the customizers in their activities. Akkerman and

Bakker (2011) presented an example in which message boxes with system-related information about a medical technology failed to be supportive because the concerns and interpretations of users were not taken into account.

The proposition that spanning boundaries of diverse professional and organizational settings can become a key organizational competence has received extensive theoretical support(Levina and Vaast 2005). Scholars such as Vera and Crossan (2003), Levina and Vaast (2005) and Sheikh and Braa (2011) have highlighted several approaches for competence building. In order to encourage and assist in forming positive attitudes and practices on the individuals spanning DHIS2 customization boundaries, Braa et al. (2004) proposed networks of action (NoA) strategy. The strategy says that learning process and sharing of resources can flow better in situations where sites are connected through networks, rather than individual locations. NoA is used in all the DHIS2 customization projects performed by HISP and the process of training and experience sharing happens as shown in Fig. 1. While the first box describes capacity building activities taking place in each site, the last two describes activities supported by partnerships or networks.

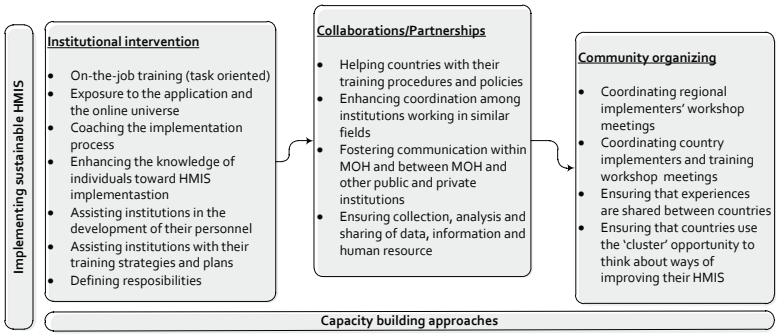

Fig. 1: A process model of how capacity building occurs within the broader HISP network

Competence building as addressed by the above strategy works perfectly when time is abundant. However, most of the times the pressure to deliver that customizers suffer cannot be addressed by this strategy. To contribute to this gap, we extend the strategy by looking customizers' competence building through the four Akkerman and Bakker (2011) dialogical mechanisms of identification, coordination, reflection and transformation.

Identification entails a questioning of the core identity of each of the intersecting sites that leads to renewed insight into what the diverse practices concern. The mechanism is split into two processes. The first is

called *othering* which is a process that occur by defining one practice in light of another, delineating how it differs from the other practice with focus on personal as well as cultural differences of practices. Akkerman and Bakker (2011) describe tensions of this process using examples of a student who does homework with his mother's help. Through this example the boy's identity as, for instance, someone wanting to play and the mother's identity as helper, checker, and enforcer of homework may not harmoniously coexist. These differences may lead to a negotiation of identities. Another example describes how salespersons' work is not a matter of crossing fixed boundaries but a matter of continuously redefining and thereby shaping boundaries of the seller and buyer markets. The second process is called *legitimating coexistence*. The process is highly political and sensitive and attempts to address the need of considering the boundary-crossers' multiple memberships in order to be able to pursue them and their acceptance by others. This assessment is meant to prevent situations such as those described by Akkerman and Bakker (2011) where in-house staff and outsourcing technicians of a tertiary education institute were unable to come to terms with their distinct roles and responsibilities.

Furthermore, learning at the boundary is a matter of **coordination** which involves establishing dialogue between boundary-crossers (Braa et al. 2004) toward the sharing of diverse practices. According to Akkerman and Bakker (2011) this process is possible through *communicative connections* between the practices or perspectives shared by multiple parties; cross-side practice and object *translation efforts*; *boundary permeability enhancements* so that leaning at the boundary can take place without one being aware of the different practices, and finally cross-boundary coordination need to be *routinized*, i.e., need to find procedures by means of which coordination is becoming part of operational practice.

Reflection is the third mechanism and emphasizes the need for boundary crossers to realize and explain the differences between practices, as pre-condition to enrich their knowledge with something new about their own and others' practices. The mechanism involves *perspective making* - making explicit one's understanding and knowledge of a particular issue, and *perspective taking* - looking at specific boundary-crosser practices through the eyes of others. An example by Akkerman and Bakker (2011) illustrates how joint workplace visit (between teachers and students), made teachers aware of the cultural differences in both college and work, each

having its own conventions and rules, and also the misunderstandings resulting from these perspectives.

The fourth mechanism is named **transformation** and involves investigating the effects of working at the boundary. Usually, transformation starts with *confrontation* which consists in encountering discontinuities within the boundary-crossers' current practices and interrelations. The direct response to this confrontation may be recognition *of a shared problem space*. Boundary objects are used to refer to this shared problem space. The ingredients of the shared problem space that combine practices from different contexts may be submitted to a creative process labelled *hybridization* which will culminate in a new or unfamiliar cultural form or practice. New practices can be presented in a form of tool, sign (concept) or an analytical model. This process is called *crystallizat*ion which can occur as the result of both reification process, which consist of congealing the experience into 'thingness' (Wenger 1998), e.g. a boundary object, or developing new routines or procedures that embody what has been created or learned. Furthermore, *continuous joint work at the boundary* is required to preserve the productivity of the boundaries, i.e., transformation involves continuous dialogue, collaboration and negotiation of meanings between the boundary crossers.

Research Approach

The paper reports on the process of customization of FLOSS for healthcare management called DHIS2 performed in four countries. The research takes the form of multiple case studies and the epistemological stance is interpretive (Walsham 1995; Walsham 2006). The study is based on a series of events which occurred over a period from January 2009 until November 2011.

Background information

DHIS2 is a java based FLOSS framework developed for the management of healthcare information, i.e., an empty shell that need to be filled out with metadata and data values. The framework supports the collection, validation, analysis, and presentation of aggregate statistical data. These features are spread across the four main modules: *DHIS2 Routine* for the management of aggregated data; *DHIS2 Tracking* used to manage community data*; DHIS2 mHealth* for management of health data using mobile devices; and *OpenHealthMapper* which is used as data display and analysis based on spatial data. The core DHIS2 developer team is located at the University of Oslo in Norway and has collaboration from Indian, South African, Ethiopian and Vietnamese developers. DHIS2 can be

customized by adapting its features to fit local context countries. Countries that have done this include India, South Africa, Kenya, Tanzania, Malawi, Sierra Leone and Zanzibar.

For comparative purposes we have selected to include in this study, four customizations projects, three of which (Malawi, Tanzania and Guinea Bissau) part of HISP. Other characteristics that guided our selection include:

a) Mozambique, located southern corner of Africa, DHIS2 (*Routine and OpenHealthMapper*) was adopted by a group of NGOs under Ogumaniha project and used as a framework to the development of what they called Ogumaniha Information System (OgIS). Its customization was done by an internal team and, currently OgIS is being used by data managers, district coordinators, and program manages in fifteen districts of Zambézia province. The application is also being used by three regional supervisors, two data entry official, monitoring and evaluation coordinators, project coordinators among other specialists at provincial level.
b) Malawi, also situated in the southern region of Africa, adopted DHIS2 application to manage routine healthcare data and specific data managed by HIV/AIDs programme. The experience shared in this paper is taken from customization of three DHIS2 modules, namely *DHIS2 Routine*, *OpenHealthMapper* and *DHIS2 Tracker*. The customization and implementation was performed by local HISP team.
c) Located in the western region of Africa, Guinea Bissau was the most recent country adopting DHIS2 application for similar purposes as Malawi and Tanzania. The customization process is being performed by a global team and, actually, the application is being piloted.
d) Tanzania, located in the Eastern region of Africa, uses DHIS2 for similar purposes as Malawi. However, contrary to Malawi, Mozambique and Guinea Bissau, the implementation has been done not only by the local HISP team, but also by partners (NGOs) such as Clinton Health Access Initiative (CHAI), Elizabeth Glaser Pediatric AIDS Foundation (EGPAF) and Ifakara Health Institute (IHI). Each of these partners has its own team responsible for implementing the application, training the end-users and addressing the technical problems faced by end-users. The difference between the NGOs in Tanzania and Mozambique is that, in Tanzania de customization is performed by local HISP team while in Mozambique both customization and implementation are performed by the NGOs team.

Data Collection

Concerning data collection and analysis, the research relies on the qualitative research tradition (Iivari 2010), considered as a situated activity

that locates the observer in the world, and is supported by a mixed methods including interviews, observations, reflective discussion, and document analysis. Semi-structured interviews were performed to the customizers in four customization projects, and users in two. Informal observations were performed in the three customization environments and during the sessions in the two regional workshop training (5 days in one and 10 days in another). Workshops and reflective discussions were performed during the customization of some DHIS2 modules in some settings. Documents (such as project description, and training reports) were also examined. The collected data was stored as field notes and voice recording files on field notebook and phone respectively. Throughout the entire study reflective notes about the lessons being learned from the data have been recorded. These memos have been later included as additional data to be analyzed.

Since creating a database of information is not sufficient to conduct a study, the study findings needed to be transformed from raw data into new knowledge (Thorne 2000). The data transformation mechanism applied in this study follows interpretive philosophy and its deductive process was possible through data reduction, data display and conclusion and verification steps of (Miles and Huberman 1994) data analysis framework together with the four Akkerman and Bakker (2011) learning mechanisms. During the data reduction phase an intra-case analysis technique was adopted. By applying this technique the data sources were examined and relevant information extracted. Following, inter-case analysis was performed. Data resulting from these analyses were organized and compressed in forms of text and diagrams.

Empirical insights and analysis: DHIS2 customization boundaries and practices, objects and learning mechanisms

The DHIS2 customization boundaries and general practices

The development of DHIS2 framework has been performed by individuals with skills necessary to handle its ‘high level’ java programming frameworks. Even though the use of these frameworks and templates has helped to make the application more manageable and easy to mastery, its customization requires a solid combination of knowledge both of software as well as domain.

Given that health professionals rarely hold this knowledge combination, the customization of DHIS2 is possible through interaction of individuals holding different roles. The general setup of DHIS2 customization require

three main groups of professionals (see Fig. 2), namely (a) ***software developers*** who are the designers and developers of the framework. They hold knowledge about the domain and expertise in programming. To fulfil their goals, they usually work in strict coordination with the customizers and users (e.g. healthcare workers, healthcare managers', and researchers); (b) ***software customizers*** who have the responsibility of collecting user requirements and adapting DHIS2 framework to meet those requirements, i.e., creating their DHIS2 application. For this reason they are requested to have knowledge about the domain as well as the DHIS2 framework. They are also requested to have knowledge about several issues that make DHIS2 to work in practice including database, interface, reporting tools, process flow as well as infrastructure; knowledge which is improved with daily contact with users, developers and fellow customizers. For example, in order to understand the business processes, validate the requirements and define the best way of approaching local user needs, customizers in Malawi and Guinea Bissau were supported by local context users, customizers from other countries and in some cases by software developers.

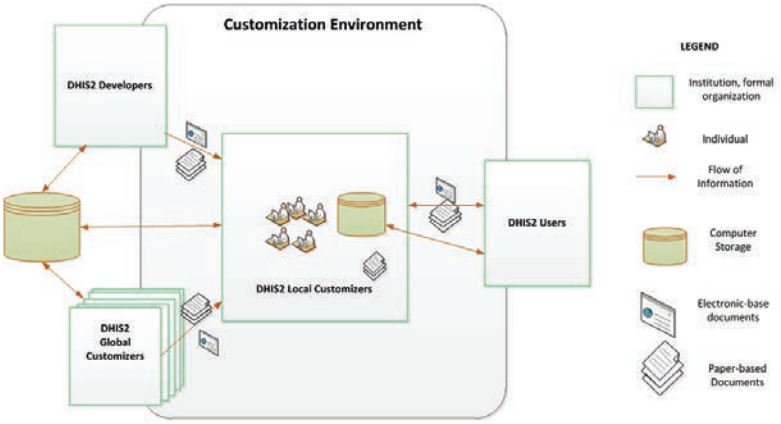

Fig. 2: Organizations, activities and service relations and tools used during the customization of DHIS2 to local user needs [Symbols used in this figure are borrowed from the landscape methodology (Korpela et al. 2008)]

Since fitting the local business processes into the application was their duty, whenever the tool was not aligned strictly to specific processes, they had to perform improvisations and report the problems to the developers.

For example, in order to have the *OpenHealthMapper* module displaying health data customizers in Mozambique, Guinea Bissau and Malawi performed several improvisations (see examples in Saugene and Sahay (2011)). In some situations where improvisation was not possible, for example the sharing of data elements between programs within *DHIS2 Tracker* needed in Malawi, the team had to report the problem to the developers; and (c) ***software users*** who are members of the MOH and other institutions using the application in their work setting. In general, they have knowledge about health domain (specifically in the areas covered by the DHIS2 modules). There are users who are experts in the domain while others are novices. Some have advanced computer skills, while others have not. Users with advanced skills are usually invited to make part of the customizer team either doing customization work or helping to clarify customizers concerns about the domains.

Therefore, people have organized the activities in different ways in these four countries: there are couple of organizations both having customizers and users (e.g. in Mozambique); there countries where customizer and user roles belong to two separate groups of organizations (e.g., in Malawi, HISP team is responsible for customizations and MOH responsible for the users); and in countries like Tanzania the situation is totally different from the above cases, i.e., there is a customizer organization (the HISP team) and there also customization being performed within the user organizations.

Specific DHIS2 practices and tools used during local customizations

DHIS2 customization entails more than just sharing application, requirements or practices among the above specified groups of professionals; it also means transforming, sometimes radically, the framework requirements to fit new environments. Being DHIS2 a general and customizable framework, fitting local requirements into it requires always specific activities. Among others customizers are requested to create and standardize data elements, indicators, and datasets, define organization units and organise their hierarchically, create reports. In all sites studied, this process is supported by local customizers who face various kinds of challenges. In Malawi, for instance, difficulties in designing the reports, changing the application to perform on-the-fly validations, and also finding documentation that could help them to understand issues related to *DHIS2 Tracker* module were experienced. Apart from the challenges faced in Malawi, customizers in Mozambique experienced difficulties in integrating data exported from the districts due

to the adopted database language, and also in getting support to resolve problems experienced during the customization of *OpenHealthMapper*.
In order to reduce some of these problems, HISP has scheduled once a year, workshop trainings and meetings in each of the three regions (East Africa, West Africa and South Asia) where DHIS2 has a huge number of known users.
Furthermore, besides assessing professionals, the ability to customize can be provided by the effective usage of artefacts. Fig. 2 summarizes the objects or artefacts used to support customization processes and are grouped into three categories, namely paper-based, electronic and computer databases. Electronic documents are available in forms of, for instance, (implementer, user and developer) manuals which can be downloaded from the DHIS2 webpage, and workshop training presentations. For instance the customization of *DHIS2 Tracker* in Malawi relied on workshop presentation provided by a researcher who has been in one of the settings (India) where the module was in use. During the customization of this module in Malawi and Guinea Bissau process flow diagrams were created to help validate diagrammatically the business process and later were included in their respective manuals. Paper-based documents were used in all the settings under this study as a source of requirements. Computer databases were also used by customizers to seek help. For instance, DHIS2 user and developer mailing lists are available for everyone inscribed to seek for help from the community. Locally, customizers create also their own databases. For instance, the customizer team in Malawi created a local customizer mailing list used to diffuse news and problems. In Tanzania, on the other hand, local database called *HISP CRM* is used to manage 'tickets' related to problems faced by users. The database is available to the customizers, users as well as implementing partners.

Learning at DHIS2 boundary interactions

In this session we use the four Akkerman and Bakker (2011) dialogical learning mechanisms to describe and address the tensions generated during the customization process.

a) Identification. Our findings illustrate that, the customization of DHIS2 in the four settings was a centralized process where a mixed team of professionals (including health professionals with very little IT experience, project managers, and individuals with high programming skills but little domain knowledge) were in constant interaction. Besides being engaged in this process, individuals were also

performing their daily duties. For instance, health statisticians and data managers in Guinea Bissau had to leave the customization process because they had to do activities such as producing the reports, attending meetings, doing supervision work in the regions; a network administrator had to leave in order to solve internet connection issues and problems on his colleagues' computers. Analogous situation had also been experienced during the customization of *OpenHealthMapper* in Malawi where meetings with health and spatial data managers were postponed because they had 'priority' activities (related to their daily duties) to perform. In Mozambique, a customizer team member reported to us claiming that in addition to activities to which was hired he had to do many other extra activities. Furthermore, our findings reveal that customizers' work is turned from crossing between software development, and use boundaries (as illustrated in Fig. 2) into continuously redefining and thereby shaping themselves within each of these boundaries in order to get the necessary information to have to work done. This redefinition has consisted in customizers 'wearing layers' of for instance project managers while taking important decisions of sending members to workshop trainings or inviting persons to help address specific problems, of users while helping to validate the customization outcomes, and of developers while producing tickets for software evolution. Analyses of the above illustrations' present difficulties if we have to identify what is the position of each customization participants in terms of developer, user, manager or simply customizer, i.e., it will be difficult to explain what each participant did during the customization as distinctive from others. However, bringing them together is a result of recognition of the differences between the individual participants' practices or identities. This recognition has been labelled *othering* (Akkerman and Bakker 2011). Therefore, as shown above, the existence of individuals, within customizers' team, that besides being customizers performs additional tasks as shown to influence negatively the work progress. However, members were always 'released' to do their jobs and joined the team when finished. Thus, the fact that customization in none of the settings has ever stopped because of that shows that the interference between members multiple participations or identities were considered and accepted by others, a process called *legitimacy of coexistence*.

b) ***Coordination.*** Customization of DHIS2 requires continuous dialogue between the local context users and the global HISP members. For this research, the dialogue was possible through various mechanisms (see Fig. 1 and 2) including: on-the-job training, refresher workshop training for customizers, implementers and users where the moderation was done by developers and experienced customizers; and detailed learning material available within the DHIS2 electronic universe (such as HISP webpage, DHIS2 manuals and DHIS2 mailing list) or in the HISP members hands. Tools and approaches have been institutionalized so that every country that adopts DHIS2 with support

from HISP follows similar procedures (Braa et al. 2004). The artifacts (DHIS2 electronic universe) developed to support the stakeholders were institutionalized within the HISP network and are embedded within the customization tasks, so that whenever questions arise, the first place where customizers seek answers is on these objects. Help was also received from regional training workshops institutionalized by HISP and planned to run once a year in each of the three regions. The features of coordination presented above suggests the Akkersman and Bakker's (2011) *routinization* mechanism. However, the dialogue between individuals within the network, and effective use of the boundary objects could not be possible if communication did not exist. For instance, if DHIS2 artefacts with rich examples displaying how certain features work were not accessible to the customizers it could not be possible to align those features with local contexts requirements. These structures or linkages is what Akkersman and Bakker's (2011) label *communicative connection*. Furthermore, the customization of DHIS2 was performed without even being aware about the different in practices within each team members. This coordination feature is labelled *boundary permeability*. We have witnessed positive as well as negative sides of this permeability. For example, as described in the above sections, despite few marginal challenges much of the customization work done in Guinea Bissau and Mozambique was supported by knowledge gotten after getting access to DHIS2 artefacts and professionals. Furthermore, the willing to help local countries contexts while customizing DHIS2 through the HISP NoA approach and the openness of the network to allow the possibility of receiving and interacting with individuals not taking part of the HISP, such as customizers from Mozambique who attended the workshop training, illustrates some kind of permeability. However, the team experienced several problems that could not be addressed through the boundary objects and the available supporting mechanisms, as the cases of Malawi during the customization of DHIS2 Tracker module. Still in Malawi, customizers could not inscribe some requirement requested by users such as 'on-the-fly' validation.

c) Reflection. Throughout the study we have observed that, while the countries in which the customization was led by HISP members, IT professionals stayed months working together with healthcare managers, data managers, and statisticians, in the other countries customization was led by in-house team. 'Guest' customizers have been shared between the customization contexts. For instance, two customizers involved in the customization in Malawi were also involved in the customization in Malawi. Given that customizers in Mozambique could not adapt the *OpenHealthMapper* module by themselves, one of the customizers which have been in Malawi and

Guinea Bissau was invited for a couple of days to help local team. These customizers carried with them the experiences and practices learned from the earlier customization settings. This experiences helped them customizers to be aware of, for instance, how specific programmes are institutionalized within DHIS2. This knowledge was used in the other settings and also since their forwarded to contribute to the global development team, was used to improve some features of the DHIS2. For instance, DHIS2 Tracker experiences obtained in Malawi were used Guinea Bissau, and *OpenHealthMapper* experiences from Malawi were used in Mozambique and later in Guinea Bissau. The problems of sharing data elements between programs and also with the construction of logic expression of the queries faced in both settings were forwarded to the developers. Furthermore, as expressed earlier the 'same' DHIS2 materials were used as a support mechanism in all customizations. Additional to these materials, to clarify the requirements the customizers in Malawi and Guinea Bissau draw process flows which were later discussed with users. In Guinea Bissau these drawing were included in user training materials. This adoption of similar objects and practices to support customization suggests the reflexive mechanism called *perspective taking*, and the process of making explicit the understanding of the business process through drawings of the process flow is called *perspective making*.

d) ***Transformation***. Prior to introduction of DHIS2, healthcare data was processed using different tools including stand-alone access applications, excel spreadsheets, and paper forms. For instance, maternal and child health data in Malawi was not captured by the database system; each of the NGOs using OgIS in Mozambique had their own database; and the access database used to manage health statistic data in Guinea Bissau was not capturing all programmes data. There had also been a lack of communication between the different sources of health statistic data. Thus, introducing DHIS2 intended to improve the management of the data through an integrated HMIS that had been proved to be successful in doing similar tasks in other settings. This common concern or problem that forces the interaction of stakeholders (presented in Fig. 2) characterizes the *confrontation* feature of transformation mechanism. Given that a 'common' problem within and also between countries was identified, similar approaches and tools (see Figs. 1 and 2) were used by the customizers. Considering this mutual concern or use of approaches and tools is the same as recognizing existence of *a shared problem space*. However, this process created huge opportunities and challenges. Among others our findings emphasizes: the emergency of implementer role in Tanzania as result of existence of NGOs brokering DHIS2 implementation process; after getting access to the *DHIS2 Tracker* module, TB managers in Guinea Bissau, for example, engaged in activities that culminated in the revision of their information flows and tools; inclusion of *OpenHealthMapper* in Mozambique led to

negotiations with the developers regarding the way some of the DHIS2 modules were removed from later versions of the framework; problems presented by customizers compelled the developers to realize the weaknesses of the supporting tools and draw plans for improvements, and the emergence of practices enforced by the difficult to inscribe local user requirements into the global tool, i.e., in Tanzania local customizer team was split into developers and customizers in order to address programming tasks. The practices that make part of this space have emerged as hybrid cultural form combining practices from users, and developers. While the NoA strategy adopted to customize DHIS2 in most of the settings can be considered a new cultural form or practice that is already crystallized within HISP, we have observed the materialization of new practices - the cases of regional workshop training held in Tanzania and Ghana, and the emerging of implementer institutions. Since the new cultural form come with specific practices and is result of combination of practices from different contexts, following Akkerman and Bakker (2011) we label this transformation mechanism as *hybridization*. Thus, much of the new practices undergone to a reinforcement process – some were institutionalized other were transformed to objects. Make part of this, users' and developers' practices used during the customization which have been crystallized and today are considered as customizer practices; boundary objects such as DHIS2 user, customizer and developer manuals which were also created to congeal the practices (Wenger 1998). In Guinea Bissau, for instance, manuals showing the new procedures inscribed into DHIS2 were developed and institutionalized. This transformation mechanism is labelled *crystallization*. The crystallization process has observed some problems such as the artefacts (in Fig. 2) not capturing the entire DHIS2 practices, i.e., some of the challenges faced in Mozambique and Malawi by the customizers were originated by the artefacts not containing description of how to customize certain features. The emergence of a customizer community represents a successful form of boundary crossing because both users and developers started to enact new ideas in their own daily practices. During this study we have observed *continuous joint work at the boundary* as prerequisite to preserve the productivity of boundary crossing. In the four customizations projects end-users, software developers and customizers met several times to discuss and work on shared problems. For instance, customizers from Malawi and Tanzania apart from informal electronic meetings have participated in two regional workshop meetings organized in Dar-es-salaam together with the developers. The customizers from Mozambique joined one of them. Finally, Guinea Bissau customizers attended the workshop training organized in Accra. Based on these collaborations learning was

produced. Being planned to be held annual these trainings illustrates an effort to maintain united practitioners from several countries for a common purpose. Following Kerosuo (2001), this is the reason of considering customization as a boundary crossing activity where professionals from different communities are invited to meet and together make the software more close to users requirements.

Discussion and Conclusion

Being DHIS2 a FLOSS framework, its extensibility or adaptation to local contexts depends on several factors. The need to understand these factors urged us to look at how groups and individual with different expertise, tasks, or cultural backgrounds collaborate during customization work. In order to gain better insight into this process, our first question aimed at investigating the customization process in term of mediation mechanisms (actors, tools, and practices); and the second stressed about generated tensions and how learning mechanisms helps in indentifying and addressing them.

In response to the first question, our cross-case comparison reveals key customization similarities and differences among the four settings. We have observed developers, users, and customizers engaging in collective knowledge generation by crossing boundaries in order to make the software applications less distant from the users' context. For example, software developers and users helping to enrich customizers' knowledge; and customizers filling knowledge gap of other customizers'. Our findings have also indicated that, besides boundary spanners (people), customization has been reinforced through boundary objects (artefacts). While manuals, physical documents and official webpage were used to bridge customizers' knowledge gaps by providing ways of adapting DHIS2 features, database system, emails and mailing lists were used to share concerns among customizers.

Despite the above discussed similarities, differences have also emerged. Boundary spanning competence was seen as emerging very slow, with nominated boundary spanners failing to fulfil their roles in some settings as compared to others (e.g., while customizers in Malawi were not able to cope with some challenges in inscribing some user requirements, customizers in Tanzania addressed similar problems through development, thus creating new role). Differences were also identified in the practices of boundary spanners. For instance, besides having similar interest, each boundary spanner community member had different culture and practices represented by the boundary where he belongs (e.g., while the developers were responsible in providing guidance related to the design and development of DHIS2, the customizers were responsible in fitting local

context requirements on it and users validating and texting the customized application). It was also observed the emerging of new boundary spanners (implementer institutions), producing new kind of practices (e.g., users performing customization). Their participation in the joint field became the basis upon which they were distinguished from those in their local fields who were not participating in a similar activities (e.g. a user responsible for customization in one setting but on another this activity assigned to customizers).

Since boundary spanning requires an ability to negotiate customization issues between the involved practices, it requires the development of, at the very least, a peripheral understanding of each practice (Levina and Vaast 2005). However, we have observed similar boundary spanners (local context customizers) performing different activities (e.g. the developer role emerged in Tanzania as result of the need of making local adaptations in order to make the generic tool fit 'totally' their local context). However, similar problems happened in other settings like in Malawi and Mozambique, but boundary spanners continued performing the same activities (e.g., did not turn themselves to developers).

	Identification	Coordination	Reflection	Transformation
HISP Global	• othering; • legitimacy of coexistence	• routinization; communicative connection; • boundary permeability	• perspective taking; • perspective making	• confrontation; • shared problem space; • hybridization; • crystallization; • continuous joint work at the boundary
Tanzania	-	• routinization (database HISP CRM);	-	• confrontation; • shared problem space; • hybridization; • continuous joint work at the boundary
Malawi	• othering; • legitimacy of coexistence	• routinization (mailing list);	• perspective taking; • perspective making	• confrontation; • shared problem space; • hybridization; • continuous joint work at the boundary
Mozambique	-	-	-	• confrontation; • shared problem space; • hybridization; • crystallization; • continuous joint work at the boundary
Guinea Bissau	• othering; • legitimacy of coexistence	-	• perspective taking; • perspective making	• confrontation; • shared problem space; • hybridization; • crystallization; • continuous joint work at the boundary

Table 1: Overview of the characteristics of the different mechanisms identified in the four DHIS2 customization projects

Furthermore, being boundary spanners means being capable of reshaping the local practices into the generic software tool. In response to our second research question, we analyzed the extensibility of DHIS2 in the four countries through four dialogical boundary crossing learning by Akkerman and Bakker (2011) known as (i) identification, which is about coming to know what the diverse practices are about in relation to one another; (ii) coordination, which is about creating cooperative and *routinized* exchanges between practices; (iii) reflection, which is about expanding one's perspectives on the practices; and, (iv) transformation, which is about collaboration and co-development of (new) practices.

Table 1, presents the summary of the analysis of our findings regarded to the interplay between the mechanisms and the four customization projects. Lessons from this analysis present the opportunities and tensions experienced in the projects (e.g., documents failing to help the customizers in daily activities; customizers failing to get proper support), as related to boundary spanners and boundary objects, are due to several factors that are intertwined between the mechanisms. For instance, a) we have observed that countries part of HISP network did not face challenges that other did, i.e., the network helped them to share resources, address complexities (Williams 2002) on their customization activities; b) the information intermediaries or boundary spanners while helping to shape and facilitate the work within the network, they allow information symmetry, foster cooperation and exchange, and reduce communication costs and uncertainty. The possibility of having individuals that are part of the global network working with local staff allows the production of capacity in exceptional way, consequently, creating room for local staff to increasingly feel the ownership of the applications; c) countries not taking part of the networks addressed customization tensions through training workshops (e.g. regional trainings allowed OgIS customizers to enhance their skills), which is addressed by the process of *continuous joint work at the boundary*. The process of reflection (perspective making and perspective taking) taking place either during the work at the customizers working place or during the workshop trainings also increases the ownership of the application. Thus, it appears that coordination mechanism happening through processes of *routinization* (e.g. institutionalization of annual regional workshops), the existence of *communication mechanisms* (e.g., via HISP NoA customizers are shared by different countries) and the *permeability of boundary* (e.g., artefacts capturing application functionality), is very important in order for FLOSS to be extensible. This is also strengthened by considering the processes of *othering*, *coexistence*, *confrontation*, *hybridization* and

crystallization between the artefacts, and practices of boundary spanners; and conversely, d) given the existence of facts that cannot be avoided during customization (e.g., health statistician having to leave the customization to attend meetings or to perform supervisions); we cannot expect to have local staff only focused on customization. Thus, recognition to this factor goes through, for instance, *accepting or legitimating coexistence* of boundary crossers activities.

Addressing the above tensions involves taking into account the factors in comprehensive manner. Connection and collaboration themselves may be beneficial to ease the above tensions but they do not guarantee that customization process is performed in a productive way(Engestrom and Kerosuo 2007), i.e., networks are not enough, customization need objects. Thus, for objects to acquire a local usefulness, boundary spanners must use and make sense of them in the context of each field (Levina and Vaast 2005). In this regard, apart from permeability and translation effort features, boundary objects containing crystallized practices are required (e.g., manuals containing 'proper' description of the feature).

Thus, to extend the networks of action approach to local customizers' everyday practices, toward competency developed during customization, our focus on the learning mechanisms provide a solid ground for studying how competence is developed, and how will these affect local level customizations. Since the extent of control of FLOSS provided to local context users can be limited, or difficult to understand and implement, by deepening and extending our understanding on the learning choices that customizers face through the dialogical mechanisms, organizational learning can be improved.

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IV

The Influence of Community Structures in the Development of Software Customization Capacity

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Abstract

Although some traditional values of communities have been overshadowed by considerable adoption of information technology, communities remain critical to capacity development. It is therefore unsurprising that, although new technological innovations such as social media in part weaken communities, they are increasingly being used to enhance the sense of community. Drawing on the notions of *community-of-practice* and *cluster*, the paper discusses the influence of community structures in the adoption of open-source software, especially with regard to the building of software customization capacity. The concepts *improvisation* and *bricolage* are also used to explain emergent actions adopted to counter customization-related disturbances.

1. Introduction

Free/Libre Open-Source Software (FLOSS) applications are receiving much attention of governments and managers, especially in developing countries. Leading reasons for this interest include the free acquisition costs (Pozzebon & Pinsonneault, 2005), the build-in knowledge and organizational practices, and the opportunity of accessing a larger community of stakeholders (Michaud, 1999; Randell, 2003).

The adoption of FLOSS in organizations, typically takes place through a process of software customization (Dittrich, Vaucouleur, & Giff, 2009; Draxler & Stevens, 2011) which refers broadly to the activity of modifying software systems to better suit the needs of particular task in a local context. Customization can also be considered as a situated activity (Suchman, 2007) or practice (Nicolini, 2012) where people sharing aims (a community) collaborate in adjusting software tools to fit specific user needs and demands. This work, usually, involve the understanding of business processes - how activities occur (e.g., the sequence of tasks, the decision-making and communication system, and the difficulties encountered) and the software contents - what is actually changed (e.g., data, control or interface).

In the view of some scholars, this activity is capable of being planned and managed. The underlying reason for such assumption is that work activities can be organised according to their division of labour, hierarchy of actions and people responsible for the actions (Hayes, 2000). For instance, with regard to the people working as intermediaries, it is assumed that they have the domain-relevant skills (e.g., knowledge that can be used to perform tasks), and the relevant background information (e.g., a good comprehension of the environment in which the technology will be implemented) necessary to carry out tasks.

However, several other Information System (IS) scholars have recognised that software customization is not that straight forward work activity. Suchman (2007), Ciborra (2002) and Gasser (1986), for instance, consider work activity difficult of being fully planned and controlled. This assertion support the discussion about failures in implementing information systems in the contexts of developing countries posed by researchers such as Richard Heeks (2006) and Sahay and Walsham (2006). Because of that, work-around approaches of *bricolage* (Teoh, Wickramsinghe, & Pan, 2012) and *improvisation* (Vera & Rodriguez-Lopez,

2007) have been suggested as strategies to deal with the unexpected problems. While *bricolage* is defined as an approach where people make do with resources at hand (Ciborra, 2002; Ferneley & Bell, 2006; Lanzara, 1999); *improvisation* describes the process of exploring and use of both prior experience and resources at hand (Tan & Hallo, 2008). Differently from bricolage, improvisation is adopted when there is a possibility of seeking for resources.

Although the use of the two work-around approaches helps in understanding the nature of actions, during software customization there are actions which cannot be explained by them. For example, is it possible to understand how skills, practices, experiences and knowledge is shared between two community members (one with and another without) during customization activity using these two concepts?

This paper analyses the nature of actions leading to knowledge sharing/capacity-building in the adoption of FLOSS; and argues that while FLOSS' potentials have been recognized, their adoption is unlikely to be successful unless there are networks that provide a platform for customizers, users and developers to collaborate. The notion of community is adopted to conceptualize the environment used to share knowledge during the customization of FLOSS (Dahlander & Magnusson, 2008; Lakhani & von Hippel, 2003).

Within community informatics literature, this notion is used to refer to social organizations or institutions that interact regularly. Community is also used to explore groups of people that come together in search of common aims or shared practices (see, e.g., Gurstein (2007), Loader and Keeble (2004), Simpson (2005), Stoecker (2005)). Hence, since people work together to solve problems (Wilkinson, 1989), it is argued that communities are vital social entities with interactions being their key defining elements.

Furthermore, with the aim of assessing the influence of such communities in the development of customization capacity, the study examines how organizations make use of communities to elevate the skills of their personnel. Of this analysis it appears that, in addition to the challenges faced by local context people during customization of FLOSS applications, problems exist in the communities and are primarily related to the exercising of intermediation role. To contribute to this, the paper presents the strategies adopted by customizers to access expertise from beyond their boundaries. In the body of this, learning scaffolding strategies of network and partnerships through *community-of-practice* and *cluster* are used to explain the process of transferring experiences, practices and skills from one team member to another.

The paper proceeds as follows: section 2 describes the theoretical foundation which serves as the basis for the analysis of the findings. Within this section, overview discussion of the notions of improvisation, bricolage, community-of-practice and cluster is presented. Section 3 presents the research approach, empirical setting as well as the data collection and analysis mechanisms. Section 4 explores empirically the activity of customization and its related actions. The paper ends with discussion and conclusion in sections 5 and 6 respectively. Here the questions of the study are evaluated through the analysis of the findings and their relation to the theoretical concepts.

2. Theoretical perspective: software customization

While a wide variety of FLOSS projects such as DHIS (District Health Information Software), OpenMRS (Open Medical Record System), HRIS (Human Resource Information System) and OpenLMIS (Open-source Logistics Management Information Systems) have been adopted in various spheres of society with emphasis on healthcare management; customization has

been one of the processes through which organisations benefits from them (Kimaro & Titlestad, 2008; Saugene & Sahay, 2011; Sievånen, 2002).

Software customization refers broadly to the activity of modifying software systems to better suit the needs of particular task in a local context. Among other actions, the activity involves capturing requirements studying the content of black-box software systems and performing adaption of the technology to meet the needs and demands of the users. As a middle-level activity, which is activated to fit Generic Software System (GSS) into local contexts (Daniels, Edwards, Engeström, Gallagher, & Ludvigsen, 2010), software customization requires dealing with unfamiliar threats. In order to deal with these threats, organizations require both work-around and capacity-building approaches.

2.1. The role of improvisation and bricolage

Software customization, as defined earlier, can be regarded as a mechanism used to reduce the design-actuality gaps in information systems adoption (R. Heeks, 2002; Lungo, 2008). Despite its importance, carrying out software customization has been problematic. Difficulties are due to intrinsic as well as extrinsic challenges.

Intrinsic challenges refer broadly to barriers coming from inside the organisation. They range from human resource skills and capacity up to coordination and leadership issues. Sahay and Walsham (2006), for instance, stressed that due to troubles such as lack of human resource capacity and weak governance, health information system implementation in India was problematic. Moreover, Richard Heeks (2006) relate the failure of technology adoption, especially in developing countries, with the gap between the technology and the organization processes, lack of coordination and leadership, lack of skills within the organization, among others. Conversely, extrinsic challenges refer to barriers caused by factors beyond the reach of the user organizations. In software application that crosscut several application domains like DHIS, an extrinsic challenge is associated, for instance, to difficulties in getting spatial data, getting access to system documentation or development roadmap. With regard to this, Saugene, Juvane, and Ernesto (2012) argues that, the fact that activities are articulated by different institutions and in isolated manner, pose challenges to the accessibility and sharing of its results. Unpacking these barriers is a matter of knowing beforehand the key aspects that makes the activity of software customization.

In overall, the activity is composed of practices, objects used in daily routines and the rules guiding the execution of activities. Together these aspects contribute to the development of knowledge about the activity. Several approaches have been used by IS scholars to theorize this. Among them appear the strategies of *improvisation* and *bricolage.* These approaches are typically used to investigate how local people work-around threats during customization. More specifically, *improvisation* which has been used in the domains of organizational learning (e.g., Miner, Bassoff, and Moorman (2001)), technology implementation (e.g., Rolland and Monteiro (2002)) and new product development (e.g., Magni, Proserpio, Hoegl, and Provera (2009)), is devoted to understand emergent behaviours during execution of activities or to the making of effectual responses during catastrophes (Holloway, Green, & Brady, 2013). Several definitions have emerged from these domains, but all converge in viewing *improvisation* as a process that assumes changes as unpredictable and evolving out of situated experiences. The process focuses essentially on the temporal sequence of planning and acting (Ralph, 2013), whereby time to wait for optimal resources and optimize the activity is abundant (Pina e Cunha, Vieira da Cunha, & Kamoche, 1999; Tan & Hallo, 2008; Teoh et al., 2012).

However, Baker, Miner, and Eesley (2003) have noted that when creation and execution occur at the same time, there is little ability to plan ahead to seek for resources. In this regard, scholars such as Magni, Provera, and Proserpio (2006) advice for the use of immediately-available resources toward the answer of particular stimuli. The *bricolage* approach has been adopted in the disciplines such as information system development (Johri, 2011; Teoh et al., 2012) and education (Hutchinson, 2011), to understand actions supported by these immediate-available resources. The concept consists of making improvisation work by using ready-at-hand materials Ciborra (2002) or applying a combination of resources at hand to new problems and opportunities (Baker, 2007).

2.2. The capacity-building approaches

The success of a customization activity can be measured through the achievement of end-user needs and demands. This achievement is, however, dependent on the availability of capacity or on the ability of enhancing customizers' capacity. While capacity is the ability of individuals, organisations or systems to perform appropriate functions effectively, efficiently and sustainably, capacity-building is the process by which these individuals, groups, organisations or societies increase their abilities to: (a) perform core functions, solve problems, define and achieve objectives; and (b) understand and deal with their development needs in broad context and in a sustainable manner (UNESCO, 2006).

IS researchers such as R. Heeks (2002) and Sahay and Walsham (2006), while studying implementation of IS in developing countries, have presented several challenges from where capacity and capacity-building take part. Similar challenges were suggested by Rankin, Dahlbäck, and Lundberg (2013) as the factors laying behind decreased improvisation performance by team members. Of these challenges appear ineffective staffing (Bossert, 1990); professionals lacking skills, and domain knowledge (Rankin et al., 2013); poor (technical and physical) infrastructure (Gordon & Hinson, 2007); uncoordinated efforts (Hilderbrand & Grindle, 1996); inadequate resources (Baillie, Bjarnholt, Gruber, & Hughes, 2009); and inappropriate policies and strategies (Shediac-Rizkallah & Bone, 1998; Zelaya-Zamora, Senoo, Suzuki, & Lasmin, 2013).

Traditionally, capacity-building activities were administrated by individuals, institutions and government agencies themselves. Nowadays this is giving way to a model that relies on collaborative arrangements. These arrangements occur when "people from different [backgrounds, institutions or] organizations produce something together through joint effort, resources, and decision making, and share ownership of the final product or service" (Kamensky, Burlin, & Abramson, 2004, pg. 8).

The notion of scaffolding (Granott, 2005) has been applied as a metaphor in many fields, most notably in learning theory (see, e.g., Orlikowski (2005)), to describe this process, especially when learning is mediated by experienced individuals. Scaffolding occurs typically through collaboration (Yelland & Masters, 2007), and its execution benefits from virtual as well as face-to-face mechanisms. *Community-of-practice* and *clusters* are some of the theoretical approaches used to conceptualize this process. These approaches are now briefly discussed.

A community-of-practice perspective

Ensuring technology transfer presents enormous challenges, especially for developing countries, mainly because local countries are expected to handle unforeseen threats. The

ability to deal with these threats, besides organizational partnerships, requires interpersonal networks.

Organizational researchers see these networks of people as mechanisms that help to communicate and disseminate ideas (Briggs & Snyder, 2004). Within these networks, people ask each other who know what, and who has previously provided knowledge that turned to be useful and reliable (Davenport & Prusak, 2000).

Communication within these networks has increased with the advent of the internet. Through virtual forms of interaction it is, nowadays, possible to get ideas disseminated to a wide audience (Kirkman, Cordery, Mathieu, Rosen, & Kukenberger, 2013). For instance, it is through these networks that new technologies often adopted by mentors are passed along to other persons. Briggs and Snyder (2004) call these collaboration spaces communities-of-practice and define them as "social learning systems where practitioners informally connect to solve problems, share ideas, set standards, build tools, and develop relationships with peers and stakeholders" (Briggs & Snyder, 2004, pg. 175).

Key characteristics of community-of-practice (CoP) include a focus on building and sharing knowledge among practitioners, and a reliance on informal channels (Dionnet et al., 2013). An outstanding benefit of these CoPs is the capability to "bridge formal organizational boundaries … [and] … increase the collective knowledge, skills, and professional trust and reciprocity of practitioners who serve in these organizations" (Briggs & Snyder, 2004, pg. 176). Other benefits include form instance relating people, activities, and the world; providing a living repository of ideas, information, best practices, experts and resources (Briggs & Snyder, 2004).

A cluster perspective

The choice of this approach is based on the principle that clusters enable greater agglomeration of larger pools of skilled employees and specialized personnel (Delgado, Porter, & Stern, 2011). It is claimed that individuals build capacity through this proximity or temporary agglomeration of professionals. Thus, capacity-building efforts that benefit from these agglomerations can reduce costs, and enhance knowledge and information transfer especially for people that rely only on informal infrastructures to address their concerns. Even if these clusters are activated for a short period (days or weeks), just being part of helps in eliminating technological as well as domain shadow areas and also helps to build trust (Stonehouse & Snowdon, 2007).

Clusters are defined as geographic concentrations of interconnected institutions, objects, events or occurrences of a particular event (Dai, Sun, & Liu, 2013; Porter, 1998). They can represent geographic proximity in regions, neighbouring countries, and cities within single countries, or based on type of skills shared, e.g. user/domain, customizer/implementer and technology/developer. Each of these clusters thus represents a mix of actors from different sectors wherein the common element between them is related to their overlapping obligations.

Clusters are also considered boundary-spanning laboratories in which people from different system of activity are invited to meet, discuss and work on shared problems (Kerosuo, 2001). Drawing productive advantage from their mutual proximity and connections (Cortright, 2006), participants can learn and adopt common standards (Porter, 1998), define and share common beliefs and attitudes, discuss and develop common agendas (Stonehouse & Snowdon, 2007), and more importantly, diagnose and discuss

common strengths and challenges, and identify realistic ways to shape future directions (Cortright, 2006).

3. Research methodology

This study is part of an on-going research that focuses on understanding the practices employed when customizing generic software systems for healthcare management in developing countries. Specifically, the paper reports on a software customization process performed by OGUMANIHA, a name given to a group of NGOs united for a purpose to improve health and livelihoods of population of Zambézia province in Mozambique (Ogumaniha, 2008).

The research takes the form of in-depth case study and the epistemological stance is interpretive (Walsham, 2006). Using combined methods as a research strategy, the study design brought together data from observations, interviews, conversations, reflections, and documents. An iterative and reflexive analytic process was used (Stake, 1995), weaving together findings from the several sets of data to confirm, augment, and challenge the understanding of the nature of capacity-building actions, practices and approaches. The following subsections describe the combined-methods approach, including the research context and data collection and analysis activities.

3.1. The research context

To understand the nature of actions, practices and approaches leading to the building of FLOSS customization capacity, the OGUMANIHA project was assessed. During this process, special focus was on the process of customization of OpenMRS and DHIS frameworks.

The OGUMANIHA project

OGUMANIHA is a project proposed to improve health and livelihoods of children, women and families by strengthening and integrating efforts toward strong community health and agricultural program in the Province of Zambézia. The project combine efforts from seven non-governmental organisations including World Vision, Adventist Development and Relief Agency, ACDI/VOCA, International Relief and Development, Friends in Global Health (FGH), Centre for Communication Programs of John Hopkins University and Red Cross Mozambique.

All these project members organisations are involved in activities ranging from health (e.g. promoting maternal and child health, increasing nutrition, reducing malaria and HIV/AIDS prevalence), agriculture (e.g. ensuring food security, irrigation systems), water and sanitation (e.g. installing latrines and rehabilitating water sources), microfinance (e.g. teaching farmers better loans, production, income and savings approaches), governance (e.g., approaches for community participation) in the districts of Zambézia province.

The province is located in the central region of Mozambique, with most of its 3.8 million population lacking for social infrastructure, good health and sanitation, food security, and disease control mechanisms (Ogumaniha, 2008). To soften these problems, 92 project related indicators were implemented by OGUMANIHA under the auspices of the Ministries of Health, Agriculture, and Public Works and Housing, and in strong coordination with and leadership from the Provincial Health Directorate, the Provincial Agriculture Directorate and the Provincial Directorate of Public Works and Housing (Ogumaniha, 2008).

The OpenMRS application framework

Open Medical Record System (OpenMRS) is an open-source infrastructure for the creation of medical record systems which is available for public consumption through open-source licensing. The infrastructure provides building blocks from which new implementers can construct health information systems to meet specific needs (Mamlin et al., 2006).

Initially, OpenMRS was built to support HIV/AIDS care in Kenya and Rwanda. Given that programs dealing with HIV/AIDS are simultaneously confronting with malaria, tuberculosis, maternal health, and many other issues, OpenMRS was expanded and transformed into a generic medical record system. Its development has gone through various versions that aimed to solidify the support of the care of patients, gathering observations, encounters, and other data from the healthcare system and rendering those in summaries and reports that would improve the effectiveness of the people using the system.

One powerful aspect of OpenMRS is that of being a framework developed and maintained collaboratively by a large network of developers and coordinated by the Regenstrief Institute and Partners in Health. This collaboration has enabled the development of a core application programming interface (API), a data model, and a framework for a web-based application running on top of the API (Mamlin et al., 2006).

The framework has been used mainly for developing software systems that enable the treatment of HIV/AIDS and Tuberculosis patients' information and its management in developing countries of Africa. Currently OpenMRS has a large community of users residing in countries like Malawi, Kenya, Rwanda, Lesotho, Tanzania, Uganda and South Africa.

The District Health Information System (DHIS) application framework

DHIS is a software application framework that has existed for about seventeen years. Developed by the Health Information Systems Programme (HISP) through an open and globally distributed process, the application has been expanded and improved continuously. HISP is a global south-south-north collaborative network coordinated by the Global Infrastructures Research Group at Department of Informatics of the University of Oslo. The group aims at supporting the improvement of health care systems in the developing countries by increasing the capacity of health care workers to make decisions (Braa & Sahay, 2012).

DHIS is designed to allow the users to design the contents of their health management information system without the need for programming. Over fifteen countries and thousands of healthcare professionals, in Africa and Asia, use DHIS to capture, collate and analyses primary healthcare related information. The software is implemented at the national level in many countries (e.g., in India, Vietnam, Kenya, Sierra Leone, Tanzania and Zanzibar) and adopted by isolated institutions for management of project activities in other countries (e.g., in Mozambique).

The DHIS version analysed in this study, i.e., the second version (DHIS2), is composed of four main modules that are focused on providing generic features for data collection, validation, reporting and analysis, namely: OpenHealthMapper for mapping or spatial data display and management; Aggregate for the management of routine data; Tracker for community data management; and mobiHealth for patient-based data management using mobile device. Data managed by these modules can be extracted from or send to other systems using SDMX-HD standard specification.

3.2. Data collection and analysis

Five main sources of data were used to develop the findings in this paper. The three primary sources were participant observations, interviews and informal talks. Participant observations were conducted during the customization of the DHIS OpenHealthMapper module when the researcher was invited to join the OGUMANIHA customizer team. Observations were also performed during meetings and conversations. Through this, it was possible to strengthen the relationships with the OGUMANIHA customizers.

Interviews and informal talks were conducted with the OGUMANIHA customizers and managers. The interaction with customizers focused on investigating customization practices which included among others understanding the practices and challenges of task execution, knowledge sharing and capacity development. The interactions with managers addressed their role in facilitating capacity-building activities. Interaction with customizers have been done within as well as outside of their environments (e.g., during the workshop trainings). Semi-structured technique was applied whereby part of conversation was done face-to-face and other was performed using Skype and e-mails.

Document examination and reflexive discussions were secondary sources. Documents provided during site visits and via e-mail were reviewed to supplement the understanding of the OGUMANIHA initiatives and of how the project was working. Additionally, during the entire data collection process, continuous contact and reflexive discussions were maintained. This facilitated the examination and expansion of the ideas coming from the observations, conversations and documents. Thorough reflexive discussions deepened the understanding of the customization practices and approaches and helped in developing the theoretical lens used to guide the analysis and interpretation of findings.

The data analysis mechanism applied in the study follows interpretive philosophy and its deductive process involved data reduction, data display and conclusion and verification (Miles & Huberman, 1994). During the data reduction, intra-case analysis technique was adopted. This allowed performing data memoing (Birks, Chapman, & Francis, 2008), data organization, compressing and display into meaningful analytical categories. These categories were identified based on the review of the literature and early findings of the study. Throughout the analysis, findings from the several sources were cross-walked against each other to refine the understandings. The intra-case analysis technique allowed the examination of data sources, the extraction of relevant information and the drawing of conclusions.

4. Analysis and empirical insights

The frameworks, adopted to build the OGUMANIHA Information System (OgIS) and the FGH Electronic Medical Record System (zEMRS), were imported from contexts different from where they were adopted. Because of this, customization activity had to be performed to fit the end-user needs and demands into the software frameworks. The next sections describe this process with special focus on actions, interactions and resources.

4.1. Characteristics of the software systems

The Electronic Medical Record System

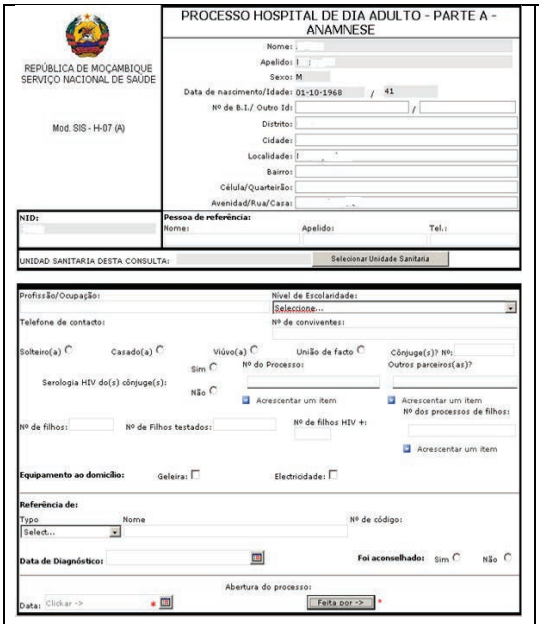
FGH is a non-profit organization assisting the Ministry of Health of Mozambique to scale-up the provision of HIV/AIDS care and treatment services in rural districts in Zambézia Province.

As part of its holistic approach, the organization decided to develop an electronic medical record system, the zEMRS, for the management of HIV/AIDS patients receiving treatment in the clinics. The approach includes also addressing human resource as well as infrastructure constraints.

The development of zEMRS was entrusted to FGH internal IT team composed of five professionals - two software programmers, one analyst, one communication infrastructure officer and one monitoring and evaluation manager. While using the platform provided by the version 1.3.2 of OpenMRS, the team was responsible for responding to the needs and demands of the users. This also included developing new forms and reports, developing new modules, supporting the needs of the Monitoring and Evaluation (M&E) team, and integrating facility and district level health information systems and applications as well as ensuring their security and integrity.

Two patient related processes were implemented within zEMRS, namely patient management which beyond keeping track of patient data included implementing the workflow of the patient receiving 'TARV treatment' (see screenshot of this process within zEMRS in Figure 1a); and patient treatment plans management which include mechanisms of handling clinical processes of patients, and medicines delivered to patients if they started with medication (see screenshot of this process within zEMRS in Figure 1b).

After its development, zEMRS was first piloted in one district and later scale-up to other districts as a client-server application. In each site the system was operating within a network composed of an Inveneo Hub Server running Linux Ubuntu distribution and two or three computers for data management. Network points were also available for medical doctors to connect their computer and get access to their patients' data when needed.



a)Patient registration form b)Patient treatment data

Figure 1: Screenshot of the zEMRS application

The OGUMANIHA Information System

To help the management of the information collected by the partners of OGUMANIHA project, decision was made to develop the OgIS software application. Its development was performed on top of DHIS2 framework and the general setup team includes two groups. First, the end-user team which was composed of individuals representing each project partner, including field officers managing data collection at community and health facility levels, and their representatives at the M&E board. These individuals were responsible for providing insights about end-users' business process and ensuring high quality of data. The second group was made up of senior professionals hired by FGH to manage the M&E unit and M&E officers specialized in information systems.

The technical oversight of OgIS development was left to the second group, i.e., the IT team responsible for developing OgIS was the same that developed zEMRS. However, differently from zEMRS, OgIS was deployed on a web-based architecture and made available to fifteen districts. Due to internet connectivity problems it was not possible the districts to have access to the province server residing in the FGH office. Thus, standalone databases were installed in the districts. Each month data was exported and backup files generated and sent to the province level. While export files were used to populate the OgIS province database server, back-up files were kept in a safe place for future use (e.g., recover the databases if any tragedy happens to the computer).

In overall, the application was available to district data managers, regional supervisors, data entry officials, project coordinators at district, region and province levels, monitoring and evaluation managers and other project stakeholders. Data gathered from communities and health facilities using paper forms were sent to the data managers at district level which had the responsibility of entering into the OgIS database.

4.2. The software customization process

Software customization activities do not have an end as such. Rather, they support other activities such as software development, decision making, or software use. To describe the process of software customization two sections are roughly presented. The first section focuses on the actions and interactions, and the second section deals with infrastructure and technical resources used to access and share issues and concerns with the users, customizers and developers.

Actions and interactions

As previously referred both zEMRS and OgIS were developed on top of generic frameworks. As opposed to custom systems, designed for a specific user or group of users (Bansler & Havn, 1994), there frameworks are intended for general use. Their attractiveness has been discussed by many scholars (see e.g., von Krogh and Spaeth (2007) and Lungo (2008) who highlighted these advantages in the context of FLOSS). Clearly, there are many more benefits, but overall benefits include the possibility of users to utilise information, knowledge and best practices embedded within the tools as a key resource for their business.

Among others, tasks performed during the customization process included collecting end-user requirements; inscribing the requirements into the generic tools; and adjusting misfits. To capture requirements, customizers contacted end-users, attended meetings, workshops and conversations as well as assessed documentations of the project (manuals and reports).

Requirements were also obtained through analysis of information contained and/or generated by software tools used by project partners. One of these tools was the monitoring and evaluation tool used by FGH to manage HIV/AIDS data which was developed on top of OpenMRS, the zEMRS.

After developing clear understanding of end-user needs and demands, the generic frameworks were studied and changes or adaptations performed. Activities such as creation and standardization of data elements, data sets, indicators, definition of organization unit structure and hierarchy, and design of data entry forms and reports were executed.

In some situations the (adaptation) tasks required adjustments. Two categories of adjustments were verified. The first included adjustments being performed on response to local context problems. The second category refers to adjustments being performed in response to problems with the software tool.

With regard to the first category it was observed that OgIS partners were collecting similar data for same period and period type. However, since organisational units could not have duplicated names inside DHIS2 database, customizers realised that they could not have OgIS as close to the users' business structure. In addressing this, customizers decided to replace the data management levels (treated in DHIS2 as organization unit) with data collection partners. In a situation where the duplication of an organizational unit name was needed, specific characters (such as hyphen, colon or dot) were used to differentiate one from other.

Another local context problem was observed with the translation files. As the version of DHIS2 framework used to develop OgIS was in English, customizers used the instructions contained at the DHIS2 webpage to translate some of its strings to Portuguese. Thus, because the translated files were not delivered to the developers, whenever a new release was made available customizers had to perform a cumbersome manual work. This work involved making a backup of the files containing translated strings in the old version and, performing a manually copy/replace of the backup files after the upgrading of the system.

Problems related to the second category included the identification of software metadata in the user interface, i.e., software metadata including indicator type and indicator name, and data element type and data element name were displayed in the user interface through their short name. This problem was observed during the customization of the data visualization modules, the DHIS2 OpenHealthMapper. When the problem was presented to the DHIS2 community, customizers were told to first upgrade the version (from 2.0.4. to 2.2). However, since one of the intensively used features, the excel template reporting, was removed from the version 2.2, customizers entered into a dilemma. To overcome this, customizers decided to have two parallel systems (versions of OgIS application), one running each version, i.e., OgIS instance based on DHIS version 2.0.4 containing excel template feature used by regular users and the OgIS instance based on DHIS version 2.2 for managers.

With regard to zEMRS, because of the *key system* used by OpenMRS framework it was difficult to create an embedded export/import feature. Customizers developed an external .Net application to perform such tasks. The application was also used to collect data from other Microsoft Access databases. Since OpenMRS *key system* was changed in the new releases, the application had to be amended accordingly. Additionally, since OpenMRS report module was very weak, customizers included within the .Net application a reporting module. However, this module was later replaced by a Java version. When customizers where asked the reason of this replacement, they said that "*.Net was used in the beginning*

because it was urgent…but [at that moment] since things are calm [they were] developing a new version, this time using Java."

Similarly, belonging to this category are the problems of linking, integrating or synchronizing zEMRS with OgIS. Behind this was the lack of skills. Even having access to OpenMRS and DHIS2 source-code, customizers were not able to perform these tasks by themselves. As result data was extracted from the zEMRS database and entered manually into the OgIS.

Adjustments were also performed when the applications were in use. For instance, since the DHIS2 feature that permits the internationalization of database content (e.g. data elements and indicator) was used to provide the database content in two languages (Portuguese and English), the team identified during the use of the application that "*the application was not fixing the database language in use. Whenever the computer was restarted the language was set back to English. So, if the user exports data without setting the language to Portuguese, for instance, when data is afterwards imported to the province database, the system displays new data elements. But those are not new instead instances (language versions) of the same data element.*"

Human and technical supporting infrastructures

When working with GSS, one of the basic needs is the access to infrastructures that would serve as a support during the customization activity. Within this study such infrastructure was made of objects (e.g. documents) and people (e.g. human capital from both local institutions and the software vendors).

During the development of zEMRS, OpenMRS online universe composed of webpages, manuals, mailing list, and wikis, were used as source of clarification of doubts. Additionally, e-mails and discussion forums were used by the customizers to get in touch with developers and other customizers and express ideas and concerns. E-mail messages were mostly used to seek advice on customization problems, to share information and also as virtual discussion forum with people that customizers already knew socially. As consequence, several tasks were performed after accessing this online universe. For instance, by accessing DHIS2 webpage, OgIS customizers were able to translate the application interface from English to Portuguese and database content from Portuguese to English.

As opposed to passively relying on the information provided by developers in the online universes, customization work was also supported by human sources. Yet, although cooperation was encouraged by the vendors as a mean of addressing challenges in the initial stages of customization, the first source of knowledge that customizers relied on in the beginning of the projects was their friends and colleagues. For instance, since some of customizers' friends had been involved in customization of generic application (some with DHIS2 and others with OpenMRS) they were a very important source to seek information. However, in situations where friends could help they contacted the (DHIS and OpenMRS) communities. This was observed throughout the entire project. Managers of the different project partners and the monitoring and evaluation experts were also consulted by customizers to enrich their knowledge especially with regard to explaining how specific tasks (business processes) were performed by the end-users.

In fact, most noticeable knowledge gained by customizers was observed after attending workshops and participating in the evolution of the generic tools. Customizers attended one DHIS East-Africa workshop training held in Tanzania and several OpenMRS workshop

trainings held in South Africa. Figure 2 illustrate the regions where the workshop trainings were performed. The two ellipses, for which the arrow is directed, represent the workshop trainings attended by customizers of the applications considered in this study. Moreover, since workshop participants of each country were given the opportunity of working on their own databases, the practical sessions were used to solve country implementation problems.

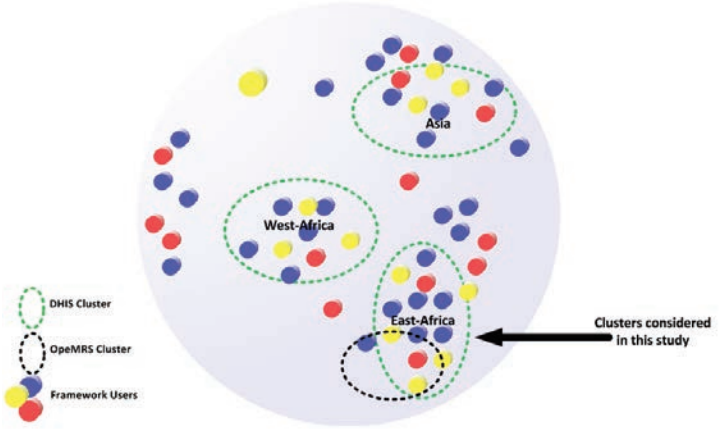


Figure 2: Sample of DHIS and OpenMRS workshop trainings (clusters)

So far the overall achievement of the workshop training programmes indicates that they provide a great opportunity for customizers of a wide variety of countries (including implementers, managers and users) to come together to learn, debate and exchange information and ideas related to HMIS. For instance, with the knowledge received from these workshops, customizers were able to perform several tasks including (a) integrating the excel module into the new versions of the DHIS2, thereby enabling the same version of OgIS to be used both by end-users and by managers; (b) providing DHIS2 language translation files to the community; (c) participating in the translation of the strings of entire application framework.

Both DHIS2 and OpenMRS communities used these workshop trainings to understand and compare implementation performances between countries. Developers also used these workshops to present in details each of the improvements made in the software and also receive feedback from the participants. Part of feedback was registered as issues to be considered in the future releases.

Moreover, as OpenHealthMapper module was adapted with help from global customizers, knowledge gained during its customization was used by local team to develop other tools. For instance, customizers developed an application that enabled mobile devices to collect the spatial location where health related activities were performed.

Table 1 below shows an overview of the infrastructure used to enhance knowledge and skills of the customizers. However, access to objects and contact with other persons did not always provide the expected results. For instance, the fact that the documents were presented and discussion held in English was seen as a barrier. Regarding the use of the online resources, customizers claimed that they visited the DHIS2 online universe regularly, and asserted that *"during the process in situation where they could not get local support they*

looked for the documentation; but, sometimes, the documentation was outdated and in some situations lacked details".

Supporting infrastructure		***Use during the customization process***
People	OGUMANIHA project partners	Seek for clarification of requirements and the project business processes; and helping in testing the application (performance indicators that was agreed upon with the provincial government)
	Project members	Share concerns about the database system, supporting capacity building activities (user as well as customizers).
	Fellow customizers	Seek advice about issues with the database and problems faced during the customization process; and seek for help in the customization of some features.
	Framework developers	Seek advice about issues with the database and problems faced during the customization process
Tools	Virtual communications (e-mail, mailing lists)	Seek and share information (e.g., problems with database, sharing database export files, project documents and plans), spreading problems with external people, sharing the challenges with other customizers, discussing database related issues.
	Websites	Share information (e.g., database release roadmap, installation instructions, user and implementer manuals, presentations, war files of new releases, source-code, sample data) and additional tools (e.g. for fetching data and reporting).
	Archives (paper and digital)	Spread within the team project related information such as plans, project description and requirements

Table 1: Supporting infrastructures used in the customization projects

5. Discussion

Getting access to technology is much easier today than ever. In the past, problems in accessing technology especially in developing countries were due to high acquisition costs, lack of human resource capacity, lack of access to software source-code, and so on. By overcoming some of these problems, FLOSS presents itself as an enabler for the development of a critical mass of software technology adopters.

However, after having full access to the technology, adopters are not expected to perform work-arounds, but to adapt and align FLOSS solutions with local business requirements. Previous studies show that this process is not that simple, especially in developing countries due to lack of technical capacity (e.g., Sahay and Walsham (2006) and Saugene and Sahay (2011)). With this in mind, it is imperative to understand how customizations work gets done and what practices are lived in the everyday life at the workplace.

This study has empirically illustrated that for several reasons, such as time pressure and shortage of skills, the activity of customizing software systems cannot be entirely planned

and controlled. This corroborates with Suchman (2007) 'plans and situated actions' argument. Both OgIS and zEMRS were 'wrapped' into a myriad of disturbances. Most of these disturbances led to work-arounds. While some actions were planned others were unplanned.

Planned actions included adapting the organizational levels of the DHIS2 framework to match the partners' flow of data, designing the data entry screens and reports, to look like the paper-based forms used by the end-users, and resort to external tools such as excel if the data entry forms and reports coming with the framework did not allow future editing. Unplanned actions, on the other hand, consisted of handling disturbances such as those that rose due to difficulties in getting support to address problems with the framework version adopted to build the OpenHealthMapper module.

As described in the findings, while some of these tasks did not require support from the software community members, other required their strong participation. These issues are now discussed.

5.1. Addressing emergent problems during software customization

Several studies underscore how technology adoption work is context-centric; also referred as a situated activity (see, e.g., Orlikowski (2002), Bada (2002), Suchman (2007)). The analysis of how local customizers coped with the emergent problems within these situated contexts led to the study of work-around strategies. Key in this study was the consideration of the processes of *bricolage* and *improvisation*. Among the customizers' actions described in the findings, it is possible to identify some whose execution had been possible thanks to the use of materials at hand of the customizers and other performed only after receiving support.

Actions executed with resources readily at hand were observed, for instance, when customizers decided to deploy two versions of the same application. This happened when they found themselves in dilemma on whether to upgrade to a new DHIS version, to have the OpenHealthMapper and loose the excel module, or keep the current version thereby losing the possibility of benefiting from the potentialities of the OpenHealthMapper. Other situations included addressing the organizational unit problem by considering data collection partners as organization units; entering data from OpenMRS manually into the DHIS database; and instructing users to always certify the database language in use before exporting data.

Furthermore, it could be tempting to accredit customizers with being able to work-around the problems only through skills or materials at hand. Several work-arounds observed in this study involved resource-seeking. For instance, whilst the OpenHealthMapper module was customized with the support of global customizers, the integration of excel module in each new OgIS version was only possible after customizers had enhanced their skills. zEMRS customizers benefited from support of developers and users to understand the OpenMRS data model. This support was also extended to the reporting modules developed on top of the OpenMRS framework.

The use of *bricolage* and *improvisation* strategies as response to unexpected problems has been used by Tan and Hallo (2008), Saugene and Sahay (2011), Teoh et al. (2012), Ralph (2013), when they elaborate on how work-arounds are a result of the complexity of customization and implementation activities. However, since *bricolage* consists of using the available resources to fully respond to emerging problems, customizers are expected to be

able to do so. Moving beyond this, and contrary to *bricolage*, improvisation requires that customizers have time to search for required resources.

It was also observed that organizations are barely prepared for the emergent activities and very often the time required to adjust is very limited. Because of that products of work-arounds are usually replaced by others after some time of use. For instance, two parallel versions of the OgIS application that were released and used for a while by OGUMANIHA users were later replaced by a common version for all OgIS stakeholders. Farther, zEMRS .Net reporting module was also replaced with a Java version. Both cases occurred because customization time was tight with no slack, which triggered *bricolage* related approaches to problem solving.

In line with this argument it is important to draw attention to the approaches used to enhance customizers' capacity so that they were able to *bricolage*, improvise and replace the products of their previous work-arounds.

5.2. The power of communities

Historically, the issue of lack of qualified human resources has been attributed to as one of the main factors leading to failures in technology adoption, especially in developing countries. Several studies have illustrated the negative results of personnel not being able to perform customizations or to maintain their implemented IT systems.

To soften such a problem a couple of approaches have been developed. Crisp, Swerissen, and Duckett (2000), for instance, proposed four approaches, namely: bottom-up, top-down, network or community, and partnership. The first two approaches concentrate on providing skills to staff through capacity-building activities administrated by individuals, institutions and government agencies themselves. Conversely, the last two give way to capacity-building models that rely on collaborative arrangements.

Despite the importance of the first two, the development of capacity in the internet era relies extensively on communities. For instance, as argued in section 2, generic software systems require skilled customizers. Since most of these systems suffer constant changes, customizers rely on communities. These communities are expected to provide members with new knowledge and skills. Examples of the use of community related approaches in building customizers capacity are also shown in the works of scholars like Braa, Monteiro, and Sahay (2004) and Sheikh and Braa (2011).

Figure 3 illustrates the different communities involved in the customization of generic software systems.

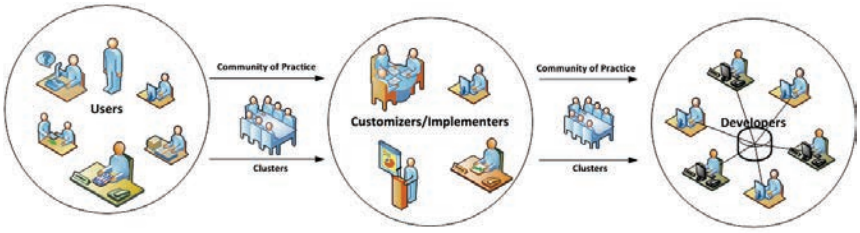


Figure 3: Influence of networks on building stakeholder identity

To explain how capacity is developed during this process two principles are highlighted. Both principles regard successful capacity development as influenced by strengthened

networks. The principles also explain how, through capacity-building activities, individuals belonging to particular communities move to others.

The first principle relates to capacity development as influenced by informal networks composed of people with commonalities usually called CoP. The findings from this study have illustrated examples showing that local customizers acquired new skills through informal channels. Examples of channels used within these virtual communities include e-mail, mailing lists, websites and digital documents. In addition, even though OGUMANIHA customizers had access to the developers' virtual repositories, they mostly contacted people they knew, especially at the beginning of the project.

The informal nature of networks upon which this principle is based, reduces capacity development to a learning process performed using online communication as well as accessing electronic materials. But, findings reveal challenges linked to this approach, which among others include the fear of not being understood because of language barriers.

As is evident in the literature review informal networks alone may not help to address all the capacity problems. This leads to the second principle. From van Geenhuizen and Reyes-Gonzalez (2007) viewpoint, organizations collaborate better when they are clustered. Thus, since the study findings have illustrated the building of capacity as result of face-to-face conversation during training workshops, clusters are regarded as mechanisms that may help to build organizational capacity. Because clusters intended not only to create competencies, but turning the participants into 'reflective thinkers', they were used as organizing framework whereby policymakers and practitioners shared experiences to develop joint strategies.

The DHIS2 and OpenMRS clusters analysed in this study offered opportunities for members of the three communities in Figure 3 to: (i) develop new ways of thinking about their work and organization of efforts in their own countries; (ii) learn from each other, for example, on how to better align their capacity development efforts, where to get support (defining the role of each of the partners) or how to organize their implementation process; (iii) participate in a forum where constructive dialog is developed as a means to identify common problems and opportunities, and learn from each other; and (iv) rapidly diffuse best practices and provide on-going, visible performance comparisons and strong incentives to improve country specific HMIS.

Reflections along the above principles confirm capacity-building as an enormous undertaking task, but one, which is vital if the benefits of FLOSS are to be achieved. Overlapping within the principles is the building of capacity within networks of people in which the advantages over isolated individuals or collaborative approaches in the emphasis placed on creation of capacity via clusters. Through this it is possible to (a) move beyond the sharing of information to the aggregation and creation of new knowledge; (b) identify and implement strategies to engage customizers more directly into the discussions around software issues; and (c) strengthen the capacity of members in the network.

With regard to (c) the following section takes a customizers' perspective and discusses in detail how the approach influences the strengthening of capacity.

5.3. Stimulating customizers involvement into community tasks

In adopting generic FLOSS, local users/implementers are expected to perform customization tasks. However, just because they perform such tasks, does not mean they are always efficient. As presented in the findings, some problems faced by customizers were due to

their lack of skills and knowledge. In line with arguments from scholars supporting segmentation of the user-base toward the design of generic software systems such as Pollock, Williams, and D'Adderio (2007), community networks especially those organized in clusters are seen to contribute strongly in the building of customizer identity within the network.

From the study it was observed that after attending workshop trainings and having face-to-face conversations with developers and customizer communities, the work of OGUMANIHA's team was much visible to the global arena. Likewise, participation in the workshop trainings appeared to be a rewarding experience for the OGUMANIHA team. Through this, they gained motivation and shared their work with the rest of the community as well as participated in community activities. Examples of such activities included the sharing of translation files as well as participation in the translation of other software modules.

This positive attitude might have stimulated developers to give better, faster or more elaborated responses. For instance, through the use of advice received from developers and customizers, the team succeeded with the tasks that were still causing 'headaches'. One of those problems, consuming users' time and resources, was the existence of two parallel versions of the OgIS application that were run for a couple of weeks. Just after returning from the workshop training and having face-to-face meetings with developers the parallel instances were integrated into one.

It is, therefore, important to note that before the trainings and meetings with other customizers' in-person it was not possible to perform such activities. Of course it might have been possible if the customizers could insist in posting the questions in the online discussion forms. However, since they were not fluent in the language used in the discussions forums they feared not to be understood. Instead, they relied on sources they could physical contact.

When member contribution is valued by the global community, its membership is acknowledged (Gilpin & Miller, 2013; Hou, 2013; Johnson, 2012). From the findings it was observed that successful interaction between developers and customizers resulted in the acknowledgment of local customizers work. The acknowledgement of their competence added confidence to local customizers.

As illustrated in Figure 3, software customization players benefit from communities (whether on a temporary or permanent basis, or virtual and face-to-face). Through these communities developers communicate and come to know more the needs and worries of the software stakeholders, while those stakeholders earn knowledge about the software capabilities and their providers. In addition, it is through these communities that players strengthen their roles/identities. Some even start playing other related roles. From the findings it was observed that, through skills obtained in the workshop trainings, customizers started to perform tasks that previously were not within their reach. For instance, as consequence of performing by themselves tasks such as integration of the excel module into the DHIS framework, OGUMANIHA customizers moved from being mere customizers to become contributors/developers. Similar developments could be observed for end-users who now actively participate in community activities.

6. Conclusion

This paper attempted to discuss the influence of communities, as people coming together in search of their common aims or shared practices, in the adoption of FLOSS applications,

especially as regards the issue of capacity-building. This was done by highlighting the role of networks, and how the informal and formal networks when combined influence the development of capacity.

Considering skills and knowledge as important resources for effective adoption of IT systems, arguments emerging from this study were threefold: first, commitment from individual staff alone is not sufficient to successfully address customization problems; there is therefore a need of infrastructures to facilitate knowledge acquisition. With regard to this, the study illustrated that skills and time influence the decision to either seek for help (*improvise*) or *bricolage,* i.e., when there is need to perform work-arounds but customizers are not able to *bricolage,* 'enough' time is required for support-seeking to happen. Thus, since knowledge in generic software system is obtained from a wide range of individuals with diverse backgrounds and levels of experience, participation of developers, customizers and users is required.

Second, sustainability with regard to generic software systems customization is dependent on active participation in knowledge communities. Studies on FLOSS gave priority to informal networks (e.g., through virtual channels) and left formal networks at the periphery. With regard to this it is argued that the need of building capacity goes beyond informal networks. For instance, since participation in communities presents both social (e.g., language barriers) and technical (e.g., shortage of skills) challenges to members, if FLOSS is to benefit its adopters, organizations cannot solely depend on capacity-building models, such as CoP, that rely predominantly on informal and virtual networks. There is a need of shifting capacity-building from being synonymous to information sharing, to become an experience gained over time through commitment with clusters.

Third, it is not secret that active participation in community affects learning, however it is important to highlight that communities help individuals to strengthen their identities. Although the cluster-based approach requires some formalism, it enables skill shortage to be tackled in a more formal and collaborative manner. Additionally, the approach enables customizers to move from, for instance, being just passive adopters and users to becoming customizers or from customizers to active contributors/developers, i.e., the approach helps software stakeholders to develop their identities.

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V

LEVERAGING FROM CUSTOMIZATION TO INFORM GENERIC SOFTWARE SYSTEMS DEVELOPMENT: DHIS TRACKER AND ITS INTRODUCTION IN HEALTHCARE

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Abstract: A growing tendency is being observed in developing countries toward adoption of generic software systems. One proposition driving this shift is the possibility of adapting their embedded and 'mature' tools, practices and procedures to address local needs. Since these systems are developed based on 'generic' principles, their institutionalization differs considerably from traditional models. Major difference consists on the fact that user organizations are left with the full responsibility for customizing the tools. However, customizability has been a major issue of these systems. In the context of healthcare sector, for instance, it is critical to have possibility to adapt generic software systems to match particular health services. This paper reports on a study performed in an organization that chose a strategy of multisite adaptation of a generic software system with the goal of learning-by-trying so that customizability could be attained. The system described in this paper seeks to support users of different activities including Mother and Child, and Tuberculosis programmes. By discussing the way software evolution or maturity was informed through customization, the paper seeks to contribute to the increasing body of literature on boundary spanning in generic software systems adoption.

Keywords: Generic software systems, software customization, boundary spanning, health information systems, developing countries.

LEVERAGING FROM CUSTOMIZATION TO INFORM GENERIC SOFTWARE SYSTEMS DEVELOPMENT: DHIS TRACKER AND ITS INTRODUCTION IN HEALTHCARE

1. INTRODUCTION

The World Health Organization indicates that the lack of reliable data on several health related issues is what will hinder most developing countries not to meet the Millennium Development Goals. YEAGER (2012), for instance, argues that the lack of post-partum haemorrhage and pre-eclampsia/eclampsia data, together with the lack of skilled personnel hinders the accurate identification of gaps in service coverage. To this situation, it is also coupled the inability of health information systems to effectively provide reliable data.

To help countries with data problems, organization such as Health Information System Program (HISP), Regenstrief Institute and Partners In Health have developed Generic Software Systems (GSS). For instance, through the District Health Information Software (DHIS) developed by HISP it is possible to record and manage data of health programmes and information of patients. The DHIS framework offers also other potential advantages to clinicians including the monitoring and tracking of patients enrolled in health programmes (e.g., HIV/AIDS, Tuberculosis and Maternal Health).

However, it is a fact that customers of these generic products have needs that are quite heterogeneous(Franke & Hippel, 2003). It is also true that software vendors try to address these needs by designing systems around basic organizational functionalities, usually using 'generic' principles. Built to meet the demands of a mass of users, geographically spread across countries and living in completely different contexts from each other, the benefits of most GSS are various. These benefits are, generally associated with access to accumulated knowledge about organizational practices and the community of stakeholders sharing these practices(Michaud, 1999; Randell, 2003), and specifically, to the freedom in accessing the tools source code, and making changes to it.

In order to benefit from them, organizations need almost always, to undertake to the process of customization(Michaud, 1999). This process, apart from organizational and management factors(Sahay & Walsham, 2006), is influenced by GSS customizability. Swaminathan (2001) asserts that customizability of Information Technology (IT) systems depends on three factors: modularity, standardization, and predictability of demands and operations. While modularity is a principle that ensures that 'complex' and 'larger' software systems are divided into simpler and more manageable modules, thus making them more adaptable(Sullivan, Griswold, Cai, & Hallen, 2001); standardization allows multiple customizations to be performed on the same line without major changes, and predictability refers to the degree to which software developers can predict what the software will do(Bell, 1966).

Few software systems have, however, been released at their first glance with the above properties. Because of that, myriads of disruptions are observed during their customization. Likewise, the diverse amount of requirements associated with the fact that customization responsibility fall on use organizations, may lead to distinct versions of customized products(Iivari, 2010; Pollock, Williams, & D'Adderio, 2007). Their harmonization can be challenging to software developers, specifically when they have to collect the requirements expressed by the features added in the use nodes and include them into the generic tool. Pollock et al. (2007), for instance, state that too much diversity influences the ability to make software products generic.

Addressing most of these disruptions usually require global - local negotiations between customization players(Pozzebon & Pinsonneault, 2005). These players involve not only internal people (from different departments and hierarchical levels), but also a network of external individuals such as software developers, customizers and champion users(Pozzebon & Pinsonneault, 2005). The different interveners meet, discuss and share customization experiences and lessons. Therefore, it is during these negotiations that GSS gain properties that allow them to become mobile. These arguments point out to a discourse relating customizability as dependent on interconnections between domains, sites and organization, usually referred to as boundary spanning. Drawing from Levina and Vaast (2005) work, the paper intend to (a) build an understanding of the kind of boundaries spanned in making GSS customizable; and (b) discuss weather organizations should encourage or restrict the growth of practice during GSS customization.

To answer these questions, the paper builds on material collected during the customization of DHIS Tracker framework for use in the Malawian and Bissau Guinean healthcare information systems. Data was collected using artefact examination and participant observations, as well as document review and reflexive discussions. Findings of the study illustrate that adoption of DHIS Tracker by different healthcare service providers has resulted in instances distinct from the standard configuration of the framework, i.e., customization have resulted in fragmented versions of DHIS Tracker. In turn, this fragmentation posed challenges to both developers in harmonizing and satisfying user needs, and the end-users in their continuation of benefiting from the improvements being added to new framework versions.

The paper proceeds as follows: after introducing the main discussion that will be undertaken in this paper, the next section presents the theoretical framework. The third section presents the research approach. Within this section the contexts and the data collection and analysis techniques are described. The fourth section explores empirically the study research questions contrasting them to the research perspectives. This is followed by the analysis and discussion section where the contributions are presented. The conclusion of the study is presented in the later section.

2. THEORETICAL FRAME OF REFERENCE

GSS offer the possibility of adapting systems' functionality to users changing needs and requirements over time and thus stay current, applicable, and useful longer(Dourish, 1995). These applications predict that some maintenance tasks are offloaded to 'local developers'. The offloading of tasks is based on the principle that the mechanisms for resolving possible conflicts in the needs are in place and they enable the software application to meet undocumented users' requirements, thereby increasing the longevity of software system. To effectively perform software customization 'local developers' take advantage of the experienced actors (with different background) including 'marginal' maintainers and developers. This process involves also accessing a large pool of domain and professional knowledge that will free organizations of dramatic changes(Schmidt, Gokhale, & Natarajan, 2004).

However, the execution and sustainability of software customization projects has been a major concern in developing countries. According to Claeson and Waldman (2000) sustainability in healthcare affects several issues including design, management and execution of projects. Moreover, since GSS allow software functionalities to be changed, added, and deleted as required (Dourish & Edwards, 2000; Fischer & Scharff, 2000), sustainability includes also the ability of 'local developers' to change the software to fit local business processes. Fischer and Scharff (2000), for instance, asserts that customizable software system "allows users to invest

the world with their meaning, to enrich the environment with the fruits of their vision and to use them for the accomplishment of a purpose they have chosen"(Fischer & Scharff, 2000, pg. 398).

Besides bringing comfort, reinforcing a sense of individuality(Fischer & Scharff, 2000) and empowering 'local developers'(Michaud, 1999), the 'fruits of users vision' can lead GSS to completely separate paths. Several factors may influence the tool during its journey that might not allow the resulting tool to be easily integrated with its original version or the evolutions. For instance, 'local developers' might change the source code without following the guidelines described by the global team, global developers might decide to remove features that are already institutionalized in some local contexts, and so on. Understanding or easing these problems requires construction of knowledge about the software. The importance of collaboration between developers and users of the tools cannot be underestimated. This cooperation ensures knowledge to be shared and relevant information to be properly considered and acted upon by the tools' stakeholders, and is raised by considering customization as work spanning boundaries.

Boundary spanning is considered by Information System (IS) literature as a process of connecting two or more sides. Since it involves spanning professional and organizational settings, Levina and Vaast (2005) assert that the process benefits organizations. And, its study is suggested by boundary theorists as a way forward toward building an understanding of the nature of actions occurring at the boundaries. Boundaries, in this context, are considered as instruments for both splitting and connecting sides. Levina and Vaast (2005), for instance, while studying the issues surrounding the adoption of IT artefacts in organizations suggested paying special attention to boundary. To do that they posed four questions, namely which 'boundaries should be spanned?'; 'should boundary spanners be nominated or emerge from practice?'; 'how should boundary spanners be nominated?' and 'should organizations encourage or restrict the growth of practices?'

To answer these and other questions, boundary spanning literature relies on boundary-spanners and boundary-objects. While boundary-spanners are the individuals or groups of people that establish and maintain inter-organizational relations(Stock, 2006), relating the organization with elements outside it"(Lindgren, Andersson, & Henfridsson, 2008); boundary-objects allow different groups to work together(Star, 2010), thus articulating meanings and addressing multiple boundary perspectives(Akkerman & Bakker, 2011).

However, the practical assessment of GSS boundary spanning is whether the tool meets end-user needs and demands, and whether it is sustainable. These properties are attained when GSS are customizable, which as described in the introduction is dependent on modularity and standardization and predictability of demands and operations. In line with that, Daniels, Edwards, Engeström, Gallagher, and Ludvigsen (2010) stress that customizability can be attained as a result of general development, i.e., result from a software engineering work leading to versions of the IT artefacts; and as result of incremental changes made to it during customization work. The last is possible due to involvement of people from different backgrounds, institutions or organizations that contribute to the production of a share IT artefact.

Therefore the importance of understanding boundary issues through healthcare projects is driven by the fact of healthcare being a global subject, involving several bodies and organizations. And also because the majority of GSS tools become mature thanks to several lessons learned in each of its adoption sites, contexts and countries. This cross-country, cross-organization and cross-customization perspective might help to answer some of the above questions posed by Levina and Vaast (2005).

3. RESEARCH DESIGN

This research was performed under the umbrella of an action research network known as HISP and conducted from an interpretive perspective(Walsham, 1995). The study is empirically developed within the GSS context through DHIS Tracker and its adoption for the management of healthcare services in Malawi and Guinea Bissau.

The data used in this paper was collected from interactions with customizers, developers and end-users. The techniques adopted rely on a qualitative research tradition(Iivari, 2010) and has used software artefact examination and participant observations(Mason, 2002) as the primary data source. This process was done firstly in Malawi from 2010 to 2011, and subsequently in Guinea Bissau between 2011 and 2012. During this period the author was an 'involved researcher'(Walsham, 2006) acting as a customizer and performing activities such as requirement analysis, adaptation of the tools to meet those requirements and end-user training. Additionally, the author positioned himself as a resource, for both local and global teams, and collected local requirements and forwarded them to the developers. Through these activities it was possible to gain first-hand knowledge about several issues including system features and the customization disrupts. The author has also had the opportunity to inspect different versions of DHIS Tracker, and participated in the discussions around DHIS Tracker as well as test beta (unreleased) versions of the framework.

Moreover, document reviews and reflexive discussions(Jacobs-Huey, 2002) provided a secondary data source. Several documents including DHIS user and implementer manuals were analysed. In Malawi, for instance, notes taken by researchers that had been interacting with healthcare users and managers of mother and child health programmes were accessed. Through this, it was possible to draw the mother and child process model diagrams (Figure 1 and 2) and translate them later into DHIS Tracker. While performing customization work and observing the practices, the author interacted with end-users and local customizers, and observed the evolution of DHIS Tracker. The later was done by maintaining continuous contact with researchers working in other settings and with software developers. For example, several thoughts have been exchanged with customizers including those involved with DHIS Tracker in Malawi and Tanzania. Additionally, the author participated in several reflective discussions at local contexts, workshops at regional and at HISP global level. Through these workshops and discussions it was possible to reflect on DHIS Tracker features, and on end-users requirements and challenges.

To analyse the findings an interpretive cross-case approach was adopted. The approach was supported by Miles and Huberman (1994) data analysis framework steps of data reduction, data display and conclusion and verification. Through these steps, intra-case and inter-case analysis was adopted as data reduction techniques. By applying these techniques the data sources were examined and relevant information extracted. The data was visited several times for cross-checking with emerging conclusions, a process called interim analysis (Curro, Craig, Vena, & Thompson, 1995) which is characterized by cyclical practice of collecting and analysing the data. For instance, since the author participated in the customization of DHIS Tracker in the local contexts, he had the opportunity to participate in all the discussions related to the disturbances or challenges of the tools and also recalled and analysed them later with software developers.

4. EMPIRICAL INSIGHTS

HISP is a global south-south-north collaborative network(Braa, Monteiro, Sahay, Staring, & Titlestad, 2007) coordinated by the Global Infrastructures Research Group at Department of

Informatics of the University of Oslo. The group aims at supporting the improvement of health care systems in (the) developing countries by increasing the capacity of health care workers to make decisions. As a part of its activities HISP developed the DHIS software application framework. Over 15 countries, in Africa and Asia, use DHIS to capture, collate and analyse primary health care and hospital related information. The software is implemented at the national level in many countries including India, Vietnam, Kenya, Sierra Leone, Tanzania and Zanzibar. To ensure this flexibility, DHIS is provided as a generic tool with an open meta-data model and an adaptable user interface that allows the users to design the contents of their specific information system without the need for programming. The software is composed of four main modules, namely: *OpenHealthMapper* for mapping or spatial data display and management, *Routine Data* for the management of routine data, *Tracker* for community data management, and *mobiHealth* for patient-based data management using mobile devices. These four modules are designed to provide support to health workers and managers at all administrative levels through a balance between flexibility and standardization, and with a strong emphasis on using information for local action.

The paper investigated the DHIS Tracker module. The module was first developed in India as a context-specific module. After a while the request for similar features in other contexts triggered its integration within the global DHIS software framework. As a community data management, DHIS Tracker primary features include tracking patient enrolled to health programs, as well as the managing of single and anonymous events such as in-patient morbidity and mortality. Overall features available in the module include:

- Managing individual records: this feature permits the user to add details of persons including their relative's information;
- Managing Health Programmes: the tool also permits the creation of health programmes such as mother health, child health, HIV/AIDS and Tuberculosis (TB). This process includes the definition of the programme represented by its stages and their data elements;
- Enrolling persons into programmes: after having created the individual records and also the programmes this feature permits to relate each individual to a number of health programmes;
- Tracking action: the tool also allows the user to perform data entry related to specific programme stages;
- Run aggregation queries to produce data for other modules. i.e., data entered to the DHIS database using the Tracker module can be afterwards aggregated and presented using the different data/information presentation tools available within DHIS application such as data visualizer and GIS.

Several countries have tried to adjust DHIS Tracker to suite their local needs. Among those countries are Tanzania, Malawi and Guinea Bissau. Experiences gained from these three countries are outlined in the two sections below. Although presented as customization within countries the sections discusses the customization of DHIS Tracker in two phases. With this, the paper aim to describe how the maturity of the module was nurtured as well as the challenges faced during this process.

4.1 DHIS Tracker for Maternal Healthcare Management in Malawi

The customization of DHIS Tracker in this setting started with assessment of the Maternal and Child Health (MCH) programme data and requirements collected by a fellow researcher. This process was followed by the design of process flow diagrams (e.g., Figures 1 and 2). User

requirements were identified and specified during the design of these diagrams. With the requirements specified, the customization began.

To support a primary focus on functionality the three most important programs within the MCH comprising of antenatal care, delivery and immunization were included in the first customization plan. This decision brought two general advantages namely: it kept the focus on very few functionalities and it also reduced complexity related to number of specificities of the system. The customization process started by identifying and defining and creating the data elements needed in each of the selected programs into DHIS. After having all of them, the data elements were mapped (associated) with its respective programme (and programme stage), including the creation of client data (relationships, etc.). However, because the programmes are organized into stages it was required to define for each programme the stages and assign data elements to be collected in each program stage. With all these activities completed, data entry screens were created.

The process has not been as consistent as it should have been. The customizability of DHIS Tracker was assumed to make local adaptation easier; this could reduce time and complexity compared to developing a new system that performs almost the same as the generic DHIS Tracker. However, much time was spent in identifying which features are available in the tool; and at the end it was found that the module did not support all the required functionalities from the MCH. The problems encountered in trying to get DHIS Tracker into operation, include:

(a) The tool was not allowing mimicking the workflow of the MCH business processes (e.g., see Anti-natal care (ANC) in Figure 1; and Delivery in Figure 2). This process required decisions from the end-users. However, since the introduction of computer system at low level of Health Management Information System was not asked by the users, instead suggested by the researchers, it was difficult to assure the quality of the system through validation and test. Weaknesses were also identified with the tool including difficulty in sharing data elements between different programmes, i.e., the prediction that DHIS allow the sharing of data elements between different programmes stages belonging to the same program was not valid. The sharing of data elements feature is characterized as the possibility of allowing, for example, HIV test result of a woman captured by the HIV program to be displayed at the woman's interface of ANC or delivery services.
(b) The system was not allowing adding calculated data elements. Some of these data elements include date of next ANC appointment that could be calculated from the gestation age, and next programme stage and expected date of delivery from the last menstrual period date. Procedures to fill data on these data elements could not be automatized.
(c) The tool was released first with very weak documentation. The nonexistence of a critical mass using the system caused the lack of documentation to be even more resentful by customizers. For instance, customizers needed guidance in defining the best way of organizing the complexity of the MCH program within DHIS Tracker, which could not get through documentation.

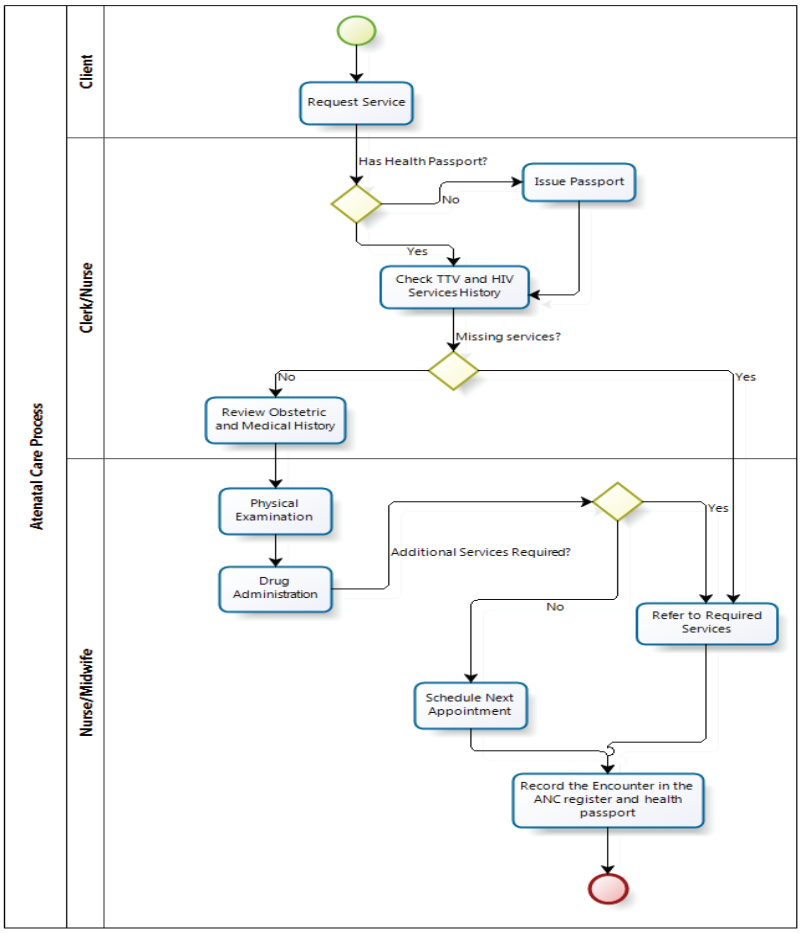

Figure1: ANC Process Flow

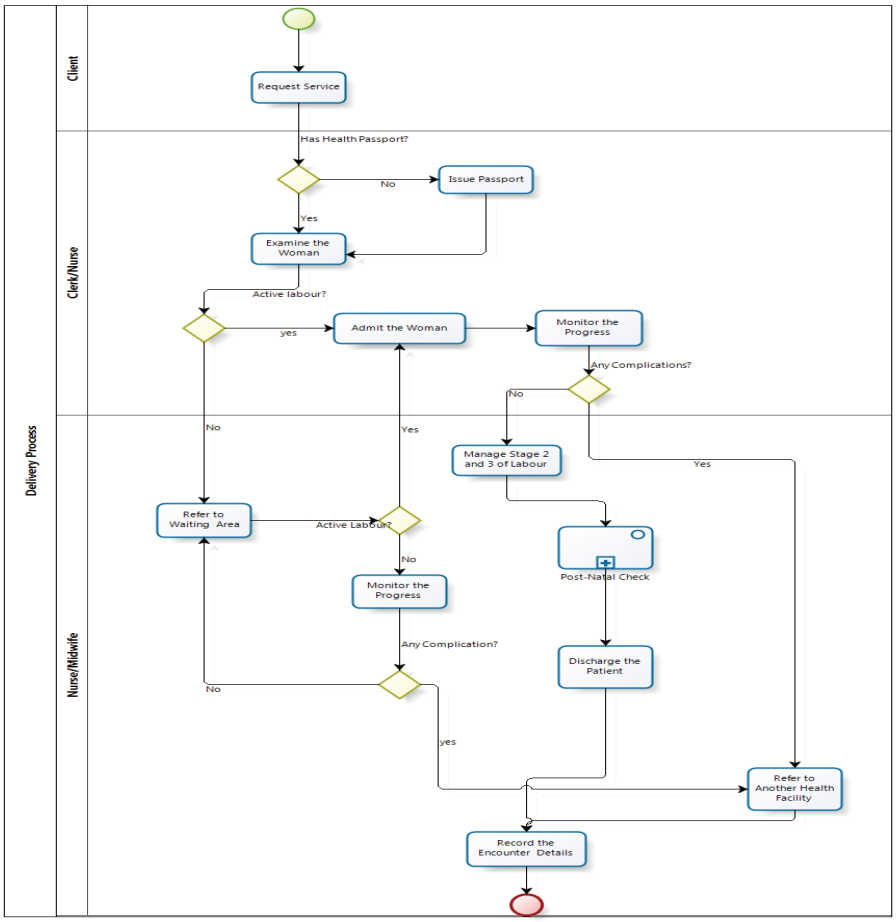

Figure 2: Delivery Process Flow

Furthermore, the customization has benefited from ideas and information of other individuals within and across the customization settings. For example, the local team had exchanged ideas, lessons and experiences with customizers of DHIS Tracker in Tanzania. It is through this process that the local team discovered that similar challenges had been faced in Tanzania. To solve those problems different approaches had been followed. While in Malawi customizers forwarded their problems to developers, in Tanzania customizer team decided to hire a developer to adjust the DHIS source code in order to match the local requirements.

4.2 DHIS Tracker for Management of Tuberculosis Patients in Guinea Bissau

Similar to Malawi, the customization of DHIS Tracker in Guinea Bissau was done in two broad stages: requirement analysis and software adaptation.

Requirement Analysis: Unlike Malawi where requirements were provided by a fellow researcher, here the TB program was assessed by the author. This process involved evaluating

the data collection, analysis and presentation tools. Subsequently, as in Malawi, process flow diagrams were designed and requirements identified.

Software Customization: According to its characteristics, of people involved and the time that was performed, this project can be regarded as a follow-up of the Malawi case. Due to the fact that customizers developed expertise during the customization in Malawi, lessons were transferred and applied in Guinea Bissau. Because of that, some of the troubles experienced in Malawi were no longer regarded as such in Guinea Bissau. This was also possible due to the improvements that DHIS Tracker framework has undergone since its introduction in India. Nevertheless, other problems were faced as follows:

(a) Since it was not possible to import and export data from/to DHIS Tracker, it was imperative to be connected to the server in online mode. Moreover, when the offline data entry feature was introduced within DHIS, it did not include Tracker data. Because of this, the suggestion to ease the introduction of historical data whereby central level staff was supposed to go to the hospital where TB patients were treated with their laptop with DHIS Tracker installed was discouraged.
(b) To benefit from features of new versions of the system, customization was to be done almost from scratch at least three times. Also changes made in the framework after the customized software was being used by data managers, required the redesigning of considerable parts of it. For example, considerable customization work had been rebuilt when DHIS Tracker framework allowed the definition of repeatable stages.

When the customization was complete, end-users were trained and given the opportunity to test the tool. It is, therefore, important to note that some of the problems highlighted earlier in Guinea Bissau were not verified in settings like Tanzania where changes have been made at the DHIS Tracker source code. In Tanzania customizers were able to export/import data from one DHIS Tracker version to another, and also to make DHIS Tracker to meet the end-users needs by changing the source code. However, they had other challenges. One of the most prominent challenge was motivated by the non-sharing of their source code with the framework developers. Because of that DHIS Tracker improvements could not match the changes made locally, thus they could not benefit from the periodically released enhancements. Figure 3 presents a screenshot of the customized application for tracking TB patients including its demographic information, stages and data entry screen.

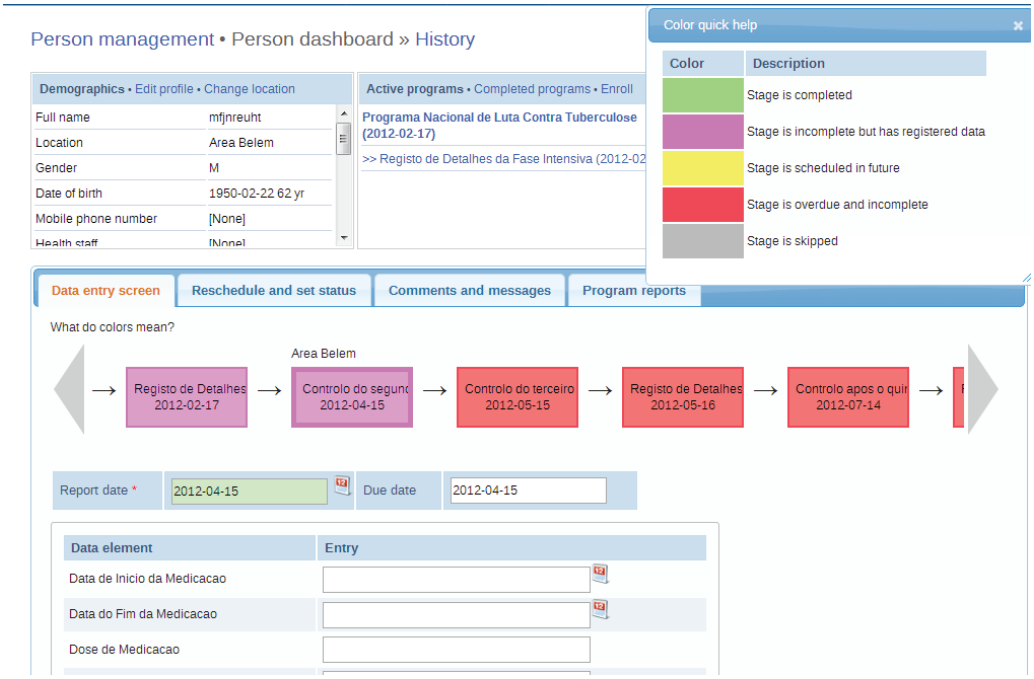

Figure 3. Screenshot of a Customized DHIS Tracker showing an example of a TB patient Dashboard

5. ANALYSIS AND DISCUSSION

Besides emphasizing the importance of health promotion, Primary Health Care has moved toward the use of appropriate information technology. Thus, to allow an unbroken decision support process that could support the very bottom level of Health Management Information System, DHIS Tracker was introduced. As a module developed to manage community based data, DHIS Tracker allows among other activities, the traceability of health data. This traceability increases the reliability as compared to aggregated data and leads to better quality. The implementation of DHIS Tracker in the settings evaluated in this paper, like many other studies of technology adoption, report success and failures (see e.g. Heeks (2006) and Pozzebon and Pinsonneault (2005)). While attempting to answer this paper research questions, the study generates two important lessons.

5.1 GSS can Challenge the Adaptation Process

One of the fundamental benefits of GSS is the possibility of allowing users to perform changes to the software to meet their own needs. Customization is one of the processes being, increasingly, adopted toward this aim. So far only few organizations benefit from the adaptability of GSS. Reasons are many and range from capacity and competence to complexity of the tools. Findings of this research have illustrated the existence of several barriers during the spanning process. For instance, in Malawi DHIS Tracker did not allow the mimicking of the business processes workflow, as well as the sharing of data elements between different health programmes. Likewise, in Guinea Bissau users could not use the offline data entry feature. This

problem became more challenging because of the absence of import/export functionality. To benefit from features of new versions of the framework, customization had to be done several times almost from scratch. Therefore, some of the customization could have been alleviated if documentation of the tool was available.

This ambiguity and complexity with boundary spanning work was highlighted by scholars studying boundaries (see e.g., Akkerman and Bakker (2011), Barrett and Oborn (2010), Levina and Vaast (2005)). In the healthcare settings this complexity is due to the existence of different work routines in each setting (see Ngoma et al. (2012)). In attempt to contribute to the discussion aiming at providing answer to the question of 'should the organization encourage or restrict the growth of practice surrounding IT?', analysis of the findings reveals that there is not a straight answer to this. For instance, as health systems are highly context-specific, there is no single set of practices that can be put forward as a model for process performance. The study findings indicate that customizers in Malawi were not able to align DHIS Tracker with some of the user requirements through source code. They chose to forward those requirements to the developers. Tanzanian customizers, on the other hand, performed changes on the source code level. Since the development was not coordinated with the developers the decision led to additional challenges. As presented in the findings Tanzania could not benefit from the enhancements of the generic DHIS Tracker. Thus, even though restrictions could eliminate challenges faced by customizers like the Tanzanians that decided to make changes at the source code, encouraging can therefore increase local developers' ownership and freedom and help to address challenges that were faced by customizers.

Thus, it can be asserted that there is a need to create balance between assigning the flexibility and controlling inclusion of new practices. And if customizers follow paths like those of customizers in Tanzania, the resulting code should be shared with the developers to allow future benefits from the enhancements of the tools, especially for systems that are still evolving such as the DHIS Tracker.

5.2 Development of GSS is informed by the Customization Process

As described in this study, DHIS Tracker was initiated in India and then expanded, first to Malawi and Tanzania and then to Guinea Bissau. The previous section have illustrated that across all sites, the generic framework provoked 'headaches' to customizers. However, after reporting the problems to the developers, Tracker failures were reduced. The result of this effort was observed in Guinea Bissau were customizers did not face the same challenges faced in Malawi and Tanzania, but faced other type of challenges. Some of the problems like the 'form name' were reported to developers and fixed later on. Others faced in Guinea Bissau were not within the developers' scope and had to be work-around by customizers.

It was, however, thanks to these pains that DHIS Tracker succeeded in reaching the maturity that showed both in Guinea Bissau and also in settings where it is currently being implemented. In the attempt to contribute to the discussion aiming at providing answers to the question of 'which boundaries should be spanned?', analysis of the findings reveals that DHIS Tracker development and customization was possible due to the collaborative arrangements available within the HISP network. Customization is here recognised as an important phase in the development of generic IT artefacts. It is, thus, during this phase that collaborative arrangements occur. People from different backgrounds, institutions or organizations collaborate in producing the tools and share ownership of the final products(Kamensky, Burlin, & Abramson, 2004). For instance, effective development, customization and use of software systems like DHIS is no longer possible if organizations work in isolation, but it requires joint

effort whereby professionals from many fields (e.g., healthcare, software development) and institutions (e.g., health authorities, universities, researchers) work together.

The findings of this study show that the collaborative arrangements besides helping in building systems that meet the needs of end-users permits the reuse of knowledge. This process contrary to the traditional view of customization where it is performed by vendors' representatives or the relatively recent view where the task is left to local people was facilitated by a technical middle-man acting as an intermediary between developers (experts about the system) and the end-users (experts about the domain).

Moreover, the process was not only between the domains of use and development, it also involved boundary spanning between different customization nodes. In between customizations, both the spanners and the developers accumulate expertise which allows them to operate the technology more efficiently as well as enhance or improve the software features. As observed in this study, technical middle-men were shared between domains, settings, and customizations (e.g., from Malawi to Guinea Bissau), thus providing a common ground for mutual understanding between diverse organization members including end-users, customizers and developers in a multi-cultural network. And, their understandings of the multiple cultures were imperative when features of the generic tools were discussed.

6. CONCLUSION

In the context of generic software systems, where software is developed envisioning a wide range of users, it is critical to have the tools customized to each particular use context. Lessons from this paper indicate that this process is influenced by the software customizability. An endeavour is then made to outline a basic mechanism through which customizability of generic software systems is achieved. Customization is, however, used as the mode through which boundaries and spanning activities are analysed. Software customizability is in this case a sequence of boundary spanning activities, i.e., customizability is seen to emerge as materialization of lessons learned after spanning domains, settings, and customizations nodes.

Moreover, in attaining customizability the aspect of encouragement or restriction of growth of the generic software system need to be taken into account. The paper argues that customization is to be expected in the development of working systems, as an outcome of a 'learning-by-trying' process. Through this process there is a need of balancing decisions, i.e., developers need to encourage local development with some restrictions on the tasks to be performed. If properly performed this can facilitate the handling of uncertainty involved in customer needs and design changes.

By evaluating the boundaries spanned during software customization, together with the issue of encouragement or restriction of the growth of practice surrounding IT artefacts', the paper provides important contributions to the boundary theory that is particularly relevant for institutions that will seek to enhance customizability of generic software systems through the mechanism of customization.

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VI

Software customization in healthcare domain of low-resource settings: a model for building capacity

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Despite its benefits, software customization is exposed to a variety of disorders. In the healthcare domain of low-resource countries, for instance, disorders are due to factors like workforce crisis and lack of capacity. Researchers have come a long way in identifying approaches for addressing these problems, but still much work remains to be done. Adopting practice-based lens, the study develops a model for building customization capacity in open-source software. Practice is regarded as an approach that helps to understand people actions in their everyday work. On the way to this, the study provides an appraisal of the practices adopted in three projects that customized District Health Information Software in healthcare domain. The advocated model suggests combining three overlapping but complementary approaches, namely: guest - capacity resulting from pairing with people doing similar tasks, cluster - capacity resulting from inter-professional collaborations; and situatedness - capacity resulting from exposure to the domain complexity.

Keywords: open-source software systems; low-resource countries; software customization; capacity building; e-health.

1. Introduction

Due to its potential to provide rapid and comprehensive access to information, Information Technology (IT) has been considered as a key enabler for improving healthcare processes. Despite the validity of this assertion, at a moment where organizations are investing in IT systems that support a wide range and users and tasks, it is much easy to lose managers acceptance than it would be, for example, with custom software systems.

To reduce the probability of such to happen, suppliers have been delegating the task of customizing these software systems to end-user organizations. The logic behind this is that, if the 'engine' that will drive the adaptation of software to fit their local business processes is located in the end-user organization, chances to be successful are high, i.e., local context people hold more potential to transform their own business than people from outside.

However, there is a gap between the idealized image of end-user organization and their ability to perform everyday work. In the literature, most of the times, customization is presented as a highly well-organized and well-disciplined activity where local context people are able to perform the work without any pitfall. But customization is a rather complex matter. Leonard (2011), for instance, underscores that even though developers reduce the uncertainty during the development, "as soon as the technology gets into the hands of the production department the complexity will increase again" (Leonard, 2011, p. 432). Pollock and Cornford (2002), on the other hand, asserts that either moving across boundaries of a commercial organizational to a public sector context, or from a general to a specific setting, technology do not translate easily to their new settings.

Furthermore, the healthcare domain of low-resource settings have additional undeniable particularities that increases the complexity of customization work, which include among others the lack of human resource capacity and governance (Braa, Monteiro, Sahay, Staring, & Titlestad, 2007; Sahay & Walsham, 2006), workforce crisis (Huddart & Picazo, 2003; Liese, Blancher, & Dussault, 2003; Unger & Criel, 1995) and the resistance of powerful actors (Fichman, Kohli, & Krishnan, 2011).

In recognition of this, the society agrees that technology adoption require that methods of, for instance, capacity and team building are tailored to local contexts. However, there is very little practical guidance informing this process. Taking this as point of departure, the paper's research question is: how different software stakeholders interact to shape customization capacity?

To accomplish this goal, examination of the customization of District Health Information System (DHIS) were conducted at three projects in Mozambique, Malawi and Guinea Bissau. This process was evaluated using a practice-based perspective. This approach sees technology adoption as a work performed "by engaging more deeply in the empirical details of organizational life on the ground" (Orlikowski, 2010, p. 24), and capacity as the ability to perform everyday work. Capacity is also acknowledged as a matter of emergence rather than people intention; its overall outcomes in terms of content and performance are a people responsibility (Jarzabkowski, 2005).

After a brief introduction of the paper's main arguments, the next section presents the theoretical framework. The third section will present the research approach. Within this section, the contexts, the data collection and data analysis techniques are described. The fourth section explores empirically the study research questions contrasting them to the

research perspectives. This is followed by the analysis and discussion section where the contributions are presented. The conclusion of the study is presented in later section.

2. Theoretical Framework

The dynamics between technology and their use contexts has been a long standing problem in understanding the adoption processes. To investigate these dynamics especially the activities performed to accomplish adoption of technology, organization theorists have embraced, among others, the notion of practice (Nicolini, 2013; Orlikowski, 2010). Practices as conceived by most practice theorists refers to "routine bodily activities made possible by the active contribution of an array of material resources"(Nicolini, 2013, p. 4). These activities include, for instance, improving one's ability to do something, temporally unfolding and spatially dispersed nexus of doing and saying, and performing action. These practices are the basic units of analysis for understanding organizational phenomena in practice-based studies.

Drawing inspiration from the works of Orlikowski (2000), L. A. Suchman (2007), Nicolini (2013) and others, this research uses a practice-based perspective to understand the dynamics of open-source software systems customization in low-resource settings. Though there are many ways that practice-based perspective is associated with technology adoption, this paper focus specifically on understanding how actors interact to shape the software customization process.

2.1. Open Source Software

The phenomenon of globalization has, through its premise of interdependencies between nations, enabled organizations to embrace IT artefacts built for global domains. As opposed to custom artefacts that target specific users or group of users (Bansler & Havn, 1994), the new are designed and developed for general use in the sense that their features can be modified and applied to a wide community (Daniels, Edwards, Engeström, Gallagher, & Ludvigsen, 2010).

Open-source software emerges from this phenomenon and refers-to both a movement and tools that are distributed with their source code, often under a license that sets conditions for modification, reuse and re-distribution (Subramanyam & Xia, 2008). While a portion of open-source software systems is used as the developers make them available, others require being suited to end-user needs and demands. The latter kind of software systems is referred-to as Customizable Open-source Software (COSS).

The provision of such COSS products has been described as a global sourcing strategy (Hauge, Ayala, & Conradi, 2010), i.e., an approach where communities collaborate in solving their own as well as shared technical problems, and freely reveal their innovations (Hippel & Krogh, 2003). These IT artefacts became ubiquitous in low-resource countries because of their affordability, flexibility, portability, and reliability (Schmidt, Gokhale, & Natarajan, 2004). Affordability refers-to the non-prohibitive costs of acquisition and evolution. Flexibility is related to the supporting of a growing range of requirements. Portability entails the possibility of reducing the effort for constant adaptations of COSS. Lately, reliability means the ability to ensure that COSS are robust and tolerant to faults.

One stream of information systems (IS) studies has focused on activities and practices around a process known as tailoring (Draxler & Stevens, 2011) or customization (Rothenberger & Srite, 2009). This process is, broadly, defined as the activity of modifying COSS to better suit the needs of particular tasks in local contexts. Key insight of these studies concerned in seeing customization as a situated, socially accomplished activity constructed through the actions and interactions of multiple actors (Feldman & Orlikowski, 2011; S. Kaplan & Orlikowski, 2012; Labatut, Aggeri, & Girard, 2012; Orlikowski, 2010). Theoretically, the understanding of the dynamics of this process has benefited from various approaches. Practice-based perspective (e.g., de Certeau (1984), Orlikowski (2000), and Nicolini (2013)) is one of those approaches, and have been emphasized as lens to study "the everyday activity of organizing" (Feldman & Orlikowski, 2011, p. 1).

2.2. The practice of software customization

Practice-based approach is increasingly adopted in IS research because of its special capacity to "understand how organizational action is enabled and constrained by prevailing organizational and societal practices" (Vaara & Whittington, 2012, p. 286). Scholars adopted this perspective to, for instance, (a) access actions in specific places and times, and develop generalizable principles of how action might unfold in other settings (Parmigiani & Howard-Grenville, 2011); (b) access people's situated behaviour and explore how problems are solved or how competence is constructed in practice (Corradi, Gherardi, & Verzelloni, 2010); and (c) access the tools and artefacts that people use in doing customization work (Jarzabkowski, 2005).

Understanding software customization through this perspective mean seeing it as both a situated (L. A. Suchman, 2007) and a 'boundary spanning' work (Akkerman & Bakker, 2011). As a situated work, software customization is embedded in contexts whose meaning is

constituted by people, their actions, and interrelated objects. In this context, the work activity is concerned as the level of analysis and the actions and interactions comprising the activity as the unit of analysis (Jarzabkowski, 2005). Moreover, to study attitudes and practices of people that enter onto territory in which they are unfamiliar and, to some extent unqualified (L. Suchman, 1994) and based on their fresh look at the long-standing practices and assumptions, create deep learning (Tsui & Law, 2007), scholars used the notion of boundary spanning. The boundary spanning approach have the potential of introducing elements of one practice into the other (Fisher & Atkinson-Grosjean, 2002).

In both conceptualizations, software customization entails a flow of activities which incorporates among others the content and process, intent and emergence, and thinking and acting (Dittrich, Vaucouleur, & Giff, 2009; Draxler & Stevens, 2011; Kimaro & Nhampossa, 2007; Zachman, 1999). Applying practice-based perspective into them, means seeking an understanding of how the dichotomies elide in the on-going shaping of the practice (Jarzabkowski, 2005).

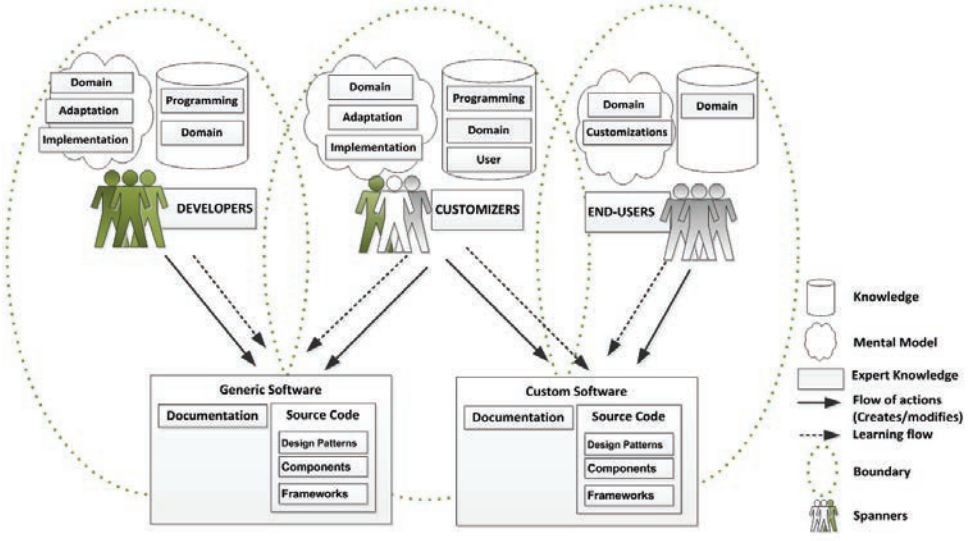

Figure 1: Components of a software customization practice (Adapted from Michaud (1999)).

Figure 1 illustrated the two software customization conceptualizations. Despite the fact that customization work is mainly performed by customizers in the use context, there are ensembles of participants (e.g., end-users and developers) engaged in and joined together by the overarching conceptual undertaking of the work. Thus, while most of these participants

might not be designed formally as ‘customizers’, their actions and interactions contribute to the customization work.

2.3.The dynamics of customization practice

The practice-based conceptualization of software customization, depicted above, highlights its importance and addresses the detailed practices which constitute the day-to-day actions of software customizers. However, given the dynamics and ubiquitous nature of domains like healthcare, software customization remains problematic.

Previous studies on this matter, illustrated various kinds of challenges. Figure 4 put together some of these challenges and links them to the various components involved in shaping software customization.

As depicted in Figure 2, some software customization difficulties are due to the complexity of artefacts on which the customization work is sparked. In addition to inexistence of features to support certain work processes, this complexity include the difficulties in comprehending, modifying and testing software systems (Banker, Datar, & Zweig, 1989). Saugene (2013), for instance, argues that the unavailability of features and problems in exporting the data entered into the database made the customization work to be redone, and from scratch, each time a new version of *DHIS Tracker* was released. Studies reveal also that *poor software documentation* influence customizers work. For instance, Saugene (2013) assert that customization of DHIS Tracker in Malawi was hampered by unavailability of documentation that could be used to guide the process.

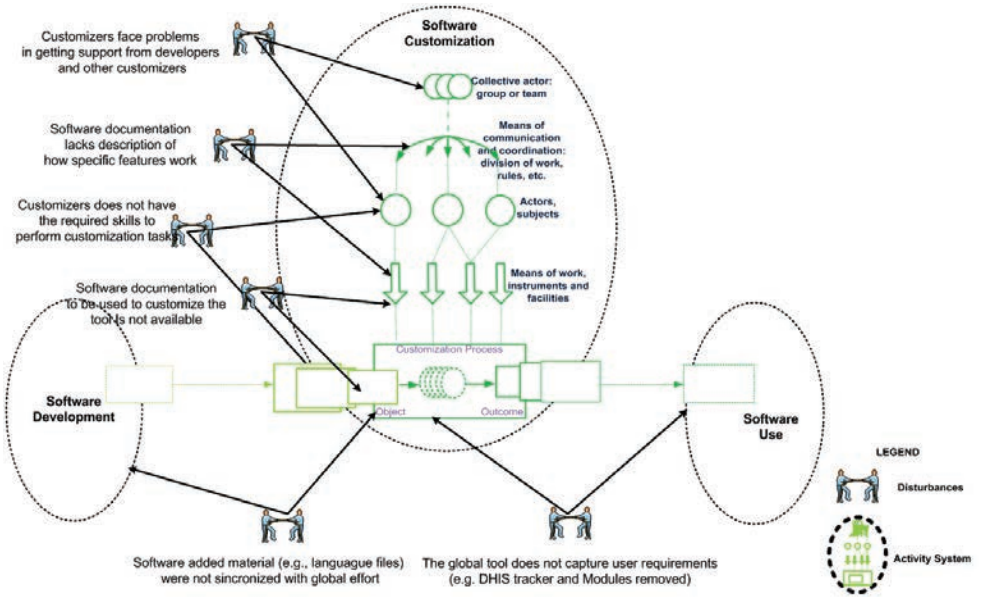

Figure 2: Software customization activity elements and disturbances (Adapted from Korpela, Mursu, and Soriyan (2002))

While the above complexities are indeed relevant in the healthcare of low-resource settings, there are incontestably other important particularities characterizing the domain. For instance, the adoption of technology in healthcare of low-resource countries is hampered by (a) workforce crisis (Huddart & Picazo, 2003; Liese et al., 2003); (b) the existence of multidisciplinary actors which require both technical and political, and leadership and governance actions; (c) the resistance of powerful actors (e.g. physicians) who regard technology adoption activities as administrative irritants (Fichman et al., 2011); and the shortage of skilled people.

With regard to workforce crisis, Unger and Criel (1995) states that since health ministries of low-resource countries experience budget crises, salaries of their workforce are often grossly insufficient. Thus, attempts to reform have frequently failed, and have devised in poor motivation and increasing dissatisfaction. As consequence, qualified professionals leave their posts, thus the substantial investment in their training produces dubious direct returns to the National Health Service (Zurn, Poz, Stilwell, & Adams, 2004).

In addition, as illustrated in Figure 1, software customization is performed by individuals with different skills. In one steam there are end-users who do not have technical skills and, in other, there are people having technical skills. Regardless of the extreme people belong to, as long as they are performing customization tasks, they are extremely important to

how routines are enacted (Parmigiani & Howard-Grenville, 2011). For instance, since each of the boundary sides has its own people, objects and practices, crossing them will create some kind of complexity (Akkerman & Bakker, 2011). Managing this complexity is a matter of 'boundary-crossing competence' (Fortuin & Bush, 2010; Walker & Nocon, 2007).

Moreover, researchers studying adoption of generic systems in low-resource countries lament the shortage of skills of these people (e.g. Braa et al. (2007), Heeks (2002) and Sahay and Walsham (2006)). With regard to this, it is argued that the existence of customizers with *poor skills and knowledge* make the customization work more difficult (Hauge et al., 2010; Sahay & Walsham, 2006; Saugene, 2013; Saugene & Sahay, 2011). Saugene (2013), for instance, argues that some of the problems faced in Guinea-Bissau were due to existence of local people that did not have experiences with customization of IT systems. Additionally, although developers provided the DHIS with its source-code, i.e., indirectly giving customizers the freedom to change as they wanted; several customizers were not able to perform such changes. OGUMANIHA customizers, for instance, had problems in integrating by themselves a module that was available in earlier versions and removed from the last versions. In Malawi customizers were not able to align DHIS Tracker with end-user requirements by changing the source-code.

The situatedness avenue of practice-based approach attempts to deal with these work disruptions and denotes to the way that activity both shapes and is shaped by the society within which it occurs (L. A. Suchman, 2007). For instance, rather than conceiving resources as something that an organization has, this perspective is concerned with the learning processes that the organization does (Jarzabkowski, 2005). In this regard, given that customization requires flexibility to cope with the uncertainty and complexity of both technology (Kimaro & Nhampossa, 2007; Wirfs-Brock, 2010) and domain (Braa et al., 2007; Sahay & Walsham, 2006; Tsiknakis & Kouroubali, 2009) of the organizational activities, practice-based perspective can "shed light on the way capabilities emerge, are developed, modified and changed over time" (Jarzabkowski, 2005, p. 7).

This learning process requires proper governance mechanisms. While analysing employer - employee relation and its impact on projects, researchers such as Bill (2012) asserts that organizations should enable the sharing of wealth of information. He asserts also that if fluent, clear, enriched, and meaningful information, is not shared projects are likely to fail, i.e., they require effective leadership and governance. According to Meyer (2004), governance entails the process of coordinating and controlling organizational resources and actions. The process involves a systematic shaping of "who makes each type of decision (a

decision right), who has input to a decision (an input right) and how … [individuals] (or groups) are held accountable for their role" (Weill, 2004, pg. 3).

Therefore assuming that, in the low-resource settings, most of the above experiences and problems bear a close resemblance, an investigation of their practical influence and impact in the customization of COSS is what this paper is about.

3. Research Design

The research was, empirically, developed within the healthcare domain of developing countries, in which the authors have been involved for a couple of years. Specifically, the focus was on understanding the practices employed during the customization of District Health Information System (DHIS) with regard to team and capacity building. In order to get a richer picture of these practices, experiences were collected mainly from three customization projects held in Mozambique, Malawi and Guinea Bissau. Insights were provided mainly by interacting with DHIS developers and from customizers and healthcare managers of these settings.

The study was conducted from an interpretive perspective (Walsham, 1995). Empirical data started to be collected in 2009 in Malawi; and as opportunities arose the customizations of DHIS in Mozambique (from 2010 to 2011) and Guinea Bissau (from 2011 to 2012) were assessed. Together these experiences allowed the generation of different insights on the subject of software customization.

An iterative and reflexive analytic process was adopted (Stake, 1995). Data from participant observations, interviews and documents analysis was combined and used to confirm, augment, and challenge the understanding of the strategies adopted toward team and capacity building and its related challenges.

3.1.Data Collection

Data collection methods relies on the qualitative research tradition (Iivari, 2010). Participant observation was used as primary data source. The technique was applied while performing the role of customizer in the three settings considered in this paper. In Malawi, observation occurred in several occasions from 23rd February, 2009 until January 13th, 2011. In Mozambique, however, it was done in a week that lasted from March 27th to 2nd of May 2011. In Guinea Bissau participant observation was performed during two periods: the first, started in June 27th and ended in 28th August 2011, and the second from 11th January until 1st March 2012.

In each site, as 'involved researchers' (Walsham, 2006), members of the research team lived the customization everyday experiences in health care organization. They have enrolled themselves in performing customization tasks, training local customizers and users, testing the accessibility of the application server from the regional and health facilities, and so on. While being in the customization settings, members used this opportunity to observe customizers performing their daily duties, participated in meetings and discussed team related issues. In Guinea Bissau, for instance, one member was responsible for identifying from the available health personnel, individuals to take part in the customization team. A total of twelve individuals (see Figure 3) were provided by the managers, and based on the daily interaction these individuals were segmented into three main sub teams, i.e., five individuals were assigned the responsibility of entering historical data into the database, three were creating the validation criteria and four were defining and creating the metadata.

Observation was also performed during four DHIS2 training workshops, two in the West Africa and the other two in the East Africa. During both the visits in the settings and in the workshops, interaction was maintained with countries end-users, customizers and managers. Discussions were also held with customizers and developers in several other meetings. The discussions had several disparate purposes including: deliberating on software requirements, end-users needs and demands, customization teams and approaches to deal with customization challenges, implementation strategies, and training approaches.

Figure 3: Customizers office in Guinea Bissau

Interview and document review constituted our secondary data collection techniques. During one of the East Africa DHIS2 training workshops, held in Tanzania from 18th to 29th

of June 2011, a total of seven in-person interviews were conducted with customizers and implementers of selected countries like Mozambique and Tanzania. The interviews covered issues such as customization practices and challenges, team composition and structure, recruitment practices, retention practices and challenges, and capacity developmental issues. Furthermore, in sites such as Mozambique access to customization background and team was done through documents. The OGUMANIHA project description provided, at a minimum, information on the history, structure, core competencies, project practices, culture and infrastructure.

3.2.Data Analysis

Interpretive approach was adopted for data analysis and its deductive process followed Miles and Huberman (1994) data analysis framework steps of data reduction, data display and conclusion and verification. Within this approach a cross-case strategy was adopted to analyse the study findings. Essentially, the analysis process was split into two steps: intra-case and inter-case analyses. The intra-case was used to analyse data in each customization project. Inter-case approach, on the other hand, was applied to compare and identify the similarities on the data across the customization projects.

The use of this cross-case approach helped to cross-walk the findings against each other and refines the understandings. This has been done in all the steps of our data analysis and it helped to identify the nature of constraints faced by the customizers of each of the settings during the customization DHIS. During this process, data memoing (Birks, Chapman, & Francis, 2008; B. Kaplan & Maxwell, 2005), data organizing, compressing and its display into meaningful analytical categories was performed.

4. Empirical insights

4.1. Introduction

DHIS is a generic tool with an open meta-data model and a flexible user interface that allows users to design the contents of their specific information systems. The framework is designed, by Health Information System Program (HISP), to support healthcare workers and managers in four key areas, namely: managing aggregate data (*Routine module*), managing community data (*Tracker module*), mapping or performing spatial data analysis (*OpenHeatlhMapper module)* and handling patient and aggregate data using mobile device (*mobiHealth module)*. To ensure its adaptability and consecutive scaling, DHIS comprises a range of generic

functionalities within an architecture that separates the core from the modules, and the common from the context-centric (see Figure 4).

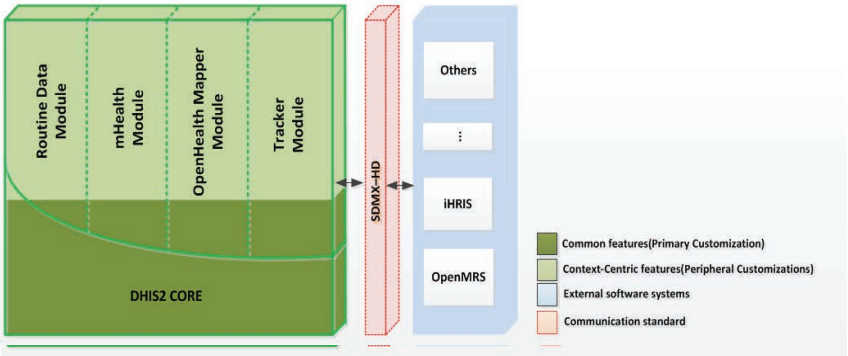

Figure 4: DHIS Architecture

This study reports on lessons from three customization projects in Malawi, Mozambique and Guinea-Bissau. An overview of these lessons is presented next.

4.2.The customization in Malawi

In January 2009 two of the authors of this paper were invited to participate in the process of customization of DHIS in this country. The participation consisted of, among other activities, lead the process of customization of OpenHealthMapper and collaborate on the adaptation of DHIS tracker. Some of tasks that took part of this involvement are describe next.

The customization of OpenHealthMapper*:* The aim of this project was to adapt the OpenHealthMapper module so that healthcare managers could carry out spatial analysis. In order to perform this work a team was created, and besides them, was composed of one staff of the Central Monitoring and Evaluation Division (CMED) of the Ministry of Health, one staff of the Department of Geological Surveys (DGS) of the Ministry of the Ministry of Natural Resources, Energy and Environment, and the customizers of the DHIS aggregate module. In this team, while the DGS staff was responsible for providing spatial data, non-spatial data provision remained on the responsibility of the team performing the adaptation of DHIS aggregate module. The CMED staff, in addition adaptation, had the task of identifying the institutions that could provide the spatial data and facilitate such transactions.

On some occasions, such as when facing difficulties in generating *GeoJSON* file format from the *shapefiles* (as reported in Saugene and Sahay (2011)), e-mails were exchanged with fellow HISP researchers (more experienced in DHIS and in customizing

OpenHealthMapper), and they helped to address the problems. See bellow an extract of a conversation held via email between a customizer and a HISP researcher.

> Customizer: *I have converted shapefiles to geojson but when I try to link them with the DHIS2 organization units the polygons are not displayed in the panel. I attached two files containing spatial data of Malawi; can you please check what is wrong?*
>
> HISP Researcher: *The problem is that the original files have a different projection from the one we use as standard in DHIS2, namely lat/lon. Therefore, you have to re-project. You must first determine the source projection, which for Malawi will often be UTM 36S. Alternatively, UTM 36S corresponds to EPSG 2736. This means we can use ogr2ogr (part of FWTools) to re-project as you convert to geojson.*

Moreover, given that the version 2.0.4 of DHIS2 allowed performing spatial analysis only through indicators, there were problems that could not be addressed even after visiting the (user and developer) mailing lists. For instance, end-users wanted to perform spatial analysis based on data elements (e.g., to understand malaria causes, managers preferred to use data elements rather than indicators) and also to have a more detailed description of the spatial data stored in the database. These demands were later reported to developers.

The customization of DHIS Tracker: The adoption of this module intended to allow Maternal and Child Health (MCH) program managers to manage patient level data. This process included keeping track of patient records, health programs, enrolling persons into programs and tracking patients. Just as in OpenHealthMapper, the adaptation of this module was conducted by a team that, besides the authors of this paper, was made of local researchers and MCH services providers.

During this process several problems were faced, including: (a) the tool was not allowing mimicking the workflow of the MCH business processes; (b) weaknesses were also identified with the tool including difficulty in sharing data elements between different programmes, i.e., the prediction that DHIS allow the sharing of data elements between different programme stages belonging to the same program was not valid. The sharing of data elements feature is characterized as the possibility of allowing, for example, HIV test result of a woman captured by the HIV program to be displayed at the woman's interface of ANC or delivery services; (c) the system was not allowing adding calculated data elements, such as date of next ANC appointment and expected date of delivery; and (d) the tool did not have comprehensive documentation. For example, the team was expecting to get guidance on the best way of organizing the complexity of the MCH program within DHIS Tracker from the DHIS electronic documents (e.g., implementer manuals). This was not possible in some

occasions. Thus, they had to rely on PowerPoint presentation provided by a fellow researcher who has been in one of the settings (India) where the module was in use.

Because other countries such as India and Tanzania were engaged in customization of DHIS Tracker, these problems were shared with them and later with DHIS developers. For instance, during the East Africa workshop in June 2010 the team became aware of the customization activity being performed in Tanzania and used this opportunity to discuss some of the above issues. Discussion continued after the workshop through e-mails. See extract of conversations held with developers.

It was through these discussions that the team realized that, in order to address similar problems, DHIS Tracker was adjusted through its source-code. Unfortunately, due to lack of capacity, the team could not venture on the same path.

4.3.The customization in Mozambique

OGUMANIHA is a project proposed to improve health and livelihoods of children, women and families by strengthening and integrating efforts toward strong community health and agricultural program in the Province of Zambézia. The project combine efforts from seven non-governmental organisations including World Vision, Adventist Development and Relief Agency, ACDI/VOCA, International Relief and Development, Friends in Global Health (FGH), Centre for Communication Programs of John Hopkins University and the Red Cross Mozambique.

To help the management of the data collected by the project, the managers decided to develop the OGUMANIHA Information System (OgIS). Its development was performed on top of DHIS2 framework and the general setup of the team was comprised of two groups. First, the end-user group which was composed of individuals representing each project partner, including field officers managing data collection at community and health facility levels, and their representatives at the monitoring and evaluation (M&E) board. The second group was made up of senior professionals hired to manage the M&E unit and M&E IT officers.

The need to allow spatial analysis be carried out in OgIS and the lack of local capacity, led the managers of OGUMANIHA to invite one of the authors of this paper to assist the process of adaptation of the OpenHealthMapper module.

A team which apart of the authors of this paper included the M&E IT officers and the managers of M&E unit was created and the adaptation was performed jointly. Managers of

the M&E unit provided knowledge especially with regard to the kind of analysis required. Information was also collected from the OGUMANIHA project description document.

During the execution of the activity the team faced a number of troubles. For instance, the fact that some user interface labels were hard-coded did not allow adaptation without getting access to the source-code. Similarly, software metadata such as indicator type and indicator name, data element type and data element name were displayed in the user interface through their short name. But the way these metadata was created did not allow ease identification of them in the OpenHealthMapper user interface. When these shortcomings were presented to the developers, the team were told to first upgrade the version (from 2.0.4. to 2.2) before they could be helped. See bellow an extract of a conversation held developers.

> Customizer: *I am helping the FGH team in setting up the OpenHealthMapper module and we are facing some problems. Please take a look on the attached document. Note that, the team did not yet upgraded to the later versions, is still using the version 2.04 of DHIS.*
>
> Developer: *We don't support that release anymore, can you start by upgrading to version 2.2?*
>
> Customizer: *There is a problem in upgrading to 2.2; the team has developed a number of Excel reports using the Vietnamese Excel reports module. However, when they tested the version 2.2, the Excel report module was no longer available.*
>
> Developer: *They can build their own war file with 2.2 including the Vietnamese excel reports module. We just need to do some minor work first, but this should be the best approach for this issue.*

To overcome the above the team decided to have two parallel systems (versions of OgIS application): one OgIS instance based on DHIS version 2.0.4 containing excel template feature used by regular users and another OgIS instance based on DHIS version 2.2 for managers.

Moreover, local team members attended DHIS training workshop held in Tanzania in 2011. The workshop has been successful in informing them about new and emerging features and concepts within the DHIS framework, as well as addressing their needs and conditions of their databases. During the workshop, the team had the opportunity to have face-to-face discussions with the developers and present the problems. With the knowledge received from the workshops discussions, local team member were able to perform several tasks including (a) integrating the Excel module into the new versions of the DHIS2, thereby enabling the same version of OgIS to be used both by end-users and by managers; (b) providing DHIS2

language translation files to the community; (c) participating in the translation of the strings of entire application framework.

4.4.The customization in Guinea-Bissau

In May 2011, managers of the National Institute of Public Health (INASA) of Guinea-Bissau expressed interest in having an application that could allow them to carry out spatial analysis. This interest was channelled to the University of Oslo and was accompanied by a copy of database containing data collected by the national health system of Guinea-Bissau.

The task of adapting DHIS to meet this interest was attributed to a team of HISP researchers from where one of the authors of this paper was a member. After the adaptation, one researcher had travelled to Guinea-Bissau to perform the implementation and teach local staff. However, while in the field, INASA managers manifested the desire of having the DHIS Tracker module customized to handle the management Tuberculosis (TB) patient data. To satisfy this wish, a team composed of the researcher, INASA staff responsible for TB data and the managers of TB program at the Ministry of Health (MOH). It is important to emphasize that none of the local team members had previous experience in working with IT systems. The lack of IT expertise on the local team members has made the researcher to be accountable for all activities related to adaptation.

Due to the fact that the researcher developed expertise during the adaptation of DHIS Tracker in Malawi and attended a DHIS training workshop in Tanzania just before travelling to Guinea Bissau, lessons acquired at these settings were applied in Guinea-Bissau. These lessons made most of the troubles experienced in Malawi not to be regarded as such. This was also possible due to the improvements that DHIS framework undergone in the period comprehended from the adaptation in Malawi and its introduction in Guinea Bissau.

Furthermore, as a way to prepare the customization team toward support, maintenance and sustainability of the software application, local team members were invited to participate in DHIS training workshops. They attended two workshops: one in Ghana (2011) and the other in Liberia (2012). These trainings enabled them to (a) understand health management information system (HMIS) implementation and management mechanisms. For instance, they had provided opportunity to meet, debate and exchange information and ideas (both on HMIS and IT) with DHIS stakeholders representing the wide variety of countries; and (b) they learnt best practices, diffused in these workshops, through comparisons of performance among the countries. For example, in the workshop in Ghana, customizers from Kenya shared their experiences and practices adopted to run a cloud-based DHIS implementation.

Nevertheless, the team faced other problems such as: (a) re-doing and from scratch the customization each time a new version of *DHIS Tracker* was released. For example, considerable customization work had been rebuilt when DHIS Tracker framework allowed the definition of repeatable stages. This was motivated by the absence of import/exporting feature that could allow to move data and metadata between database versions; and (b) because of the absence of the import/exporting feature, it was imperative to be connected to the server in online mode. Moreover, when the offline data entry feature was introduced within DHIS, it did not include Tracker data. These and other troubles such as the possibility of the application providing cohort analysis, generating aggregated data from the individual data using query-builder were subsequently presented to developers. See bellow an extract of a conversation where customization issues were presented to developers.

> Customizer**:** *We need help on how to do a cohort report for ANC clients in DHIS Tracker. Is there a way of getting this done in DHIS Tracker?*
>
> Developer**:** *You can use Beneficiary Aggregation Query Builder to create data values for aggregate report. This is the core functionality for linking data between name-based information tracking system – DHIS (beneficiaries, programs, etc.) and aggregate management system (dataset, report, charts, etc.) by defining the linking/aggregating rules. This provides two functions. The first is the Beneficiaries Aggregation Query Builder, a tool to define a formula, an expression, a rule for aggregation data from the tracking (name-based) system to the aggregation system. The second is the Beneficiary Aggregation used for generating routine data values from patient data value by periods and by a facility.*

Table 1 (in the appendix) summarises the customization practices experienced in the three countries.

5. Analysis and discussion

Traditionally, in binary-coded software systems, customization could only be performed by vendors. The emergence of so-called COSS, have triggered software customization process to be offloaded to local people. This new conceptualization is claimed to allow both the production and maintenance of competence locally, and the reduction of dependence on the software suppliers.

However, findings presented in our previous publications (see e.g., Saugene and Sahay (2011), Saugene, Juvane, and Ernesto (2012) and Saugene (2013)), reveal that software customization this is not as straight as it seems. Analysis of those findings suggests that customization work complies with the notion of “practice” (Nicolini, 2013). In recognition of this, the paper applies a practice-based approach and attempts to develop a model of

understanding software customization in the domain of HMIS and the context of low-resource settings. Specifically, the paper focuses on the practices applied in building customization teams and capacity.

In attempting to provide subsidies to this goal, the practice lens applied in this paper considers software customization as practice occurring within and across activity systems. From an activity system perspective, customization practice is a flow of activities with a specific outcome (Jarzabkowski, 2005) that is performed by individuals (s*ubject*), using several types of supporting apparatus (*tools and community*) as mechanisms of obeying the procedures (*rules*) defined by the designers. The cross-activity or boundary spanning perspective, in turn, considers software customisation practice as an activity extended beyond organization boundaries (Lahtinen, 2013). The later conceptualization leads to the fragmentation of the practice into boundaries of people and practices.

In fact, several boundaries were observed during the customization of DHIS. These boundaries were made of professionals including developers, customizers (e.g., CMED staff, DGS staff, DHIS aggregate data module customizers, researchers, M&E IT officers, and INASA staff responsible for TB program data), and end-users (e.g., MCH service providers, Field officers, TB service providers and TB program managers). Besides having similar interests, each of these groups has a different practice. As observed in findings, while the developers were in general responsible for providing guidance related to the design and development of DHIS, the customizers were responsible in fitting local context requirements on it and end-users validating and testing the customized application. Boundaries were also distinguished through the mandate of the customization team and the responsibilities of other organizations that the team had to deal with (e.g., for instance the spatial data providers in Table 1). Additionally, successful execution of customization work involved (a) building capacity; and (b) managing/governing work. These are now discussed.

5.1.The capacity building model

Customization, in the projects reported in this paper, was possible due to cooperation between IT professionals, health services researchers, healthcare service providers and managers, and statisticians. While some belonged to the customization settings, others moved across settings. This means that software customization execution is possible through collaboration or participation in social activities (Gherardi, 2013).

Three distinct but interdependent participation dimensions were identified in this study, namely guest, cluster and situated. The guest dimension considers the customization

work as performed by people doing similar activities. This contrasts the view of software customization, presented in the beginning, stating that tasks are offloaded to local people. In the studied projects, customization work was seen being partially and in some cases entirely performed or dependent on outsiders, the 'guest' customizers. This spanning or sharing of responsibility, provide flexibility that enables the team to succeed despite unexpected complications (Scardamalia, 2002). Additionally, it supports the development of local customizers which are confidence and competence (Currens & Coyle, 2013), i.e., effective team players that are capable of performing problem solving.

The cluster dimension deals with customization practices involving inter-professional collaboration. In general, while the customizers had considerable knowledge of the technology, the customization actions and the settings; end-users had the know-how and tacit knowledge of the healthcare domain. Developers, on the other hand, had knowledge about the history and insights of the software and other IT artefacts. Findings illustrated in this paper reveal that stakeholders had opportunity to discuss with each other during the DHIS training workshops. Following Currens and Coyle (2013), this cluster perspective allow the stakeholders (participants of the training workshops) to develop understanding of their own discipline and the relationship to other disciplines. For instance, the workshop meetings were regarded as fruitful learning laboratories that enabled OGUMANIHA customizers to improve their system systems, as well as to share knowledge and artefacts and to work collaboratively with other community members.

Situated dimension considers the customization work as performed through engagement with tasks in the use settings. In this regard, practice is primarily gained through working with others (Currens & Coyle, 2013). The establishment and implementation of customization models like networks-of-action (Braa, Monteiro, & Sahay, 2004) is grounded on and supported by this dimension. The approach has enabled local customizers to be visited by people involved in similar projects in other contexts, as occurred in the customization of DHIS in three settings. The possibility of getting help of people from other settings permitted lessons from one setting to be transferred to other settings. This has happened with *DHIS Tracker*, where lessons from Malawi were later applied during the customization in Guinea Bissau (see details in Saugene (2013)); and with DHIS OpenHealthMapper, with lessons from Malawi being useful in Mozambique (see details in Saugene et al. (2012)). Beside spreading practices across settings, these individuals while heading the customization processes acted as requirement brokers between end-users and developer settings. The transporting of these

lessons helps to build understanding on local people and prepared them to act when problems arise.

Figure 5 depicts a model for building teams and capacity toward software customization. The figure portrays an ongoing process through which customization practice is converted into knowledge. The logic behind this model is that if adopting COSS is to contribute to the building of capacity it requires the combination of guest, cluster, and situatedness approaches. This combination will enable people (e.g., local context customizers, developers) to appreciate the complex interplay of different practice elements and approaches (Currens & Coyle, 2013).

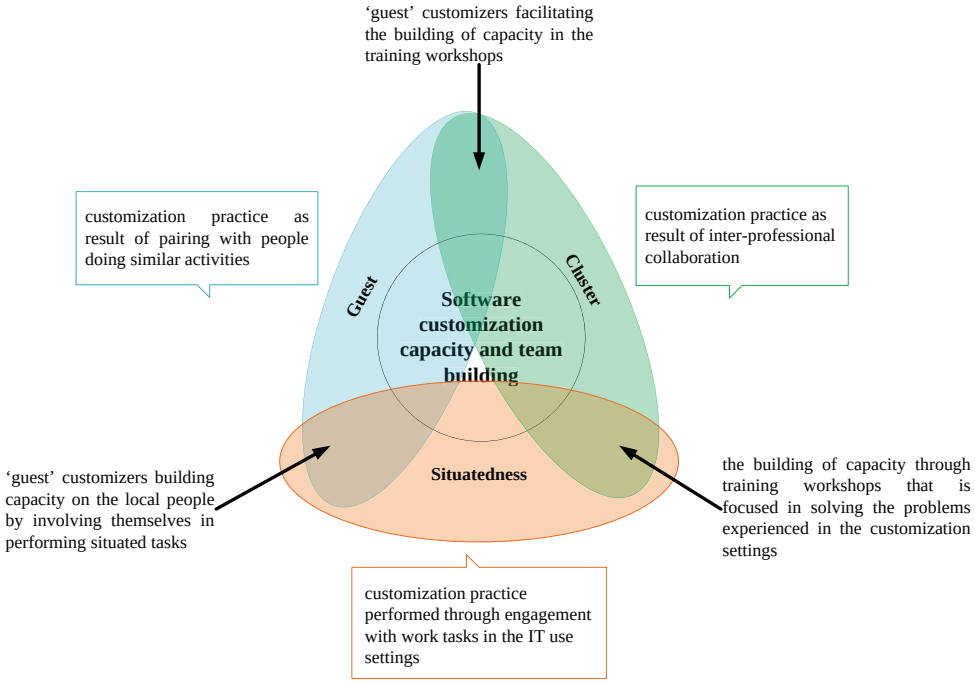

Figure 5: Model for capacity-building in software customization

5.2.The governance practice

Software customization capacity is inherent to governance practices, i.e., for capacity-building to occur smoothly there is a need of proper governance. Governance is defined as the process of coordinating and controlling resources and actions (Meyer, 2004). The process involves a systematic shaping of "who makes each type of decision (a decision right), who has input to a decision (an input right) and how these people (or groups) are held accountable for their role" (Weill, 2004, pg. 3).

Even though the study did not deepen in investigating customization governance mechanisms, shallow observation revealed disparity in some practices. For instance, while some project managers hired customizers based on job descriptions, others selected based on a superficial look at the customization tasks, thus ignoring job descriptions. With regard to this, Weill and Ross (2004) argue that, organization are more likely to perform better when common mechanisms are applied to management assets. Considering that DHIS customization work undergoes similar tasks in the settings, if there are similarities in human and financial government mechanisms, organizations can achieve better customization results and thus get more value from their COSS. It is, thus, believed that most of the customization difficulties, displayed in Figure 2, can be mitigated if, for instance, customizers are selected wisely, customizer teams have formal agreements with the software developers or teams have opportunity of meeting and discussing customization issues with other stakeholders (e.g., end-users, customizers and developers).

Moreover, an important component of governance practice is related to the management of boundaries between, for instance, the customizer teams and the developers. The networks-of-actions approach could be used toward that; but, since it is very difficult to know the individuals or institutions using a COSS tool, complementary approaches need to be developed. For instance, as long as customization work involve spanning and making linkages between the customizers and the developers, proper mechanisms will be required. The recognition of this may have contributed to the decision of introducing the regional training workshops, which are open to everyone including members of non-HISP customizations projects. Likewise, the fact that COSS are in constant change requires customizers' skills to be updated whenever a new version of the tool is released. This need becomes much more noticeable in software applications like COSS, and especially when introduced in low-resource settings.

6. Conclusion

The paper dealt with the issue of software customization in the context of low-resource settings and aimed at understanding how different software stakeholders interact to shape customization capacity. Three customization projects in the healthcare domain have been investigated with the aim of developing a model for understanding teams and capacity building toward software customization. Theoretically, and in order to provide insight into the interaction between healthcare social structures and information technologies, the study was informed by practice theory.

The study uses as point of departure the fact that, because of its dynamic landscape, adoption of COSS in healthcare was covered by a number of problems. In response to these problems, the various actions performed toward the effectiveness of the software customization practice, were identified as findings and used to address the research aim.

Particularly, insights developed in this study are threefold. First, given that "emergent" problems characterize COSS customization, customizers' tacit knowledge and skills appear to be very important. Second, due to the constant changes that COSS artefacts suffer, customization practice is most effective when combines the team tacit skills and knowledge with three overlapping approaches: guest - having guest people supporting the customization while promoting team practice and collaborative problem solving; cluster - helping customizers to appreciate the balance between their perspectives and others as they develop a broader view of practice trough inter-professional collaboration; and situatedness - revealing the realities of the practice through exposure to the domain complexity. Third, in order to maintain commitment of local customizers and manage customization support apparatus, projects require effective governance mechanisms.

These insights help in conceptualizing software customization not only as a social practice performed to suit end-user needs and demands into COSS, but also as a situated practice that require guests and clusters mechanisms. Then, it is believed that understanding software customization through these lines will help managers, especially from low-resource settings, to consider these elements when planning to adopt COSS. This conceptualization can, therefore, be seen as a cognitive strategy that might be used to sustain the development of flexible and practice-based customizers, i.e., individuals who are able to address the challenges emerging due to both complexity of healthcare domain and the low-resource settings.

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Table 1: Summary of customization tasks including stakeholders, supporting apparatus and work disruptions

Country	Customization Stakeholders		Supporting apparatus		Summary of work disruptions
	End-users	**customizers**	**Tools**	**People**	
Malawi	· MCH service providers · MOH managers	· CMED staff · DGS staff · DHIS aggregate data module customizers · local context researchers · one of the authors of the paper as a guest	· virtual communications (e.g., e-mail, mailing lists) · paper and digital archives (e.g., implementer manuals) · DHIS training workshop hosted in Tanzania in 2010	· HISP researchers · MCH service providers · framework developers · spatial data providers · local context researchers	· *DHIS2 Tracker* did not allow visualising data entered in another programs. This is framed in Saugene (2013) as "sharing data elements between programs" problem; · inexistence of documentation that could be used to guide the customization process; · customizers did not have skills to access *DHIS2 Tracker* source-code and make changes in order to meet local requirements;

Mozambique	· OGUMANIHA project partners representative at the M&E board · Field officers	· M&E managers · M&E IT officers · one of the authors of the paper as a guest	· virtual communications (e.g., e-mail, mailing lists · paper and digital archives (e.g., DHIS implementer, user and developer manuals, and OGUMANIHA project description document) · DHIS training workshop held in Tanzania in 2011	· OGUMANIHA project partners representative at the M&E board · M&E IT officers · framework developers	· problems with the internationalization of database content; · removal of excel feature from later versions; · inability of integrating the removed feature; · inability of linking OgIS database with *OpenMRS* based application;
Guinea-Bissau	· TB service providers · TB program managers	· HISP researchers · INASA staff responsible for TB program data · one of the authors of the paper as a guest	· virtual communications (e.g., e-mail, mailing lists · paper and digital archives (e.g., implementer and user manuals) · DHIS training workshop in Ghana in 2011 and in Liberia in 2012	· HISP researchers · TB service providers · TB program managers · framework developers	· difficult to find people with skills required for customization work; · problems in understanding HMIS, e.g., inability to differentiate data element from indicator, disparities in definition of formulas for indicator calculation; · lack of mechanisms for exporting a data entered into the database DHIS Tracker which made the customization to be redone from scratch each time a new version of framework was released;