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FOSS as a Platform Ecosystem: Understanding governance of open source HIS implementation in a Low and Middle Income Country context

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Abbreviations and acronyms

DHIS2 – District Health Information System 2

DMO – District Medical Officer (also known as Medical Officer of Health)

FOSS – Free and Open Source Software

HHIMS – Hospital Health Information Management System

HISP – Health Information Systems Programme

HIS – Health Information System

HISSL – Health Informatics Society of Sri Lanka

ICTA – Information and Communication Technology Agency

IS – Information System

IT – Information Technology

LMIC – Low and Middle Income Country

MCH – Maternal and Child Health

MO-HI – Medical Officer – Health Informatics

MOH – Ministry of Health

MOU – Memorandum of Understanding

NFOSHS - National Foundation for Open Source Health Software

PE – Platform Ecosystem

PGIM – Post Graduate Institute of Medicine

UNICEF – United Nations International Children’s Emergency Fund

WHO – World Health Organization

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Abstract

Free and Open Source Software (FOSS) is increasingly being used as the basis for health information systems (HIS) of choice in health system strengthening efforts in Low and Middle Income Country (LMIC) contexts. However, empirical evidence from these efforts show less than optimal results due to various systemic causes. The personal motivation for this research was driven by my empirical experiences of observing repeated “failures” of several such implementation efforts in Sri Lanka, The theoretical motivation comes from the growth of discourses around Platform Ecosystems (PE) and the potential of FOSS to be treated as a candidate PE. Hence, the research question I pursue is: who are the actors and what are their inter-relationships comprising a PE around FOSS based HIS implementation in a LMIC setting?; what are the underlying governance modalities in such an ecosystem?; and, how does trust play out in the orchestration of such an ecosystem?

Contemporary FOSS business models focus on the development side, while the PE literature primarily considers the governance of commercial software platforms. This thesis argues a PE perspective helps analyse governance issues by combining concepts of ecosystem and FOSS business models to help better understand implementation dynamics. Due to the relatively independent nature of participating actors, governance is theorized as an orchestration, the nature of it is explored in this thesis, especially in the early phases of FOSS implementation. Given the absence of a strong commercial focus and the freedom that external stakeholders have access to in FOSS implementation, the governance dynamics are unique and have not been explored earlier in ICT4D literature. Further, notions of inter-organizational trust helps to develop further insights into PE orchestration.

The empirical basis to analyse the research questions posed comes from a longitudinal study over a five-year period (2012-2016) in the State health sector of Sri Lanka which focused on 3 cases. While one concerned an implementation of a hospital information system in various hospitals, the second was around the adoption of a FOSS applications for the primary health care sector. The third case study was pertaining to the establishment of a national governance body to regulate open source implementations in the State health sector. While all three cases were studied through an interpretive lens, I was also an involved insider also engaged in different kinds of action such as design, advocacy and capacity strengthening efforts.

This thesis identified inter-organisational trust as a vital component in the orchestration process governing multi-sector stakeholder networks. This finding extends the vendor focused orchestration of traditional PEs to open source, contributing through the development of the PE analytical lens. This perspective also helps to extend understanding of traditional buyer-seller relationships to theorize the influence of trust in FOSS implementation governance through orchestration. This understanding was the basis to synthesise the proposed FOSS governance framework, and to suggest strategies to overcome barriers to effective governance of HIS implementation projects.

Chapter 1 - Introduction

This chapter provides an overview of the thesis and highlights key aspects of the research, such as theoretical and practical motivation, the reference discipline drawn upon, research design and expected contributions to contemporary Information Systems (IS) debates.

The first section of the chapter presents the practical and theoretical motivation for this study and the research questions pursued. The second section introduces the reference discipline guiding this research and the theoretical overview. The third section presents the background and the empirical setting of this research. The key contributions of this thesis are presented in the fourth section, followed by a description of the structure of the thesis.

1.1 Motivation and research questions

This research is motivated both by personal experiences and the reading of contemporary literature relating around Free and Open Source (FOSS) Health Information System (HIS) implementations in Low and Middle Income Countries (LMIC). I have, over the last decade, engaged in multiple HIS implementation projects in Sri Lanka and observed that most of the projects failed to thrive beyond the pilot phase, which has left me to reflect on the reasons. These HIS implementations were based on FOSS platform and supported by multiple stakeholders. These multi-sector actors functioned in inter-organisational networks (Powell, 1990), under the centralised governance of the Ministry of Health (MOH). The FOSS platform together with the multi-sector actors, their exchange and governance arguably form a software Platform Ecosystem (PE) around HIS implementation.

1.1.1 Practical motivation

My personal motivation was driven by my field-level experiences of observing and also participating in the repeated “failures” of several HIS projects in Sri Lanka. I have had the opportunity to participate in various FOSS project evaluations on behalf of the MOH which provided me an opportunity to understand some of the particularities of FOSS projects in the health sector, as compared to those projects based on proprietary systems. I have also been involved in establishing of the National Foundation for Open Source Health Software (NFOSHS), which provided me with intricate understandings of the perceptions of the MOH staff towards FOSS implementations and how their governance needs to be approached.

Many FOSS project failures in the Sri Lankan context could be attributed to governance related issues and the low levels of trust between different stakeholders. Similarly, the IS perspective is changing from mere software product line lens to PE lens, which can be described as a collective and inter-connected perspective of the software platform, platform developers, the community of users and a domain specific service view of what the platform provides (Bosch, 2009). I have been increasingly intrigued by the dysfunctional structures of governance, which are characterized by the feelings of mistrust between the different stakeholders involved. Within this backdrop, my thesis focuses on understanding the different aspects of FOSS implementation governance and the role of trust in shaping governance in a PE lens.

1.1.2 Theoretical motivation

The theoretical motivation comes from my readings around the discourses of the growing body of knowledge around PEs and the potential of FOSS in low resource settings. Câmara and Fonseca (2007) have identified the potential of FOSS to provide many benefits in IS implementation in LMICs. I am intrigued as to why this potential seems to remain largely unmaterialised within the context of HIS in LMICs more generally and in Sri Lanka in particular.

HIS implementation in LMIC contexts is special as it involves multiple stakeholders and a dynamic set of priorities due to a limited IS expertise within the State health sector and the relatively limited investments in information technology (IT) and health sector. To conceptualise this complexity, I draw upon the notion of PE, which has been defined to consist of a software platform, internal and external developers and community of domain experts in service to a community of users that compose relevant solution elements to satisfy the needs of an organisation (Bosch & Bosch-Sijtsema, 2010). This conceptualisation of PE aligns with the current direction of enterprise-wide FOSS implementation with its provision to build upon existing code base and accommodate the participation of different stakeholders such as software developers, domain experts and end users.

However, despite the potential that software ecosystems provide to analyse the empirical phenomenon, there are important modifications I need to make to the original concept. As compared with the discussion on PEs in mainstream IS literature, there are at least three points of difference which need to be considered:

1. Focus on FOSS
2. Primary focus on implementation rather than on development
3. Focus on the processes rather than the products (architecture)

A software platform is a software-product that serves as a foundation on which outside parties can build complementary products (Tiwana, 2013). A software platform, together with the network of organizational actors around it forms a PE. Many authors refer to commercial software platforms, especially with a software development focus (Manikas & Hansen 2013; Tiwana, 2013). I draw upon the current PE conceptualization, such as by Tiwana (2013), and apply it to the FOSS implementation context. Current FOSS business models focus more on exchange among FOSS stakeholders than on the governance within the FOSS implementation context (Dixon, 2009; Krishnamurthy, 2003). On the contrary, PE models analyse its governance, although in a platform architecture informed perspective rather than a user-based perspective. Hence, by combining these two views, I expect to reach a deeper level of understanding of the FOSS implementation governance process.

FOSS has been identified as a candidate for building a PE (Kilamo, et al., 2012). In Tiwana's PE model (2013), which is based on proprietary software platforms, the governance of the ecosystem is focused around the *keystone organisation*, which conventionally is the platform owner who orchestrates the PE (Tiwana, 2013). Orchestration implies the process of ensuring the integration of the outputs of diverse ecosystem participants through a loose coordination attempt rather than tightly controlling the process. However, in the FOSS implementation context, the governance focus seems to shift from the platform owner (platform developer) to the organisation commissioning the implementation (Ministry of Health - MOH, in my cases). Also, due to its proprietary focus, current PE conceptualisations discuss orchestration in the context of pricing. I believe by bringing in FOSS to PE discourses, I would be able to extend the orchestration concept to non-proprietary settings.

The health sector of LMIC is intrinsically political and HIS implementation involves number of actors with different agendas (Braa, et al., 2004). Identifying the network of actors to facilitate the politically charged changes is a key challenge in HIS implementation. Further, the existing literature indicates the scarcity of the PE concept being used in the stakeholder perspective, and also in understanding FOSS implementations in association with PE dynamics. Hence, this thesis aims at contributing to developing a theoretical understanding of the process of FOSS implementation governance seen through the lens of PE orchestration. I seek to build inductively from the empirical experiences and to conceptualise the relation between governance of the multi-sector organisational network drawing upon notions of PE governance.

1.1.3 Research Questions

The main argument leading to this thesis is that, in FOSS implementation ecosystems the platform orchestration is different from the traditional models as described by Tiwana (2013). I argue that the shift of governance focus from platform developer to the organisation commissioning the FOSS implementation has implications on the governance of the implementation network.

The overall objectives of the study are, t*o understand the platform ecosystem governance in free and open source implementation in the public health sector of a low and middle income country context* and; *to understand the role of trust in platform ecosystem orchestration in free and open source implementation.*

Hence, the study is based on the following research questions.

1. Who are the actors and what are their inter-relationships comprising a platform ecosystem around a free and open source based health information system implementation in a low and middle income country setting?
2. What are the governance modalities in free and open source implementation ecosystem in low and middle income country context?
3. How does trust play out in the orchestration of platform ecosystem around free and open source implementation?

1.2 Theoretical Underpinning

This study broadly focuses on the literature relating to PEs and FOSS, particularly their governance aspects. I also draw upon concepts around governance and trust from different domains of study including management, organisational studies and information systems. In drawing upon these different concepts the thesis seeks to build a deeper conceptual understanding of the implementation dynamics around FOSS based HIS applications conceptualised as a PE.

For the purpose of this thesis, I would like to introduce FOSS implementation as a collective term to encompass open source configuration, customisation, component development on FOSS platform and end-user training and support. The definitions of the other key concepts used in this thesis are summarised below.

Governance: A*ll the structures and processes that coordinate and control an organisation's resources and actions* (Meyer, 2004)

Platform Ecosystems: *A software platform, a set of internal and external developers and community of domain experts in service to a community of users that compose relevant*

solution elements to satisfy their needs (Bosch & Bosch-Sijtsema, 2010).

Trust: *A party's willingness to accept vulnerabilities, but with an exception or confidence that it can rely on the other party.* (Lewicki, Tomlinson & Gillespie, 2006)

1.2.1 Platform Ecosystems

IS discourses are currently moving towards an ecosystem thinking (Elbanna, 2010). An ecosystem refers to a networked community of organisations, which base their relationships on a common interest in a central software technology (Hansen, 2011). *A PE is defined as a software platform, a set of internal and external developers and community of domain experts in service to a community of users that compose relevant solution elements to satisfy their needs.* (Bosch & Bosch-Sijtsema, 2010). In this context, a PE is theorized as a means to construct a large software system on top of a software platform by composing components developed by actors both internal and external. Within this conceptualization, the scope of a PE is elaborated as a broader concept, including external developers and the extensions that they provide and the other parties who contribute.

PE consists of a software developed, maintained and evolved through collaboration of the software product developer and 3rd party component developers and several layers of actors customizing and configuring the software product (Dittrich, 2014). Around a PE, there exists a network of internal and external developers and domain experts in service to a community of users (Bosch & Bosch-Sijtsema, 2010). In an open ecosystem development model, both internal and 3rd party developers have the capability to release software components on top of the software platform (e.g. FOSS framework and apps). Tiwana (2013) further elaborates on PEs by highlighting the role of internal developers as the platform owner or the *keystone organisation*. In this conceptualisation, PE requires the platform owner to deliberately govern its evolution and this approach was introduced as PE orchestration.

1.2.2 FOSS as a Platform Ecosystem

FOSS seeks to promote local technological development by providing access to the community to the source code of the software artefact. This potentially supports LMICs to set up and manage their own information economy, by advancing knowledge more quickly and avoiding being held hostage to proprietary software (Câmara & Fonseca, 2007). Beyond providing free access to the source code, FOSS permits modification and free distribution of the software source code and derived

work[1]. Hence, FOSS promises reduced *Total Cost of Ownership* through vendor independence, technology and competitive costs for software adaptation and customization. With this enabling nature, FOSS is increasingly becoming central to health sector computerization efforts, especially in the global south (Twaakyondo & Lungo, 2008). However, due to technical and financial limitations in LMICs, effectively realising a FOSS HIS implementation demands active participation and coordination of various stakeholders, which is often beyond the central control of health care authorities.

FOSS is considered as a candidate platform to build PEs (Kilamo, et al., 2012). FOSS includes transparency of development and the freedom to build more complex systems out of readily available components creating PEs. The FOSS phenomena has undergone significant transformation from its free software origins (Fitzgerald, 2006) to a more mainstream, commercially viable form referred to as *FOSS 2.0* (Marsan, Paré & Wybo, 2012). Under this new business model, customers are willing to pay for customising FOSS software to align the generic FOSS design to organisational business needs (Fitzgerald, 2006; Riehle, 2007). Hence, FOSS can also be seen as a configurable IT package (Pozzebon & Pinsonneault, 2005), involving global-local negotiations to mediate the implementation process. Configurable IT implementation involves not only internal stakeholders, but also a network of external stakeholders such as software vendors, external contractors or system integrators, independent consultants, product extension vendors supporting IT capabilities.

This negotiation space is strongly influenced by initial decisions made by the organisation's top management regarding who controls the project (Pozzebon & Pinsonneault, 2005). In the FOSS implementation context, the decision rights lies with the organization which commissions the implementation process (e.g. MOH) instead of the platform owner (the FOSS developer firm) as described in Tiwana's PE model (2013). Understanding the dynamics of interactions surrounding the different actors of this PE is considered as an important aspect in FOSS implementation governance (Riehle, 2009). Hence, several open source business models attempt to describe these stakeholder relationships. *Single-vendor Commercial Open Source Model* and *Service/Support Commercial Open Source Model* proposed by Dixon (2009) and *Third Party Service Provider Model* proposed by Krishnamurthy (2003) were central among them. The Single-vendor Commercial Open Source Model describes FOSS developer firms attempting to customize its own generic FOSS code repository to create a whole software product, whereas the Service/Support Commercial Open Source Model depicts the emergence of 3rd party software product developers on

1 Open Source definition, https://opensource.org/osd

a FOSS platform. In contrast to these, the Third Party Service Provider Model elaborates the process of FOSS related service delivery around a community empowered FOSS product.

1.2.3 Governance of PE

Within the emerging FOSS 2.0 paradigm, customisation and productisation has become an important step in adopting FOSS solutions (Fitzgerald, 2006). In this paradigm shift, various FOSS governance models have been coined in the literature (Markus, 2007). Governance refers to all the structures and processes that coordinate and control an organisation's resources and actions (Meyer, 2004). The PE functions as a network of organisation which base their relationship around a common interest in a central software technology (Hanssen, 2012). In the governance of inter-organisational structures, such as in PEs, the autonomous nature of the organization participating in the cooperative endeavours has to be paid due recognition (Provan & Kenis, 2007). The authors also highlight the fact that such inter-organisational networks are not legal entities and hence the legal imperative for traditional governance may not be present. However, networks can be seen as a governance approach which could ensure that participants engage in collective and mutually supportive action. The shared form of governance inherent to networks may range from de-centralised to brokered (centralised) forms.

Governance of PE also demonstrates features of a brokered network (lead-organisation governed) with the dominant role played by the keystone organisation (Tiwana, 2013). However, due to the independent nature of participating actors, the governance in PE has been theorized as an orchestration, mainly with decision rights and control mechanisms. Tiwana (2013) has proposed four control mechanisms in the PE context. These include gate-keeping, metrics, process control, and relational control. Constantinides and Barrett (2014) describe governance as a collective action, involving poly-centric governance (compared to traditional governance with mono-centric unit) where multiple governing units appear at different scales. Poly-centric systems exercise considerable independence to make norms and rules within a specific domain (e.g. FOSS Implementation). In such network structures, governance is broken down to layers with distributed decision-making powers across stakeholders.

1.2.4 Role of trust in PE governance

With the emergence of the network organisation, the classical hierarchical governance has been increasingly challenged, requiring alternative models of governance (Ribbers, et al., 2002). In this

background, Miranda and Kavan (2005) highlight the significance of non-contractual mechanisms, such as trust in IS governance. Hurni, and Huber (2014) had highlighted the role of inter-organizational trust in the PE context, which is in the form of the trust of an employee of an organization towards the platform vendor. Schreieck, Wiesche, & Krcmar (2016) has also highlighted the trust as an important factor to shape the governance in PEs. Hence, the role of trust extends beyond its inter-organizational scope giving a unique perspective in PE context. Trust has also been identified as a risk factor in collaborative software development involving multiple organizational units in many domains, including the corporate health sector (Mohtashami, et al., 2006). However, trust has not been analysed in LMIC settings with a particular focus to FOSS implementations governance involving HIS projects.

Inter-organisational trust, which was defined as "the extent of trust placed in the partner organisation by the members of a focal organisation" Zaheer, McEvily and Perrone (1998, p142), has been identified as a key determinant in maintaining the fabric of a network organisation (Sørensen & Torfing 2009; Uzzi, 1997). While acknowledging trust as a key aspect in inter-organisational relations, Provan and Kenis (2007) have highlighted that the distribution of trust is critical in the governance of networks. They have also argued that networks face tensions between the need for administrative efficiency and inclusive decision-making. Gallivan, (2001) has argued that, while various control mechanisms can ensure the governing of autonomous agents, trust is a key determinant in control (and hence the governance) process.

Creed et al. (1996) argue that, in a network organisation, where traditional control mechanisms are generally ineffective, the requirement of trust is high. The orchestration of PE (Tiwana, 2013) can also be theorised as an occasion where the traditional hierarchical governance mechanism is challenged. There are three dominant characteristics of trust - vulnerability, risk and expectations (Edelenbos & Klijn, 2007). During PE orchestration, the keystone organisation expects a similar degree of control to hierarchical governance against the vulnerability conveyed by the independent nature of the stakeholders being orchestrated. Individual actors who play a critical role in propagating and establishing inter-organisational trust are referred to as boundary spanning agents (Perrone, Zaheer & McEvily, 2003).

Inter-organisational trust tends to be especially important in the early phase of HIS implementations~~,~~ where multi-sectoral stakeholders operate based on mutual understanding (Miranda & Kavan, 2005). Further, Brender et al. (2006) argues that trust is an important factor for HIS success even after consolidating inter-organisational relationships with formal contracts. Similarly, due to the multi-faceted nature of possible ethical issues in HIS implementation, it has

been argued that trust is an important concern in seeking sources of funding and selecting software vendors/service providers (Randeree, Kishore & Rao, 2005; Kopala & Mitchell 2011; Spriggs, et al., 2012).

1.3 Research Context

Historically, the Sri Lankan health sector is known to have achieved good health outcomes at a low cost (Somanathan, et al., 2000). This success can be due to the State's policy to maintain the quality of care by being selective in allowing participation of non-state health sector organisations in care delivery (Baru, 2003). In the Sri Lankan context, health care delivery involves the interplay of the internal actors, who usually are the State health sector owned health programmes and campaigns (Samaratunge & Bennington, 2002).

The State health sector is the main health care provider in Sri Lanka covering 93% of in-patient admissions and 50% outpatient visits (Ranna-Eliya & Sikurajapathy, 2008). Given that the MOH does not have a strong in-house IT department, it is necessary for them to collaborate with other public and private entities in the course of system development and implementations. The tension resulting from the multiplicity of partners and their varying interests creates challenges in HIS implementation governance. The State health sector administration tends to be very rigid and centralised. As a result multi-sector interactions need to be heavily brokered by the MOH (Baru, 2003). This provides an interesting opportunity to study the implementation dynamics in a brokered network setting, which may help to analyse the ongoing tensions between PE dynamics and State systems seeking to govern the network.

1.3.1 Empirical Setting

This study was conducted in the State health sector in Sri Lanka covering both preventive and curative healthcare settings. In the Sri Lankan context, the State health sector, which is the largest prospective HIS client, requires collaboration of non-health sector actors in introducing FOSS to the State health sector in various capacities such as technical and funding partners. The policy of state driven efforts (Samaratunge & Bennington, 2002) is challenged in the context of HIS projects, as the State on its own does not have the required in-house capacity and expertise, but necessarily needs to depend on various external sources of support. However, implementation decisions are taken by the central healthcare authorities, which impact the participation of these non-health sector stakeholders and their interactions with health sector actors.

The research design encompassed three case studies. Out of which, two were large scale FOSS HIS implementations, namely, the District Health Information System (DHIS2)[2] and Hospital Health Information Management System (HHIMS)[3]. The third case was a State health sector based attempt to establish a FOSS governance body, NFOSHS. The DHIS2 case study was based in the preventive sector and comprised of three programme-wide public health IS implementation projects - Maternal and Child Health (MCH) Information System, Tuberculosis and Respiratory Diseases eRegistry and Nutrition Monitoring System. The case study, HHIMS was based on an electronic medical record implementation project in several curative sector healthcare institutions within the State health sector. The HHIMS implementation network included more than 15 hospitals in five districts. NFOSHS was initiated as a proposal to establish a governance body around HHIMS implementations and later expanded to the scope of the national FOSS governance body for the State health sector of Sri Lanka. Hence, the NFOSHS was established through the contribution of multi-sectoral stakeholders.

1.3.2 Research approach

This research was based on a longitudinal case study approach over a five year period from 2011 to 2015. A qualitative research methodology within an interpretive tradition was adopted during the study. I followed a multi-site empirical approach in selecting field settings (Marcus, 1995), which was based on my involvement in HIS implementations in Sri Lankan State health sector prior to 2011 and the research objectives of this study. The DHIS2 case study provided a top-down approach perspective to this study, while the HHIMS case study provided a local initiative perspective giving a contrasting picture. The reason for the DHIS2 to take a top-down approach was the highly brokered network scenario of public health sector in Sri Lanka and the implementation was mediated and supported by a diverse collection of local and international actors.

I have played various (sometimes overlapping) roles in this study during the data collection process. These ranged from an IS researcher, an implementer, a member of HIS project evaluation committee and a member of a FOSS governance body. However, during the study my involvement in these implementations, evaluation and representation in the FOSS governance body was through representative organisations. Hence, I didn't influence the implementation process with my personal motives, but was largely bound by the organisational decisions.

Participant observation was a key data collection approach in this study (Flick, 2012), and this was

2 https://www.dhis2.org
3 http://www.hhims.org

supplemented by several other multi-method approaches (Mingers & Brocklesby, 1997) such as, unstructured and semi-structured interviews, focus group discussions and document analysis such as of project steering/evaluation committee meeting minutes, email excerpts and online forum communications.

Data analysis followed the interpretive tradition (Walsham, 2006) within a comparative case study approach (Yin, 1981; Yin, 2003). The multi-sector stakeholder network around FOSS implementation was considered as the unit of analysis in each case where data was collected, compared and contrasted (Reeves, Kuper & Hodges, 2008) to get an in-depth understanding of governance trajectories and the influence of trust. Within-case data was analysed and cross-case patterns (Eisenhardt, 1998) were identified to discern the governance trajectories, with the aim of understanding, how the PE surrounding FOSS HIS implementation has evolved and to identify the dynamics of interactions among different stakeholders. The within-case analysis focused on variations of governance and perceptions of trust amongst the different organisational actors during the orchestration of PEs. The cross-case analysis tried to identify variations of governance trajectories shaping the evolution of FOSS implementation network in the context of the different PEs studied.

1. 4 Key Contributions

This thesis with its focus on building a deeper understanding into early phases of FOSS HIS implementation in LMIC settings, contributes theoretically to current PE and FOSS implementation discourses. Practically, this work guides on-going HIS implementation activities in Sri Lanka and to FOSS implementations in the Health Information Systems Programme (HISP) network, currently being coordinated by the Department of Informatics, University of Oslo, Norway. First, I introduce the papers comprising my thesis, which is followed by a summary of the theoretical and practical contribution.

1.4.1 Findings

The empirical findings are presented in the following five papers.

Paper 1: Hewapathirana, R., and Rathnayake, S. (2014). How Health Managers' Trust Towards FOSS Implementers Changed and Shaped HIS Implantation Trajectories: An Empirical Study of Selected FOSS HIS Implementations in Sri Lanka. International Journal of User-Driven Healthcare, 4(1), 17-32.

Paper 2: Hewapathirana, R. (2015). Network governance in open innovation adoption: Case study from health domain. 13th IFIP 9.4 conference. Negombo.

Paper 3: Siribaddana, P. A., and Hewapathirana, R. (2016). Using Training as a Tool for Cultivating Communities of Practice around Health Information Systems in Low and Middle Income Countries: A Longitudinal Mixed Method Study. Electronic Journal of Information Systems in Developing Countries, 73.

Paper 4: Hewapathirana, R., and Sahay, S. (2017). Open Source adoption in health sector: Understanding the stakeholder relationships in a resource constrained setting. Electronic Journal of Information Systems in Developing Countries, 81.

Paper 5: Hewapathirana, R., Amarakoon, P., and Braa, J. (2017). Open Source Software Ecosystems in the Health Sector: A Case Study from Sri Lanka. In International Conference on Social Implications of Computers in Developing Countries (pp. 71-80). Springer.

A summary of the papers is presented in the research findings chapter and the completed papers are appended in the annexes. Based on the five papers, the thesis argues for a shift in governance focus from platform developer to the organisation commissioning the FOSS implementation which has implications on the governance of the PE. Further, the thesis seeks to deepen our understanding of the role of trust in FOSS implementation governance.

1.4.2 Theoretical Contribution

I argue in this thesis that the shift of governance from traditional centralised-focus to orchestration is less administratively efficient by dominant health care organisation (MOH) and hence contributes to a rising tension in the FOSS implementation network. In such a scenario, the building of inter-organisational trust can help to resolve some of the tensions among networked participants, and prevent a breakdown in the network. Hence, this thesis identifies inter-organisational trust as a vital component in the orchestration of multi-sector stakeholder network surrounding FOSS implementation. I extend the vendor focus orchestration of Tiwana (2013) to the FOSS implementation context by highlighting the key differences of PE governance when the platform becomes open source. Hence, I contribute to the IS literature by presenting FOSS implementation dynamics through a PE perspective, which has not been done in IS research so far.

Doney, and Cannon, (1997) have emphasised the role of the buying firm's trust of the supply firm and on the sales person in the traditional buyer-seller relationship. In this thesis, I argue that this is a

comparable analogy to understand the role of trust in PE orchestration in FOSS implementation with the assistance of the keystone-centric PE model proposed by Hanssen (2012). Highlighting the user perspective in PE, I propose extending the traditional buyer-seller relationship model (Doney & Cannon, 1997) to theorize the influence of trust in FOSS implementation governance presented as the orchestration of PE. This aids understanding the focus of tension within the FOSS implementation network, which is between the organisation commissioning FOSS implementation, the FOSS implementers and the developer entities. Drawn from current FOSS business models (Dixon, 2007; Krishnamurthy, 2003), this understanding was instrumental in synthesising the proposed FOSS governance framework presented in this thesis.

1.4.3 Practical Contribution

In the light of the role of trust on PE orchestration and the proposed FOSS governance framework, several factors were highlighted which could be decisive in shaping FOSS implementation practices. The proposed FOSS governance framework is centred on firms external to the client organization, and who manage the FOSS development and provide post-release customization support to the client organization. This contributes to the understanding of the process of commercialising FOSS in enterprise scale implementation projects with external implementation support through outsourcing. The proposed model identifies the key stakeholder groups involved in FOSS HIS implementation in a LMIC context and their relative influences on the implementation decisions and implementation trajectory. The influence of stakeholders, such as development partners, on implementation governance often tends to be neglected during the analysis of stakeholder interactions. However, they could be the ‘hidden cause’ for FOSS HIS implementation failures and need to be mitigated and managed.

Hence, the understanding of the tensions between hierarchical governance and networking, formal and informal control and coordination mechanisms and the role of boundary spanning agents may help in resolving disputes during FOSS implementation governance. Several implications of inter-organisational trust are seen to be useful in a practical context, such as the Total Cost of Ownership of FOSS product, fear of unauthorised access to HIS by platform developers during implementation and the trust-based nature of initial contracts within the implementation network.

Practically, this thesis identifies the MOH as an emerging FOSS client organisation who need to interact with a range of health sector and non-health sector organisations. The lessons learnt from this study could be used to shape the governance trajectory of several new HIS initiatives, and enable positive returns from IT investments in the public health sector. The findings of this thesis

will be useful for the other members of HISP network and prospective development partners, especially in identifying and mitigating the issues related to trust-based contracts and trust breaches between client organisation and HIS implementers in the early phase of HIS implementations.

1.5 Structure of the thesis

This thesis consists of eight chapters as follows.

Chapter 1- Introduction: This chapter describes my motivation to embark on this study. Further it elaborates the research question, theoretical underpinning of this thesis, research context of the study and research approach. Finally, the chapter concludes with summarising the theoretical and practical contribution of the study.

Chapter 2- Research Context: The first section of the chapter describes the features of the State health sector of Sri Lanka, relevant to understand this research. The rest of the chapter elaborates the empirical cases analysed in the study, namely the HHIMS, DHIS2 and NFOSHS.

Chapter 3- Research Approach: This chapter focuses on the research approach adhered to in this study. It elaborates the research methodology, including the selection of field work and data collection and analysis approaches. Further, this chapter discusses the role of the author during the field work and the ethical dilemmas came across during the study.

Chapter 4- Related Research: - In this paragraph, I will discuss the current discourses on PE, FOSS governance trend and the notions of trust in inter-organizational networks and PE context to identify the existing knowledge gap. Later in the chapter, I relate these seemingly independent concepts to synthesize a conceptual framework which I later used to discuss the findings to answer the research questions.

Chapter 5- Findings: This chapter summarises the findings of the five papers presented in this thesis. Next, it synthesises the empirical findings aligning the research questions against the findings discussed in each paper providing the insight in to understand the PE governance in FOSS implementation in LMIC context and role of trust in PE orchestration in FOSS implementation.

Chapter 6- Discussion and Analysis: This chapter presents the analysis and the discussion of the empirical findings presented in the previous chapter. In the first section, the empirical evidence has been analysed to answer the three research questions leading to this research. In the second section, the findings were discussed in relation to the objectives

of this research.

Chapter 7- Contribution: This chapter presents the theoretical and empirical contribution of this research. Theoretical contribution mainly focuses on PE governance and the role of trust in FOSS implementation. This thesis practically contributes to the HIS implementations both in Sri Lankan and HISP contexts.

Chapter 8- Conclusions and Recommendations: First section of this chapter presents the conclusions of this research. The second section presents the recommendations thereof further work of this thesis.

Chapter 2 - Research Context

This chapter introduces the research context of the study. The research focus was to understand PE governance in FOSS implementation in a LMIC context and; the role of trust in PE orchestration. The first section of this chapter describes key features of the State health sector of Sri Lanka, including the health financing model, eHealth readiness and the central and provincial administrative systems. The second section describes the three empirical cases analysed in this thesis namely, the DHIS2 implementation for MCH, Tuberculosis and Respiratory Diseases eRegistry and Nutrition Monitoring; the HHIMS project, and the attempts to establish the NFOSHS attached to the MOH to govern FOSS HIS implementations in the State health sector.

2.1 The State health sector of Sri Lanka

Even with limited resources, Sri Lanka has a well-established health services delivery system with health indicators, for example maternal mortality, neonatal mortality, and life expectancy at birth, at comparable levels to those of the developed world (WHO, 2012). The State sector managed health initiatives have reduced the incidence of many communicable diseases and the national policy of free health care at the point of delivery and universal health coverage (Silva, Ranasinghe, & Abeykoon, 2016) have brought down mortality statistics significantly. Sri Lanka has an extensive network of public health units and hospitals spread across the island. Hospitals, in general, are well staffed and equipped to meet the growing curative health demands of the population.

Sri Lanka is one of the few developing nations in the South-East Asian Region to achieve their Millennium Development Goals and to provide for universal healthcare (UN, 2015). Significant achievements have been made in eradicating vaccine preventable diseases, leprosy, malaria, Japanese encephalitis, congenital syphilis, neonatal tetanus, lymphatic filariasis, and others. The Expanded Programme on Immunisation in Sri Lanka is among the most successful in the South Asian region as well as globally, which has achieved high vaccine coverage and resulted in an extremely low incidence of vaccine-preventable diseases. However, in comparison to the other health indicators, the nutritional status of children is not satisfactory, and neither is that of adolescents and women, despite the high literacy rate and economic growth (MOH, 2008). Even though the Sri Lankan health system is well-established for dealing with communicable diseases, ongoing demographic and epidemiological transitions now pose new challenges which calls for the reform of the healthcare model, including relating to the supporting HIS.

Table 2.1 summarises selected health and financial indicators of Sri Lanka.

Health Indicators (selected)	
Life expectancy at birth (2012)	75
Under-5 mortality rate per 1000 (2012)	10
Maternal mortality ratio per 100 000 live births (2010)	35
Neonatal mortality rate per 1000 live births (2012)	6
% Underweight among the 0-5 year olds (2007)	21.6%
Health Financing Indicators	
Total expenditure on health as % Gross Domestic Product (2011)	3.4
General Government expenditure on health as % of total Government expenditure (2011)	7.2%
Contribution of donor funding to national health budget as a percentage (2011)	6 %

Table 2.1: Selected health, financial indicators [Source: Global Health Observatory (WHO, 2014)]

2.1.1 Role of external stakeholders

Several international development partners are active in supporting the Sri Lankan health sector, including United Nations' Agencies such as United Nation's Development Programme, United Nation's Food and Agriculture Programme, United Nations International Children's Emergency Fund (UNICEF) and the World Health Organisation (WHO), international non-governmental organisations, multilateral and bi-lateral development organisations such as the World Bank, the Asian Development Bank, the Japan International Cooperation Agency, the Australian Agency for International Development and the United States Agency for International Development. Both Global Fund to fight AIDS, Tuberculosis, Malaria (GFATM) and the Global Alliance for Vaccines and Immunisation are active contributors to the health sector development. Even though the contribution of external funding is relatively minor (5.4% of government health expenditure) compared to the national health budget, international development partners and non-governmental

organisations are a valuable resource to the government by providing financial assistance, technical support for pilot projects, enabling of innovations, providing different policy options, and the aligning of global standards and operational guidelines to the national context.

2.1.2 Health Information Architecture

Despite these public health successes, the health information architecture in the country is largely manual, using centrally controlled collection and reporting of data entry forms. There are two distinct bottom-up data flows, relating to clinical and public health practices. Clinical data originates (mostly on a quarterly basis, except for disease notifications) at the health institution level for morbidity and mortality statistics, financial reports, medical supplies records and health work force management information. Public health data also originates, mainly quarterly, at the Medical Office of Health area, which is compatible with *health district* defined by WHO (2004) with data being gathered by Public Health Midwives and Public Health Inspectors. Public health related data first goes to the Regional Director of Health Services and the Regional Epidemiologist and then to vertical health programmes or the Department of Health via respective Provincial Directors of Health Services.

2.1.3 Administrative structure

The state health sector of Sri Lanka can be divided in to two i.e., the MOH of the central government (also known as the *line ministry*) and the Provincial MOH~~s~~. The MOH's key functions include the formulation of policy guidelines, supervision of medical, nursing and paramedical education and training, management of teaching and specialised medical institutions, and procurement of medical supplies. The nine Provincial MOHs are responsible for implementation and effective delivery of health services in their respective provinces (MOH, 2003).

The responsibility of health promotion at the national level primarily lies with the MOH. Under the Secretary of Health, there are three Additional Secretaries for Medical Services, Administration and Development. The Director General of Health Services (DGHS, in figure 2.1) is the highest administrative officer within the MOH hierarchy. The next level of the administrative hierarchy is the Deputy Director General. Under the supervision of the Deputy Director Generals, the directors manage health services within their respective technical areas. The Director Planning and Director Health Information are the main administrative positions responsible for HIS implementation related decisions. Directors of the vertical health programmes (e.g. MCH programme) are

operational under the Deputy Director Generals of the Public Health Services (DDG PS) I and II (shown in the figure 2.1 below). Management of the line ministry curative institutions are directly under the MOH through the directors of the hospitals.

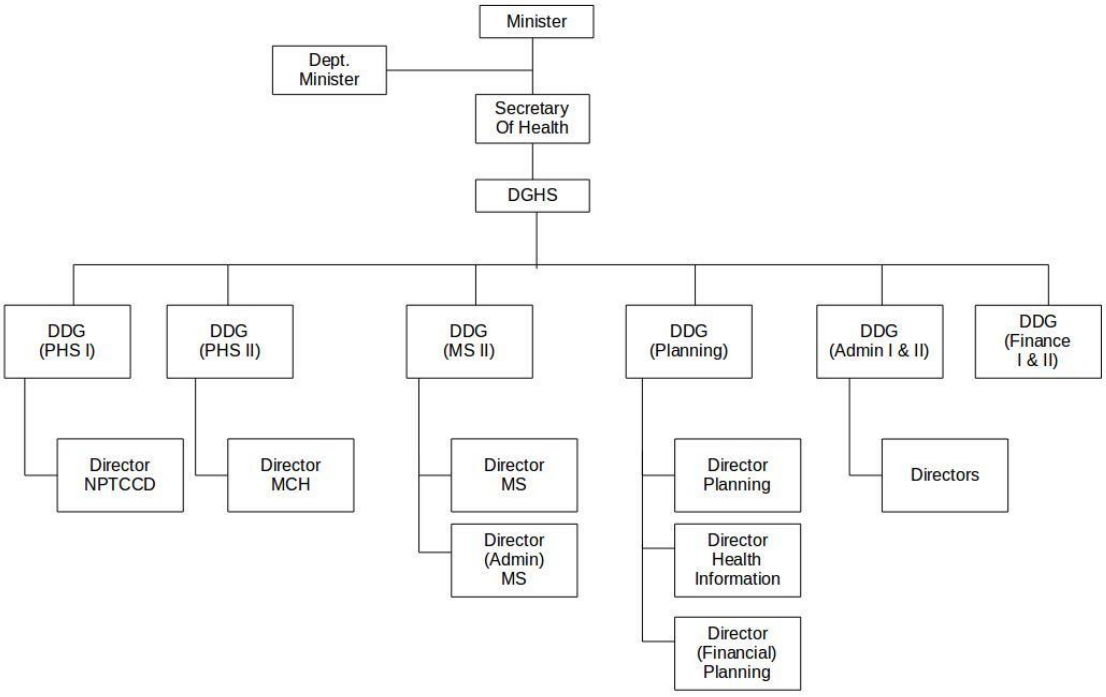

Figure 2.1: Simplified administrative hierarchy of the MOH

The enforcement of the Provincial Councils led to the devolution of state health services to the Provincial MOHs. As a result, while the central MOH has continued to function at the national level, separate Provincial MOHs have emerged in the nine provinces. Each Provincial MOH has Provincial Director of Health Services at the top of its governance hierarchy. There are 25 Regional Directors of Health Services who assist nine Provincial Directors of Health Services. Under the Regional Directors, there are several middle-level health managers for various technical areas with a regional scope. There are several Medical Officers of Health Divisions under each Regional Director, and each is managed by a Medical Officer of Health (also known as the District Medical Officer - DMO). Each Medical Officer of a Health Division caters for a population of up to 60,000 individuals. The figure 2.2 below illustrates the provincial and regional health administrative hierarchy.

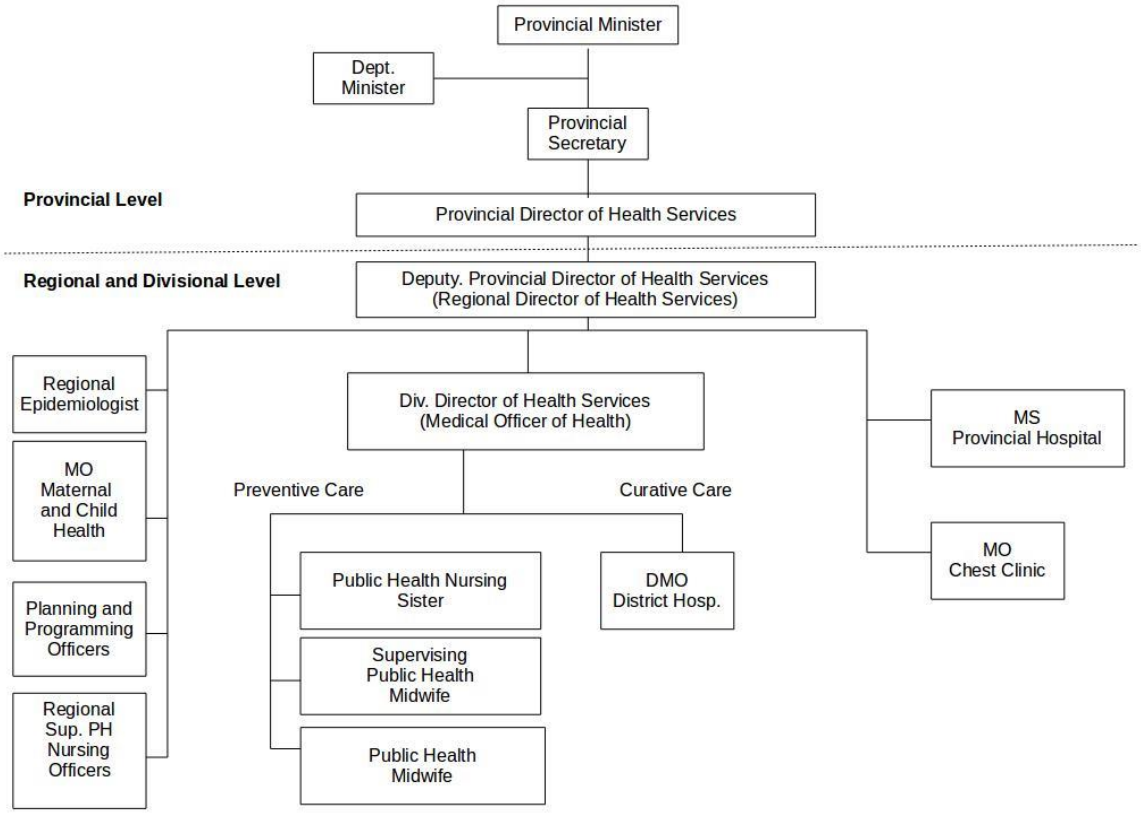

Figure 2.2: Simplified administrative hierarchy of a Provincial MOH

The Provincial MOH and the provincial health services provide a wide range of preventive, curative and rehabilitative health care through an extensive network of health institutions. DMOs are administratively operational under the Regional Directors whereas, Public Health Nursing Sisters, Midwives and Supervisory Midwives function under a DMO. The curative institutions from the Base Hospital and below are administratively under the Regional Director.

2.1.4 Health Financing for HIS strengthening

Sri Lanka is categorised as a LMIC by the World Bank. Sri Lanka's total health expenditure is lower than that of other countries with similar demographic profiles. The health sector is shaped by the concept of the welfare state and contributes to the country's significant achievements and investments in the sector. The health care system in Sri Lanka is primarily tax-financed and provides free and universal health coverage to all citizens. The role of insurance schemes is less crucial in this approach. Hence, the social welfare paradigm in Sri Lanka ensures universal health

coverage without sacrificing equity of care (Oxfam, 2013). Government allocations in the health sector remains at around 3.2 % of Gross Domestic Product (World Bank, 2015). The contribution of donor funds comprises of a minor proportion in the national health budget (Michaud, 2005). External financial resources for the health sector amounted to Sri Lankan Rupees 6302 million (roughly equivalent to $ 43 million) in 2010. Donor funds contributed 6% of the total public health expenditure (WHO, 2012). In the light of the new challenges presented by the epidemiological and socio-demographic transitions, making improvements in the national health financing system has been emphasised, to meet the need for significant modernisation and increased investments in the health system, including in the HIS.

The World Bank has been supporting the health sector to adapt to the new challenges by improving the degree of equity, quality and efficiency of the health system. The Health Sector Development Project, funded by the World Bank and implemented by the MOH, has a HIS strengthening component as a major component. The GFATM and Global Alliance for Vaccines and Immunisations are the two largest international partnerships in the public health sector and HIS is one of their priorities The Country Coordinating Mechanism of GFATM was established in March 2002 for purposes of coordinating the submission of funding proposals to the GFATM, and monitoring projects funded by the GFATM within Sri Lanka. The Country Coordinating Mechanism is a national-level multi-sectoral organisation, comprising of the public sector, private sector, members of academia, civil society, faith-based organisations, multilateral/ bilateral partners, people living with or affected by the target diseases and mass media.

The Norwegian Agency for Development Cooperation, also known as NORAD, had significantly contributed to address the health informatics manpower needs of the country. Under the NORAD *Programme for Masters Studies* (2008−2013) the Post Graduate Institute of Medicine (PGIM) of the University of Colombo together with the MOH, under the technical expertise of University of Oslo has produced about 70 medical officers with postgraduate qualifications in health informatics, known as Medical Officers in Health Informatics (MO-HI). Many national and international NGOs also support the efforts of the MOH to address the HIS needs of the country. Efforts of World Vision Sri Lanka, UNICEF Sri Lanka, Australian Red Cross and Swiss Red Cross are particularly noteworthy for their involvement to support HIS. The Japan International Cooperation Agency has provided technical expertise since 2003 to the MOH to strengthen the HIS through policy and health infrastructure development. The Korean International Cooperation Agency has also rendered support to improve the curative sector HIS implementations in several selected hospitals.

2.1.5 eHealth readiness

A key development challenge in Sri Lanka, as emphasised in the government's *10-year Development Framework*, is to accelerate growth through increased investment in infrastructure. In the health sector, this includes HIS strengthening as a strategic priority to support informed decision-making at all levels (WHO, 2012). However, Sri Lanka is still in the *experimentation and early adoption* stages in terms of eHealth and health sector computerisation (ITU, 2012). In recent times, different public health programmes and government health organisations have attempted to implement HIS to facilitate electronic capturing, storing and analysing of health data. The Health Information Unit of the MOH supports health information management while being positioned outside the major information flows. Hence, the health information management can be described as decentralised in the Sri Lankan context, where each vertical health programme or the health institute owns and manages its own data sets. Recently, the MOH has taken steps to station MO-HIs at all major vertical programmes and units at the central level, reflecting their efforts to become an information driven organisation.

Health institution-wide electronic medical record was introduced to Sri Lanka under the Swiss and Australian Red Cross aid after the 2004 Asian Tsunami. During this project, an electronic medical record system, Multi Disease Surveillance System was implemented in many hospitals in the Northern and Eastern Provinces of the country (Pole, 2010). DHIS2 was the first FOSS public health IS introduced to the Sri Lankan health sector and the first DHIS2 training was given to MOH officials in 2008 by the University of Oslo with the collaboration of the PGIM in Sri Lanka.

2.1.6 Human Resource for health sector computerisation

The IT workforce in the Department of Health can be categorised under several layers. The HIS commissioning is mostly done by administrative and managerial level staff, including the heads of institutions/units, programme directors, Director Health Information or Regional/Provincial Directors. In most cases, they are medical administrators or consultant community physicians in administrative positions, who may not have a strong IT or Health IT backgrounds. Preparing high level system architectures and requirement specifications, IT policy drafts, and tender documents to procure IT equipment and services, and the coordination of HIS implementations are mostly managed by MO-HI. They possess the required level of technical sophistication and cross-domain understanding, to perform these tasks.

Prior to specialising MO-HIs, medical administrators and managers were assisted in these tasks by *system analysts*, who were recruited from *All Island IT Staff* pool. They were not exclusive to the

MOH and were transferable across health and non-health institutions, with the potential of being promoted to the post up to Assistant Director – IT. Their role included technical duties ranging from data entry to database management and coding. Some system analysts developed small pieces of software required for the units or health programmes they were attached to. The role of the *data entry operator* was mainly performed by programme assistants and clerical staff. In the public health institutions, Midwives are expected to perform data entry tasks, while in the curative care set-up there is a post designated as *Medical Record Officer* for processing and reporting of hospital morbidity and mortality statistics. Electronic Medical Records are primarily handled by doctors, nurses and pharmacists. Since the MOH is not equipped with an IT support arm, system maintenance tasks are mostly performed on an ad-hoc basis, following a brief training, by minor-staff attached the institution and who have undergone a short training on computer repairs and network troubleshooting.

2.1.7 eHealth Policy and standardisation

There are several ongoing attempts to introduce national level guidelines to health sector computerisation, such as the National eGovernment Policy and the draft National eHealth Policy, the National eHealth Strategic Plan and the National eHealth Standards and Guidelines. The *National eGovernment Policy* was introduced in December 2009 as a cabinet paper titled, “Policy and Procedures for Information and Communication Technology usage in Government”. This policy advises on establishing IT units in all government organisations, drafting and implementing annual IT plans and allocating adequate annual budgets for IT procurement and maintenance. Further it guides on protection of personal data, standards, procurement procedures and contractual and licence issues related to both proprietary and FOSS implementations.

Subsequently, the MOH decided to formulate an eHealth Policy in 2012 to supplement the eGovernment Policy. Its mandate was “to adopt information and communication technology solutions appropriately in the healthcare sector of Sri Lanka to improve the quality, efficiency, patient safety, and cost-effectiveness of health care”. This policy was supplemented with the *National eHealth Standards and Guidelines* which provided recommendations for high level HIS architecture, ICT management, networking and connectivity, communication interface, ethics and privacy, information security and HIS interoperability. Drafting of these policies were initiated under the supervision of the National eHealth Steering Committee, a high level governance body formulated within the MOH to regulate health sector computerisation. The Provincial MOHs are supposed to adopt these policies while also modifying them to suit the provincial context. In

addition, the MOH attempted to establish the NFOSHS in 2013.

2.2 Case descriptions

Three cases are discussed in this thesis; the implementation of a FOSS electronic medical record system HHIMS, the open source public health IS, DHIS2 for MCH, Tuberculosis and nutrition monitoring and; an attempt to establish a FOSS governance body, NFOSHS in the State health sector. Figure 2.3 below summarises the trajectories of projects discussed in this thesis.

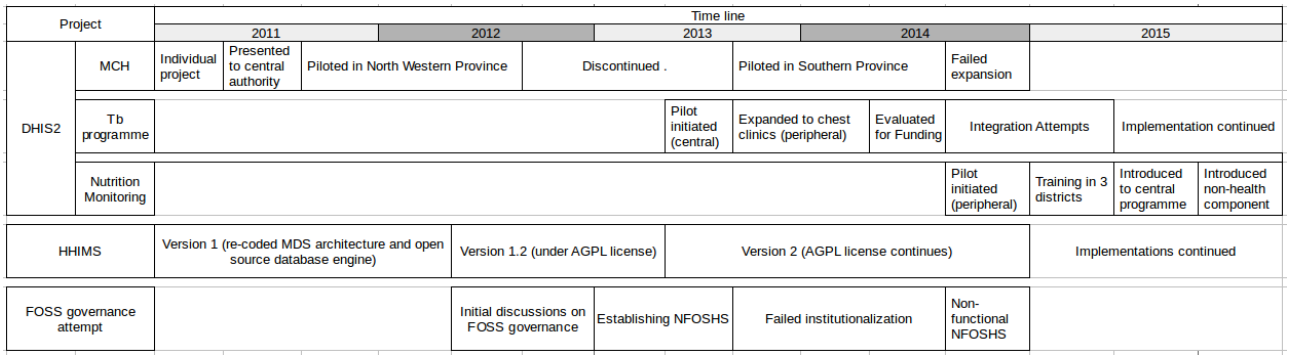

Figure 2.3: Major milestones of the projects studied under this study

2.2.1 DHIS2 implementation network

The DHIS2 is a flexible and customisable, FOSS public health IS developed by the HISP network[4] of the University of Oslo. HISP network includes the central HISP node and the core DHIS2 developer team positioned at the University of Oslo and the country HISP nodes in many countries where the DHIS2 software is implemented (Titlestad, Staring, & Braa, 2009). The DHIS2 development process involves a global collaboration between students, academics, researchers and developers in Norway, India, Vietnam and various African countries (Staring, & Titlestad, 2006). DHIS2 is a generic tool rather than a pre-configured database application, which needs further customisation during implementation to be used in a specific health programme contexts. In its current architecture, DHIS2 can even be introduced as a software platform (Braa & Sahay, 2012, p 153). The current releases of DHIS2 are equipped with two broader practices of data management, aggregate records and individual-focused records (DHIS2 Tracker component). It also possesses an Application Programming Interface (API), through which 3rd party module development is

4 http://www.mn.uio.no/ifi/english/research/networks/hisp/

facilitated.

During this study, I mainly focus on the trajectory of DHIS2 implementation in the State health sector of Sri Lanka. DHIS2 was first introduced to Sri Lanka in 2008 as a public health data collection and analysis tool by the University of Oslo and PGIM of Sri Lanka. Exposure to DHIS2 was also a part of the teaching in the curriculum of Masters degree programme in health informatics conducted by the PGIM of Sri Lanka in collaboration with the University of Oslo since 2008. Parallel to this, there were several hands on training sessions conducted for MOH officials on DHIS2 through HISP India in late 2009 and early 2010. In 2011, the Health Informatics Society of Sri Lanka (HISSL), which is the key not-for-profit health IT support team to the MOH, and the PGIM of Sri Lanka initiated the first provincial level DHIS2 implementation. Some MOH staff and students from the PGIM of Sri Lanka also participated in field visits in India in 2012 and 2013 for familiarisation with DHIS2 implementations. As of today, DHIS2 was successfully accepted by MOH for programme-wide implementations for Tuberculosis and Respiratory Diseases eRegistry, Nutrition Monitoring System and Non-Communicable Diseases eRegistry. However, in several other initiatives, such as MCH programme, the DHIS2 was struggling to get institutionalised during the period of this study.

The HISSL and a State technical university were among the major local technical entities supporting the MOH in DHIS2 implementation. The State technical university signed an agreement with the MOH in February 2013 to extend technical support for the State sector HIS implementations, including DHIS2. HISP India also extended its support for DHIS2 implementations in Sri Lanka. Initially, HISSL was primarily functional as a facilitator between the MOH and the HISP India. Due to various institutional reasons an attempt to sign a tripartite agreement between MOH, HISP India and HISSL failed. Later HISSL emerged to fill the vacuum of local technical expertise to support MOH in DHIS2 customisation and implementation.

2.2.1.1 MCH Programme

Initially the DHIS2 was customised as a student project for the MCH data stream carried out under the supervision of a senior consultant of public health. After adequate customisations, the system was demonstrated to the health managers and public health consultants of the MCH programme. This demonstration was mediated by the PGIM of Sri Lanka to obtain permission to pilot the student project under the supervision of the MCH programme. During the demonstration, ownership of the customised DHIS2 and data stored in it were questioned by the representatives of the MCH programme. As a result, the MCH programme did not approve the piloting. After the

initial failure of the top-down approach, in 2011, HISSL tried to implement DHIS2 in a bottom-up manner in the North Western Province of Sri Lanka with the permission for the pilot study from the Provincial Director of Health Services. For this purpose, the previously customised DHIS2 instance was used with minor modifications. To support the implementation, it was decided to sign a tripartite agreement between HISSL, Provincial MOH of North Western Province and HISP India, who agreed to provide technical support for the implementation. Unfortunately, the signing did not materialise due to administrative reasons. However, the Provincial Director permitted HISSL to initiate the pilot exercise under the supervision of the provincial director and Medical Officer – MCH, until it was further evaluated for a province-wide implementation. The five Medical Officer of Health divisions were recommended as the pilot sites. Figure 2.4 illustrates a midwife entering MCH data using a laptop computer at the Medical Officer of Health office during this pilot study.

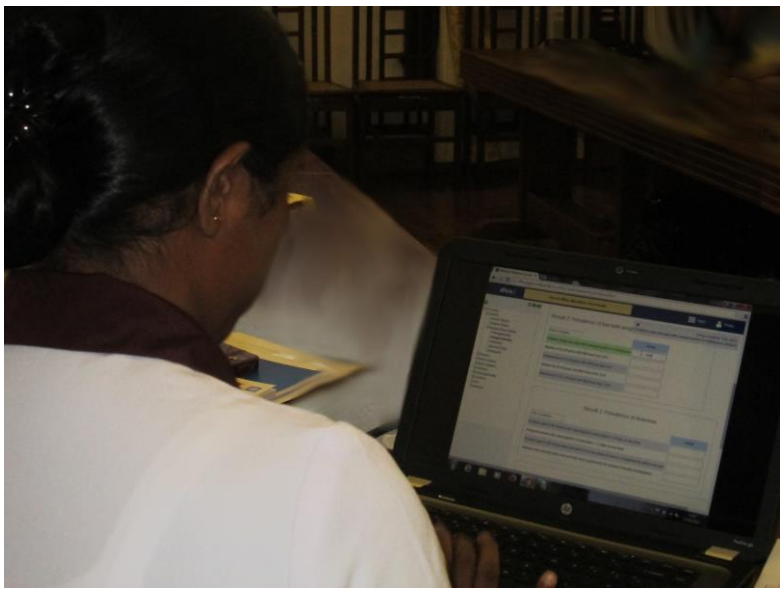

Figure 2.4: Public Health Midwife using DHIS2 to collect MCH data

Initial training was provided to the midwives and data entry was commenced in a central server provided by the PGIM. Financial support for the piloting was provided by the PGIM, HISSL and University of Oslo. Apart from the local training programmes, province staff was offered an international training programme and a field visit, collaboratively conducted by HISP India and the University of Oslo. Data entry was done by Midwives under the supervision of respective DMO. During this phase, the University of Oslo employed a local health informatics graduate to coordinate the implementation and provide training and support to carry out the customisation.

After the system was piloted for two reporting quarters, a project evaluation report was handed over to the Provincial MOH of North Western Province seeking permission to scale the system up covering all Medical Officer of Health Divisions of a district in the province. When the piloting started for the third quarter data entry, the MCH programme, in an unexpected manner, ordered the Provincial Director to abort the piloting process. The argument provided for this decision was that the DHIS2 would interfere with the supervisory role and accountability framework embedded in the existing paper based MCH reporting system.

After about a year's break, the Provincial Director of Health Services, Southern Province suggested piloting the MCH customisation of DHIS2 in the Southern Province. The PGIM and the HISSL assisted the implementation and the project was entrusted to a MO-HI attached to the Provincial MOH. The mediation with the central health programme was done through a Medical Officer-MCH attached to the office of the Provincial Director. Necessary basic hardware was also provided to all the 17 Medical Officer of Health Divisions of one district. A DHIS2 instance with further modifications to the previous design was launched for the implementation. The customised system was well accepted by the health staff and was made ready for scaling up province wide. Unfortunately, the project did not scale up in the province since the MO-HI had to move to another health institution under the annual mandatory transfer orders for the State health sector MOs.

2.2.1.2 Tuberculosis and Respiratory Diseases eRegistry

After the initial rejection of DHIS2 for MCH in North Western Province, it was discussed to explore the possibility to use DHIS2 for Tuberculosis and other chest disease registry management by PGIM and HISSL. The fact that DHIS2 did not have licensing costs was a key motivator for this idea of a pilot. The National Programme for Tuberculosis Control and Chest Diseases (also referred to as Tuberculosis Programme) decided to use DHIS2 for Tuberculosis case management as a start. At the end of 2012, the customisation process started based on requirements specified by the senior staff of the department. The customisation was led by the internally placed MO-HI who was conversant with DHIS2 through formal training and participation in the DHIS2 online community discussions.

The programme managers noted that the DHIS2 needed to be further modified to accommodate all the requirements of the Tuberculosis Programme. HISP India conducted an end-user and implementer training in May 2013 in Colombo to support this. The customisation process was undertaken within the framework of a Memorandum of Understanding (MOU) signed by a State technical university with the MOH. Several project management meetings were conducted,

following the workshop. The University of Oslo temporarily provided technical support and funds for a temporary web hosting space for the pilot to be initiated.

The requirement analysis and customisation was supported by HISSL and PGIM of Sri Lanka, which helped to build confidence of the internal implementation team of the Tuberculosis Programme. At a later stage, the Tuberculosis Programme decided to use DHIS2 for acute and chronic Asthma case management as well. Since January 2014, HISSL and PGIM have provided technical support for the customisation and server hosting process. The PGIM of Sri Lanka allocated two postgraduate trainees for the project to support the MO-HI of the Tuberculosis Programme and HISP India provided the necessary training for them. With these resources, the Tuberculosis Programme was able to expand the DHIS2 implementation process beyond the Tuberculosis and Asthma to other respiratory diseases as well. With the financial support of NORAD, in January 2014 PGIM provided a permanent server, which was physically located at the Tuberculosis Programme premises. The Tuberculosis management system was tested with the data from chest clinics and microscopy centres island-wide, whereas the Asthma management component was tested using the data from Colombo central chest clinic with plans for a programme-wide expansion. Later the Tuberculosis Programme decided to develop a custom web application based on the DHIS2 framework rather than limiting its use to the existing DHIS2 features and user interface. Figure 2.5 illustrates a chest physician from the Tuberculosis Programme using the DHIS2 during a consultation session.

Figure 2.5: DHIS2 is used to collect case base information at the Central Chest Clinic

In July 2014, there was an evaluation lead by the GFATM on the customised solution to assess its suitability and to identify Tuberculosis programme's readiness for island-wide scaling of the system. The meetings were directed also to explore the possibility of integration of Tuberculosis with HIV/AIDS data to monitor co-infections under WHO guidelines for *Three Interlinked Patient Monitoring System for HIV and TB/HIV (WHO, 2012).* The administration of the Tuberculosis Programme expressed the willingness to identify the possibility to track co-infections and to examine interoperability with other systems. GFATM suggested integrating the Tuberculosis (and HIV) reporting system with data relating to Malaria as well. However, the Tuberculosis and Malaria programmes were reluctant to support this, due to the absence of common denominators between Tuberculosis and Malaria. The University of Oslo experts reviewed the DHIS2 design and advised on effective reuse of data elements, indicators and organisation units. The National Tuberculosis Programme was satisfied with the proposal for further customisation, especially its current capability to analyse multiple data dimensions in a flexible manner. Following the evaluation a new funding opportunity emerged through the GFATM for the scale-up process. However, there were no consensus between the donor and the Tuberculosis Programme on how to apply for funding (e.g. under which funding scheme), and balancing HIS needs with those of supplies procurement. Similarly, there was confusion in the Tuberculosis Programme about the Total Cost of Ownership of DHIS2 implementation given that it is a 'free' software. This made the programme reluctant to budget adequate (which they considered as over allocation) financial support to customise DHIS2. As a result, the funding applied was lesser than estimated for the full scale programme-wide HIS implementation.

Similarly, the administration of the Tuberculosis Programme was not fully convinced about DHIS2's ability to manage Asthma related data. At that time, the Asthma case management system was using an older version of DHIS2 Tracker component with limited functionalities. During several stakeholder meetings in October-November 2014, the Tuberculosis Programme were appraised of the new DHIS2 features and how it aligned with the programme's requirements. The reason for this misunderstanding was that the programme staff did not understand the process of continuous DHIS2 releases and the need for the periodic updates of the hosted DHIS2 instance. In a follow-up meeting in December 2014, a consultant community physician in-charge of Asthma control suggested to expand the system to the private sector as well for a comprehensive capture of Tuberculosis patients both from the State and the private sector.

Due to budget limitations, there was a dilemma on how to proceed to the next phase. HISSL volunteered to perform the essential customisation required to convince the administration of the

Tuberculosis Programme on the sustainability of FOSS based approach. Parallel to this, with external funding support, a MO-HI and a system administrator from the Tuberculosis Programme were sent for advanced DHIS2 training in Vietnam. It was also proposed to integrate Tuberculosis and Asthma components to a single integrated solution, and also to extend it to include the Lung Cancer registry. It was also planned to create a dashboard to enable the GFATM to directly monitor the Tuberculosis programme's activities in the prescribed reporting format. To achieve this positive state of development, the role, played by the MO-HI was highly helpful. While playing a key role as a DHIS2 community member, he used the new knowledge gained in coordinating the implementation.

2.2.1.3 Nutrition Monitoring

The nutritional status of children has not been satisfactory although a wide range of programmes from growth monitoring to nutrient supplements have been on-going for several years in Sri Lanka (MOH, 2008). Hence, in August 2008, MOH appointed a task force to revise the National Nutrition Policy and to recommend measures to improve maternal and child nutrition. The revised nutrition policy recommended a platform for inter-sectoral coordination to concert the effort by health and non-health stakeholders under the Multi Sector Action Plan for Nutrition. In order to deliver this inter-sectoral coordination while collecting demographic and household data the idea of the National Nutrition Monitoring System was proposed. The National Nutrition Secretariat of Sri Lanka was established under the Presidential Secretariat to coordinate this. UNICEF Sri Lanka together with the AusAID programme financially supported the activities of the Nutrition Secretariat. MOH and the peripheral public administrative unit, Divisional Secretariat were the main coordination points for the health and non-health sectors respectively at the lowest administrative level. Field level coordination was assigned to the grass-root level, multi-sector stakeholder groups, and Village Committees. This consists of midwife as the focal person to identify nutritionally at-risk households. 'Grama Niladhari' (government officer to village), 'Samurdhi Niyamaka' (government appointed social service officer), Agricultural Extension Worker and Development Assistant helped the midwife to identify root causes for malnutrition from different angles, such as lack of maternal education, financial problems, socio-cultural issues and agricultural problems.

The Nutrition Secretariat facilitated implementing an electronic IS for multi-sector coordination. Three districts were selected to pilot the proposed nutrition monitoring system. Initial meetings of piloting HIS were coordinated by the Nutrition Secretariat and attended by health and non-health

sector stakeholders, funding partners and HISSL. The mechanism of household nutrition data collection and the scope of the IS were major concerns during the meetings. After several rounds of discussions, it was decided to use mobile devices as means of field level data collection through the midwives.

The DHIS2 was proposed as the HIS back-end since it had demonstrated a successful implementation in the Tuberculosis Programme. Customisation of DHIS2 commenced under the supervision of the Nutrition Secretariat starting from September 2014. It was decided to keep the health and non-health components of the IS separate to ensure privacy of the families being screened. A significant customisation was needed to adapt DHIS2 to cater to the specific requirements laid down by the National Nutrition Policy, which was carried out by HISSL. A mobile application (app) for Android smart phones was designed and its coding was outsourced to a third party software development firm by HISSL. Six hundred smart phones and 70 laptops were provided by UNICEF to pilot the system in three selected districts covering 30 Medical Officer of Health Divisions. An in-service, on-site training programme was conducted in the first quarter of 2015 in each Medical Officer of Health Division in the three districts. This training targeted the midwives and Public Health Nursing Sisters on mobile application and to DMOs, on the DHIS2 based data analysis back-end. The training component took Six months to cover all Medical Officer of Health divisions in the selected three districts, and was supervised by the Nutrition Secretariat and the Nutrition Coordination Division of the MOH. Figure 2.6 shows an in-service, on-site Nutrition Monitoring System training session for midwives.

Figure 2.6: A Nutrition Monitoring System training session for public health staff

The development of the non-health components of the nutrition monitoring system was negotiated parallel to the piloting of HIS component. This system was designed to monitor interventions done by the various stakeholders who were under the other ministries, and supporting the MOH. The minimum required data of affected households, with the root causes for the malnutrition was planned to be exported to the non-health component to initiate the intervention tracking process. After discussing with the non-health sector actors and Nutrition Secretariat with a demonstration of the HIS components, it was decided to use DHIS2 to develop the non-health component as well. A custom web app for the DHIS2 back end was proposed to be developed to facilitate easy visualisation of interventions tracking by the Village Committee and the Divisional Secretariat level coordinators. The piloting of the non-health sector component of the nutrition monitoring system was planned towards the end of 2016.

2.2.2 HHIMS implementation network

The electronic medical record system, HHIMS is the FOSS descendant of the Multi-Disease Surveillance project which was implemented in 27 state owned hospitals in the Eastern province of Sri Lanka (Pole, 2010) during the period from 2006 to 2009 after the 2004 Asian Tsunami. The system was developed to capture and process hospital admission data and to generate health statistics and routine hospital reports. The initial success of the Multi-Disease Surveillance system in the Eastern province attracted attention of the MOH to be considered for island wide scaling. The MOH reviewed the system with the technical expertise of the PGIM of Sri Lanka. This evaluation revealed that the agreement under which the Multi-Disease Surveillance system was donated to the MOH, had restricted its use only in the tsunami affected areas of the country. The main issues identified during the evaluation were that it was a proprietary system and the MOH did not have the access to its source code to conduct further modifications. However, a request came to the Multi-Disease Surveillance team inviting them to implement the system in another hospital in a different Province in a non-tsunami affected area. The Regional Director of Health Services of the district submitted a proposal to the Information and Communication Technology Agency of Sri Lanka (ICTA) requesting financial and technical support to implement the system in two base hospitals in two districts. Hence, in 2010, ICTA proposed to convert the Multi-Disease Surveillance to a FOSS medical record system. A World Bank grant was channelled through the ICTA to initiate the FOSS development.

The Multi-Disease Surveillance system team was invited to develop this FOSS version, and this

was re-branded as the HHIMS. Based on the Multi-Disease Surveillance system's design, in 2011, the FOSS electronic medical record system was developed and released as HHIMS version 1. In this release, HHIMS followed a modular architecture which enabled 3rd party component development to its core extending it from Desktop to tablet computers. However, it was not provided with an Application Programming Interface for the use of 3rd party developers. HHIMS (version 1.0) was successfully piloted in one base hospital, and was subsequently extended to three, and then to five other district hospitals with funding support from the ICTA. Figure 2.6 below captures a doctor using the HHIMS during a patient visit at a district hospital.

Figure 2.7: HHIMS is used to collect patients' visit information at out-patient department level

Subsequently, there were requests to the ICTA and to the HHIMS core-team to implement the system in three more districts. There was a review meeting conducted by the MOH with participation from central, provincial and institutional health managers, representatives of ICTA and the PGIM of Sri Lanka. Despite the positive reports from regional directors, the MOH hesitated to approve the HHIMS scaling to island wide implementation. Instead, it authorised the ICTA to pilot HHIMS in five hospitals in three more districts to evaluate security and usability of the system. In 2012, HHIMS version 1.2 was released under the FOSS licence *Affero General Public Licence*[5].

While being implemented in more than 10 hospitals in different districts, the application reached its

5 http://opensource.org/licenses/AGPL-3.0

next turning point of being implemented in the district hospital Dompe which involved the support for new ~~use~~ cases included in HHIMS version 1.3. In 2013, the feature rich HHIMS version 2.0 was released under the same FOSS licence to support the use cases received from the growing network of hospitals. In the late 2013 and in early 2014, the HHIMS system was selected to be implemented in several hospitals in the Northern part of the island. Detailed Term of References were prepared and a tender was called from suitable software development teams. There was a pre-defined minimum composition defined for the prospective software development team, consisting of a medical doctor experienced in the State health sector as well. There were several software development entities who responded to the bid, including few large software firm. However, the smaller company, which consisted of members from previous HHIMS core team won the bid and successfully delivered the product.

Dompe hospital was one of the best examples of successful HHIMS implementations (Kulathilaka, 2013). This motivated the MOH to considered establishing a national governance body to steer the future design and development of HHIMS. There were several considerations in deciding the governance model, including the composition of the governing body (representation of health sector, IT-sector and other stakeholders), managing of the code repository, and mechanisms to regulate and evolve the architecture. Later it was suggested to broaden the scope of the proposed governing body to a national FOSS governance body to encompass any FOSS development and implementation within the State health sector. Initially, it was only the HHIMS core team who possessed the know-how to design and develop components on HHIMS code base. Later a 3rd party software firm and a technical university emerged as HHIMS developers.

Technical support for HIS implementations was provided both by commercial as well as, not-for-profit entities. Few commercial software firms have won bids during the period of this study. One small scale software firm which designed and developed the HHIMS software under ICTA supervision was noteworthy for their dominant role, played as a FOSS developer firm and an implementer. This company also secured several such tenders awarded for the development of several releases of HHIMS during its development phase. Limited budgets were a major barrier for large scale software companies to survive the bid. Towards the later phases of the HHIMS project, the tender awarding body (ICTA) formulated detailed software requirement specifications and used them as a reference to evaluate the delivered software. The new 3rd party software firms as well as technical universities played a role as support teams to end the monopoly of the HHIMS core team as the sole software supplier and implementer for HHIMS.

2.2.3 National Foundation for Open Source Health Software

Followed by the discussion of HHIMS foundation, a broader FOSS governance body under the title NFOSHS was proposed to the MOH. The initial discussion towards a national FOSS regulatory body for the health sector was proposed during late 2012. A stakeholder group was formed in January 2013 and the initial version of the constitution was drafted for the NFOSHS. The stakeholder group was inspired and guided by another FOSS regulatory body called Sahana Foundation[6] which was initiated as a Sri Lankan FOSS disaster management project and later scaled up to become a leading global FOSS project. The discussion for the constitution went on for months with ongoing debates on the composition of the stakeholders and their respective roles and authorities. Initially it selected MO-HIs to represent various key positions within the MOH., ICTA, Health Information Unit of the MOH, HISSL, several government and private sector technical university representations, the PGIM of Sri Lanka and health administrators/managers representing key health institutions and ministerial positions participated in the discussions. From the beginning, there were representations from the Sahana Foundation in an advisory capacity.

The scope of the foundation was to support the FOSS HIS projects within the MOH. The NFOSHS was established in October 2013 taking the Sahana foundation as a model. Its aim was to govern FOSS acquisition in the MOH through the following objectives:

- To maintain a complete and up-to-date list of applicable FOSS health software solutions;
- To promote FOSS software solutions in the health sector;
- To evaluate appropriate FOSS health software solutions on request from National eHealth Steering Committee and provide recommendations whenever necessary;
- To ensure quality of adopted FOSS software solutions in the health sector and ensure that such solutions are in compliance with National eHealth Standards and Guidelines; and,
- To provide technical support to National eHealth Steering Committee wherever necessary in adopting recommended FOSS solutions.

The proposed functions of the NFOSHS were to maintain an up-to-date list of applicable FOSS software solutions and to evaluate candidate FOSS health software and perform quality assurance. The mechanism for achieving these goals was to establish committees to evaluate FOSS health software and to set up Project Management Committees for each FOSS HIS project recognised to be managed under the NFOSHS. The committees suggested were ad-hoc temporary committees of competent members of NFOSHS, and would automatically get dissolved upon completion of the

6 http://sahanafoundation.org/

task. The project management committees were standing committees with authority vested upon them under the NFOSHS constitution, and acted as software incubators, to nurture FOSS heath software through community participation. The volunteer community representation to the project management committee was decided in consultation with the NFOSHS. HHIMS and DHIS2 were two suggestions for prospective project management committees involving multi-sector stakeholders from the MOH, technical universities, HISSL and ICTA. Followed by discussions among prospective stakeholders, unfortunately, soon this foundation became non-functional. Thereafter, no sub-committees were established to manage HHIMS or DHIS2 projects as of today.

Chapter Summary

First, this chapter described the State health sector of Sri Lanka, upon which this study was positioned. The centralised nature of the health service and its resistance to change from what was proven to be effective are two important behaviours a HIS implementer should expect from the State health sector in Sri Lanka. The State health sector of Sri Lanka is governed by the central MOH and at each province, by the Provincial MOH. The governance of Provincial MOH and that of the central MOH are independent from each other. The health campaigns are governed vertically in a top-down manner with a high degree of redundancy and fragmentation between campaigns. In this centralised governance model, non-health stakeholders do not play a crucial or influential role in health decision-making processes. In the Sri Lankan context, inter-organisational trust between various stakeholders was key to establishing governance in the early phase of FOSS HIS implementations.

This chapter also elaborated the three empirical cases on which this thesis was built upon, including, a hospital information system, (HHIMS) implementation in four hospitals; a public health information system (DHIS2) implementation in three health programmes and; an attempt to establish a FOSS governance body, (NFOSHS) in the State health sector. The selected field setting provided a greenfield site to study HIS implementation network without the influence of vendor competition. There are several ongoing attempts to introduce national level guidelines to health IT sector, such as the National eGovernment Policy and draft National eHealth Policy, National eHealth Strategic Plan and National eHealth Standards and Guidelines.

Chapter 3 - Research approach

This chapter outlines the research design and the methodology adhered to during this study. It describes the research design followed by an overview of the fieldwork including the ethical considerations and the different roles the author played in the field setting. The next section elaborates the data collection methodology, which is mainly based on participant observations and semi-structured interviews. The interpretive approach of investigation is described in the data analysis section, followed by conclusions describing some reflections on the research findings.

3.1 Background of the research

This research is conducted on three longitudinal case studies on FOSS application in the State health sector of Sri Lanka for a five-year period from 2011 to 2014. It includes two large scale FOSS HIS implementation efforts and an initiative to establish a national FOSS governance body with the participation of multi-sector stakeholders. The research focused on understanding the behaviour of governance in the PE around FOSS HIS implementation and the influence of inter-organisational trust shaping the governance trajectory of the PE. The case studies collect descriptive data to investigate the business environment of an organisation for a deeper understanding of a particular scenario (Boodhoo, & Purmessur, 2009). The case study approach helps to set up an initial theoretical framework based up on existing knowledge (Walsham, 1995). In my context, I positioned my research within the frameworks of FOSS business models and the concept of PE.

The study employed a qualitative research methodology with an interpretive approach which, as Myers (1997) argued, can be used to produce an understanding of the context of the research. My research involved building an understanding of the meaning the behaviours of networks in the form of PEs. In such situations where meanings are shaped in a social context, the use of qualitative methods was considered appropriate (Creswell, 2013). Qualitative methods help researchers to understand people and their socio-cultural context in which they live (Myers & Avison, 2002; Silverman, 2005). My focus was to study the inherent dynamics of the PE surrounding FOSS HIS implementations shaped within a social context. The use of a qualitative methodology helped to develop ‘sensitising concepts’ based on empirical evidence (Flick, 2012), and to help describe a complex phenomenon shaped within a social context.

3.2 Research method

This study followed a qualitative research approach (Creswell, 2002) with a focus on understanding

the meanings that relevant individuals or groups ascribe to the processes of PE governance surrounding FOSS HIS implementations. The process focused on the participant's setting, and observing various dynamics around implementation efforts in the different cases. The qualitative methodology was the basis for an inductive approach, which supported the subsequent process of development of analytical themes from the data.

I tried to understand the 'world view' or the 'basic set of beliefs that guide action' (Guba, 1990) of the participants involved in the cases. World view is also referred to as epistemology (Crotty, 1998) or the research paradigm (Lincoln, Lynham & Guba, 2011; Mertens, 2010) ascribed to in the empirical work. This research took a constructivist world view (Creswell, 2002) which focuses on understanding the world in which the participants live and work reflecting the subjective meanings of their experiences - meanings directed toward certain objects or things (Creswell, 2002). These meanings are varied and multiple representing different facets of FOSS HIS implementation projects. The questions followed were broad and open-ended, allowing participants to express different opinions on the broad issue of governance and inter-organisational trust within the PE being studied. These responses were placed within the broader contexts of the FOSS, trust, health sector and public administration of Sri Lanka.

For the scope of this study, the unit of observation (Glick, 1985) or the entity observed, was the PE, which comprised individual health sector and non-health sector organisational actors around a FOSS platform together with their interactions with each other. Similarly, the PE was the unit of analysis as well, about which the generalisations are made. Considering the PE consisting of an organisational network as the unit of observation posed a considerable challenge while collecting organisational level data through individual informants. It was assumed that the perception of top management in the organization reflects a broadly collective perspective and can be seen as a reliable source of organizational-level data (Gaur, et al., 2011). So, the opinion of top-level administers was seen as a dominant view in building my interpretations. The other strategy employed was to use the group discussions to obtain an organisational viewpoint from individual respondents. In this case, the group becomes a means for reconstructing individual opinions and aligning them to the organisational view (Flick, 2012). During data collection, emphasis was given to the views of the health managers and administrators and HIS implementers.

3.2.1 Selection of field work

The study was conducted in different sites in preventive and curative health sectors. In this study, different provinces and hospitals provided geographical (resource) variations whereas preventive

and curative health sector facilities provided views on business process variations. Further, to understanding the dynamics of governance in the PE completely, the study tried to understand different administrative arrangements, such as vertical health programmes (also known as health campaigns, e.g. MCH programme, Tuberculosis Programme), central MOH (line ministry) administration and provincial health administrative settings (e.g. Provincial MOH). This design helped to provide insights into both the local context and the wider social system. Hence, in this research design, it was possible to compare three DHIS2 implementation projects for their differences and similarities for a deeper understanding in to PE behaviour.

The governance of DHIS2 implementation for MCH was mainly observed in Pannala and Kurunegala Medical Officer of Health Divisions in North Western Province and Galle Medical Officer of Health Division in the Southern Province, which were public health sector peripheral health institutions. Apart from these field settings, the MCH programme, Offices of Provincial Directors of Health Services of North Western and Southern Provinces and Regional Director of Health Services of the Kurunegala District were included as field settings to understand the central health administration perspective. The Central Chest Clinic and the Tuberculosis Programme were the main field settings in DHIS2 implementation for Tuberculosis and Respiratory Diseases eRegistry. The Nutrition Monitoring project was started in the third quarter of 2014 with multi-sector stakeholder meetings headed by Nutrition Secretariat. Subsequent data collection continued during the field implementation at 30 Medical Officer of Health Divisions in the Matale, Nuwara Eliya and Polonnaruwa districts.

In the HHIMS project, I selected four key hospitals for the field work. The Awissawella Base Hospital and Point Pedro Base hospital were medium scale curative sector institutions, whereas District Hospital Dompe and District Hospital Maha Oya were small scale curative healthcare institutions. Out of these, Dompe and Awissawella hospitals had already established the introduction of HHIMS, while systems at Point Pedro and Maha Oya hospitals were introduced during the period of my study.

Within this research design, it was also possible to distinguish between the PE dynamics of the DHIS2 and HHIMS implementations, both at individual and facility levels. Both these settings were important since they provided additional views on ethical and security concerns surrounding individually-identifiable health information. The collective governance decision-making on the State health sector FOSS implementation was observed during the NFOSHS case study. The face-to-face meetings at NFOSHS took place in the MOH or ICTA premises and the discussions continued as an online forum limited to NFOSHS members in between face-to-face meetings.

During the data collection process, I attempted to capture the social meaning (e.g. governance, trust) of the scenario parallel to the technical activities (e.g. HIS implementation) while participating directly in the settings (Creswell, 2013). The sites provided an opportunity to contrast between commercial and not-for-profit models of FOSS implementations, and support observations both in preventive and curative health services. For example, DHIS2 for MCH was a preventive care focused customisation carried out by HISSL on a voluntary basis. The HHIMS implementations were driven primarily by commercial interests for curative health facilities.

The selection of the fieldwork settings were influenced by my involvement in the DHIS2 and HHIMS projects which started before 2011. During this period, I volunteered at the Ministry of Health as a consultant to evaluate the Multi Disease Surveillance System (predecessor of HHIMS) and supported the introduction of DHIS2 to the MCH programme. Hence, I was able to use this knowledge and experience as a background understanding of the cases. According to Klein and Myers (1999), the prior knowledge of the researcher before embarking on the data collection plays an important part in the understanding of the cases. Table 3.1 below summarises the three cases studied.

	DHIS2	**HHIMS**	**NFOSHS**
PE	Preventive Sector – MCH information system, Tuberculosis and Respiratory Diseases eRegistry and Nutrition Monitoring system	Curative Sector - out patient departments of small to medium scale hospitals	Administrative body for FOSS projects within the State health sector
Governance focus	Central Programmes governing peripheral entities (Medical Office of Health facilities and HIS implementers)	Central ministry governing hospitals and HIS implementers	Central body to oversee all the State health sector FOSS development and implementation projects
Governing body (central)	MCH programme, National Tuberculosis Control Programme, National Nutrition Secretariat	Central Ministry of Health (Line Ministry)	Central Body (NFOSHS)
Collaborators within the State health sector	Medical Office of Health units, peripheral Chest Clinics, Provincial and Regional Directors of Health Services units, Nutrition Coordination Unit	Hospitals, Provincial and Regional Directors of Health Services offices	Selected hospitals, vertical health programmes and selected units of the Ministry of Health, selected Provincial and Regional Directors of Health Services offices
External collaborators	HISSL, HISP network, GFATM, PGIM, UNICEF, Presidential Secretariat	ICTA, Commercial FOSS firms	ICTA, HISSL, Technical Universities and the PGIM

Table 3.1: Summary of three cases studied for this thesis

3.2.2 Data collection methods

A multi-method data collection approach (Mingers & Brocklesby, 1997) was adopted, including participant observations, semi-structured interviews, focus group discussions and document analysis. This approach was enabled through the use of the case study approach (Maykut, & Morehouse, 1998). Table 3.2 below, summarises the key organisations and their representatives met with.

Sector	Organisation	Organisational representative	What type of data collected
State sector (central) health administrators	Ministry of Health	Director/Health Information HI-HI/Health Information Unit	Interviews Meeting minutes, Policy documents
Peripheral Public Health Institutions	Medical Officer of Health facilities – 8 facilities in North Western Province, 3 facilities in Southern Province, 30 facilities in the three districts – Matale, Nuwara Eliya and Polonnaruwa. Regional/Provincial Director - North Western and Southern Provinces	Medical Office of Health Divisions - DMOs, midwives, Public Health Nursing Sisters and Development Assistants in respective Medical Officer of Health facilities. Regional Directors - Kurunegala, Galle, Matale and Polonnaruwa Provincial Directors - North Central, North Western and Southern Provinces MO-HIs - North Western and Southern Provinces.	Interviews Policy documents Participant observations Focus group discussions
Vertical health programmes	Tuberculosis Programme MCH Programme	Director, MO-HI, Consultant Chest Physicians MOICs - Respiratory diseases clinics Director, Programme Director - MCH, Director – IS, Consultant	Interviews Participant Observations

		Community Physicians	
	Nutrition Coordination Unit	Director, Consultant Community Physicians, MO-HI	
National ICT regulatory bodies	ICTA MOH (National eHealth Steering Committee and NFOSHS)	Director Programme Managers Members	Interviews Participant Observations Online communications (NFOSHS online forum)
National Administrative Services representation	National Nutrition Secretariat Divisional Secretariat	Additional Secretory to the President, coordinator of the National Nutrition Secretariat and representatives from health, finance, ICT and Telecommunication ministries, MOH, MCH Programme Divisional Secretariat staff - Polonnaruwa and Matale, Village Committee representatives (Grama Niladhari, Samurdhi Officers, Agriculture Extension Officers)	Participant Observations Interviews Interviews
Hospitals	District Hospital – Dompe Awissawella Maha Oya Point Pedro	MO-in-chage (Dompe), Director, Doctors and Nurses Medical Superintendent - Point Pedro Regional Director - Ratnapura Provincial Director - Western Province/Sabaragamuwa, Medical Officer – Planning, Awissawella hospital	Participant Observations Interviews
University sector	University of Kelaniya, PGIM	Project Leads, Academics	Interviews
Funding agencies	World Bank (for HHIMS), GFATM (for DHIS2) UNICEF (for Nutrition Monitoring)	Country representative of World Bank Member of the Country Coordination Mechanism of	Online Communications/documents Interviews

		GFATM	
HIS implementers and developers	Technical university developer teams, HHIMS (core team), HISSL, Individual Implementers (MCH, Tuberculosis) HISP India, 3rd party developer firms	Team Lead/member	Participant observations Focus group discussions Online Communications
FOSS HIS developer firms	HISP HHIMS core team	Team Lead/member	Focus group discussions Online Communications

Table 3.2: Organisational actors who participated in the data collection process

After summarizing the key informants in the table 3.2, the different data collection methods used are now described.

3.2.2.1 Participant observations

Participant observations helped to simultaneously combine document analysis, interviewing of respondents and informants, direct participation at work or in meetings (Jorgensen, 1989; Sandiford, 2015). During this study, focused participant observations (Flick, 2012) helped me to narrow my observations on the processes and problems which were seen to be essential and relevant to understand the research questions posed in this thesis. Focused observations were made on project steering meetings where I participated as an implementer. This helped me to observe some of the dynamics in the PEs studied, such as governance decisions, without personally influencing the organizational decisions taken. Apart from the implementation team, these meetings were also attended by central and peripheral health managers and administrators, DMOs, consultants, community physicians and some of the field health care staff.

Apart from the project steering meetings, observations were also carried out during the HIS customisation and implementation exercises (e.g. on-site Nutrition Monitoring System training sessions), system evaluation sessions and technical committee meetings. During these sessions, the focus was to understand the perceptions (around trust and orchestration) of organisational actors towards each other. In establishing NFOSHS, observations were mainly done at NFOSHS core team meetings and in the online discussion forums created for NFOSHS. The focus of observation was

the approach of governance proposed for the NFOSHS. Figure 3.1 below illustrates one such participant observation session where the MO-in-charge of HHIMS at the Dompe hospital explains the possible approaches of governing the stakeholder participation in the HIS implementation project to representatives from MOH.

Figure 3.1: A participant observation session of strategising HHIMS implementation for a new hospital

3.2.2.2 Document Analysis

Participant observations were supplemented by document reviews, for example minutes of the project steering and project evaluation committee meetings, emails and online forum communications, official letters and other policy documents leading to the FOSS governance in HIS implementation ecosystem together with the government circulars, tender notices and electronic communications (emails and forum posts). These documents provided insights to develop a broader understanding of the status of each project. For example, after a participant observation session of NFOSHS council meeting, referring to policy documents such as National eHealth Policy, provided more understanding about the basis for some of the decisions made by health administrators. Similarly, the documents such as tender notices provided information on how client organisations improved their understanding on the FOSS acquisition process with time. For example, early tenders during the HHIMS project provided less information to the implementers, but later ones

prescribed mandatory requirements that should be satisfied by the HIS implementation team, such as the need for a doctor with a minimum of three years hospital experience. Similarly, with few years of experience the HHIMS project administrators detailed use cases together with the tender documents guiding developers and implementers in the customisation process.

3.2.2.3 Interviews

Participant observations were combined with interviews to get a deeper understanding of the context of the phenomenon under study (Crang & Cook, 2007). In qualitative research, interviews are a main method of data gathering using semi-structured methods to help understand how informants organise their knowledge about a particular issue (Flick, 2012). Through the interviews, the investigator can gain access to the participants' views and interpretations of actions (Walsham, 1995). Health managers and administrators and FOSS implementers were the key informants for my semi-structured interviews. Open questions were used with the aim of making the interviewee's implicit knowledge more explicit. Typically, these interviews were carried out with prior appointment and were conducted in the respondent's office. During some participant observation sessions, in-situ interviews (Jordan & Henderson, 1995) were conducted, and guided by the processes being observed. Such in-situ interviews were mostly conducted with peripheral health managers and implementers whereas formal (semi-structured) interviews were conducted with central and provincial health administrators. For example, interviews with MO-HIs of the Provinces about provincial eHealth policy and its influence on FOSS implementation governance, interviews with secretary of Nutrition Secretariat to understand the negotiation of different actors and software components (such as web and mobile app) in the PE around Nutrition Monitoring.

The interviews were semi structured in nature and an interview guide was used to lead the discussion. The interview guide comprised of different facets such as health organisation's trust on FOSS implementers and developers, stakeholders' perceptions towards governance trajectory, approaches and decisions and health administrator's view on ability (and inability) to govern the PE participants. During the interviews, the dialogues lasted for 10 to 30 minutes. The interviews were aligned with key aspects of FOSS PE governance decisions, multi-stakeholder interactions in ecosystem and inter-organisational trust during the FOSS acquisition and implementation. Semi-structured interviews with the top-management in the organisations included in the study were the main method used to understand the organisational perception of trust towards other actors and stakeholder organisations. In formulating the interview guide on trust, the organisational trust inventory by Cumings and Bromiley (1996) and inter-firm trust measurement instrument by Doney

and Cannon (1997) was consulted. Questions such as "Do you [the hospital] trust the HHIMS implementers that they'd follow the software requirement specifications provided with the tender documents ?" was directed to the Medical Officer-in-charge of the HHIMS implementation was an example of direct probing. Whereas, "Was the HHIMS team frank in dealing with hospitals in the previous phase of HHIMS customisation?" is an example of indirect questions to understand inter-organisational trust.

The table 3.3 below summarise the informants, who were subjected to the interviews and focus group discussions in the three case studies.

Project		Informants
DHIS	MCH	Director - MCH Programme, Director - information systems Consultant Community Physician representing the MCH programme Medical Officer - MCH (Kurunegala and Galle) MO-HIs (North Western and Southern Provinces) DMOs (Kurunegala, Pannala, Galle) Provincial Directors (North Western and Southern provinces) Regional Directors (Kurunegala and Galle districts) Representatives from PGIM Implementers employed by the HISSL
	Tuberculosis eRegistry	Head of the Tuberculosis programme Consultant respiratory physicians attached to the Tuberculosis programme MO-HI, Head of the IT support
	Nutrition Monitoring	Head of the Nutrition Coordination Unit of the MOH Coordinator of the National Nutrition Secretariat Head of the MCH programme DMOs Divisional Secretariats of Matale and Polonnaruwa districts
HHIMS		Medical Superintendents of Dompe, Point-Pedro and Maha Oya hospitals MO-in-charge of HHIMS implementations in Dompe and Awissawella hospitals Members from the HHIMS core team and implementation teams

	Representatives from ICTA
NFOSHS	MO -HIs representing key directorates of the MOH Representatives from ICTA Academics from the participating universities

Table 3.3: Informants interviewed in each case

The table 3.4 below summarises the number of interviews conducted during this study and the number of informants participated in the interview, according to the interviewees' official capacity. It should be also noted that in some occasions, one interviewee was interviewed more than once at different times during projects.

Type of informants	No. of informants	No. of interviews conducted
Health Managers and administrators		
- Central Health Administrations	4	6
- Vertical Programmes (MCH, Tuberculosis Programme and Nutrition Coordination Unit)	5	12
- Provincial/regional (HHIMS, MCH and Nutrition Monitoring)	6	8
MO – HI (NFOSHS, Tuberculosis and Nutrition Monitoring)	5	16
Provincial MO-HI	2	10
MOH (MCH, Nutrition Monitoring)	3	5
Medical Officer-in-charge (HHIMS)	2	11
Medical Officer-MCHs (North Western Province, Southern Province, Matale, Polonnaruwa)	4	6
Consultant Community Physicians (MCH, Tuberculosis Programme and Nutrition Monitoring)	4	8

HIS implementers		
- HIS Implementers – Health Informatics specialized (MCH, Tuberculosis Programme, Nutrition Monitoring)	4	18
- HIS implementers – IT specialized (HHIMS)	3	7
Web and mobile app developers (DHIS2)	2	5
- Midwives and other field level HIS users (MCH and Nutrition Monitoring)	14	8
Other stakeholders		
- Standard/regulatory bodies (ICTA, National eHealth Steering Committee, NFOSHS)	8	5
- Funding (GFATM, and UNICEF)	4	6
- Academic (PGIM, University of Kelaniya)	2	5
- IT staff (Tuberculosis Programme, Presidential Secretariat)	4	6
- National Nutrition Secretariat (coordinator)	1	8
- Not-for-profit organization (HISSL)	2	12
Total	79	146

Table 3.4: The outline of interview participation

The role of the health managers and administrators interviewed ranged from institutional level managers (e.g. DMO) to administrators (e.g. Programme Directors, Provincial/Regional Directors of Health Services, Heads of Health Institutions). Hence, decisions and opinions of health managers representing both central and peripheral/provincial level were considered during the study. The implementers interviewed included internal (Tuberculosis Programme, Southern Province) as well as external HIS implementers. The external implementers and developers include profit-driven (HHIMS implementers and 3rd party DHIS2 mobile app developers) and volunteers from the PGIM and HISSL.

3.2.2.4 Focus group discussions

In some instances, participant observation sessions were supplemented by the focus group discussions for getting a deeper understanding of the underlying issues. The group discussions involved interviewing a team of people, which helped to reconstruct an individual's opinion towards an organisational issue in the context of other participants (Flick, 2012). Hence, this was an important strategy to get the organisational opinion about issues related to the PE governance decisions shaped by inter-organisational trust amongst stakeholders. However, during the group interviews, the degree of moderation was kept to a minimum to enable participants to freely express their opinions. Group discussions were the main form of decision taking in the studied PEs at all administrative levels (e.g. project steering committees). As a moderator, I followed the Topic Steering method (Flick, 2012) introducing new questions and steering the discussion deeper towards specific topics. For example, in a discussion on who should be the stakeholders to be invited to the DHIS2 for MCH project in the Southern Province, I tried to direct the discussion towards, the extent to which a provincial health administrators can trust prospective stakeholder such as HIS implementers. This provided me with a deeper understanding of how FOSS related issues and inter-organisational trust affected the governance trajectories of the implementation ecosystems.

In DHIS2 for MCH project, the focused group discussions were conducted both with the central health programme and the staff of the peripheral health facilities. Two focus group discussions were conducted with the central health managers (the officials listed in table 3.3) and those were attended by the officials of the MCH programme and representatives from the PGIM and HISSL. There were several discussions at peripheral level and the informants of those could be broadly categories into two categories. One group was peripheral health administrators and the other group was DHIS2 end-user. The peripheral health administrator, who participated in the group discussions, consisted of the Medical Officer-MCH, MO-HI of the province, Provincial and Regional Directors together with the representatives from the PGIM and HISSL. Two such meetings were conducted in the North Western Province; three meetings were conducted in the Southern Province on MCH implementation. Figure 3.2 below illustrates a focus group discussion conducted with provincial health administrators in the North Western Province. These discussions were based on broader project management and governance issues.

Figure 3.2: Focus group discussion session with provincial health administrators

The other category of group discussions was carried out with the end users of the DHIS2, to assess their perception on project governance trajectories and understand the influence of inter-organisational trust in governance decisions. These end-user participated group discussions were conducted in all three DHIS2 based projects and participants included DMOs, midwives, Public Health Nursing Sisters and Supervisory Midwives together with the representatives of PGIM and HISSL. Five such discussion rounds were conducted in the North Western Province and two in the Southern Province. The discussions were conducted with the participation of medical doctors and nurses in HHIMS implementations. In these discussions, the end-user perception towards FOSS artefact, HHIMS implementation team and the direction of the project governance trajectory were the main focus of probing.

Figure 3.3 below illustrates, several group discussions were conducted with staff of Medical Officer of Health facilities during DHIS2 based implementations on mobile front end of DHIS2 in Matale district.

Figure 3.3: Focused group discussion during Nutrition Monitoring system implementations.

A dialogue such as this, with a DMO, demonstrates the dynamics of interactions around PEs were elicited during focus group discussions.

> Author: “Would you like to proceed with DHIS2 on your own [without the prior approval of MCH programme] ?”
>
> MO: “Yes. This helps very much with our day today work. And, we don’t think we should only be doing what they asked us to do.”
>
> Author: “So, you mean, you are an independent entity?”
>
> MO: “Yes, of course. Maybe we [Medical Officer of Health Office] are technically under them [MCH programme] but we don’t think they can stop us doing new things [projects]. Medical Officer of Health units are like hospital have an independent administration.”

Following picture (figure 3.4) illustrates a focus group discussion held with the DHIS2 for MCH end-users to gain an understanding of the FOSS HIS implementation trajectory and stakeholder participation.

Figure 3.4: Group Discussion with the staff of Pannala Medical Officer of Health office

The focus group discussions with programme administers were conducted in the DHIS2 for Tuberculosis and Respiratory Diseases eRegistry project and Nutrition Monitoring Project. The focus during these discussions were the governance trajectory and trust towards the FOSS approach. Also, the sensitive nature of stakeholder interactions were discussed such as access to personal/household identifiable information to non-health sector stakeholders in nutrition monitoring. Six focus group discussions were conducted with the programme administers of Tuberculosis programme. Apart from the officials representing the programme (listed in table 3.3), MOs representing the Central Chest Clinics and IT officer of Tuberculosis programme participated together with the representatives from the PGIM and HISSL. One of these meetings was conducted to discuss the possibility of integrating information flows of Tuberculosis and HIV programmes to track the co-infections. Apart from the Tuberculosis programme team, it was participated by a representative from the Country Coordination Mechanism of the GFATM and the Deputy Director of the HIV programme and his team and representatives from the University of Oslo. Two discussion sessions were focused on the funding model and the strengthening of collaboration with funding partners and participants included the director of the Tuberculosis programme. Eight focus group discussions were conducted to discuss the composition of the implementation ecosystem and governance model in Nutrition Monitoring project with the the Nutrition Secretariat and high level stakeholders (listed in table 3.3). Out of these, two discussions were with the Provincial and Regional health administrators in Matale and Polonnaruwa district respectively and the focus was on stakeholder engagement at implementations.

Regarding the HHIMS project, three group discussions were conducted with MO-in Charge of HHIMS implementation in Dompe and Maha Oya hospitals, members from the HHIMS core team and the implementation team. These were aimed at getting a deeper understanding of the role of the FOSS implementers and HIS governance decisions by central health administrators.

Within the NFOSHS project, the group discussions were focused on the different FOSS governance mechanisms and project management, FOSS licensing, and the composition of the governance bodies (NFOSHS itself and project steering committees). The focus group discussions were attended by the Director - Health Information, President and representatives of HISSL, representatives from the PGIM, MO-HIs representing key directorates of MOH and vertical health programmes, two representatives from ICTA, a representative from Sahana FOSS Foundation and three representatives from technical universities. These NFOSHS group discussions were mediated by MOH and author attended five meetings representing the PGIM.

3.2.2.5 Internet mediated sessions and online communications

Apart from the face to face sessions, several internet mediated discussion options were also used during the study. Skype sessions were mainly used for discussions with members of FOSS implementation teams and to communicate with 3rd party component developers. There, the technical matters as well as project trajectories and decisions of governance and their repercussions were discussed. For example, Skype calls with the members of DHIS2 and HHIMS implementation teams to clarify and agree to the decisions of governance taken by the health administrators and assess whether those decisions were favourable to the anticipated trajectory of the implementation ecosystem.

For the NFOSHS, a dedicated online discussion forum was established to deliberate on the key decisions regarding NFOSHS governance. This forum access was restricted to the NFOSHS committee members and the forum was moderated by MOH. “Should NFOSHS adopt all FOSS projects or is it only large scale FOSS HIS should be considered under the scope of NFOSHS?” , “Can aggregate FOSS HISs, which do not hold patient identifiable data be excluded from NFOSHS governance?”, “What is the role of non-medical stakeholders [referring mainly to technical university representation] in NFOSHS governance?” and “How should technical committees be managed, as permanent entities or temporary committees until a FOSS HIS is evaluated?” are some of the discussions posted in the forum. Figure 3.5 below illustrates a discussion thread from NFOSHS online forum.

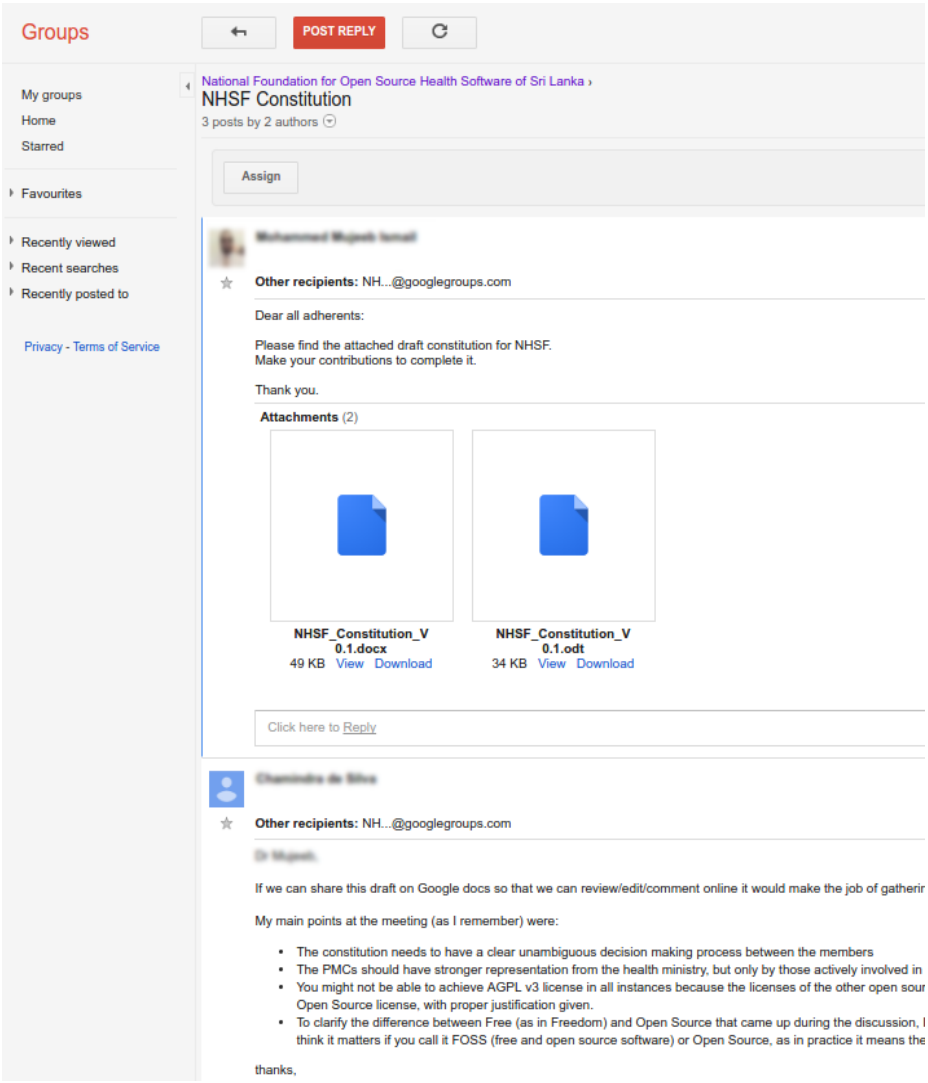

Figure 3.5: NFOSHS online forum discussion its constitution.

3.2.3 Data analysis

Data analysis was informed by the interpretive tradition (Walsham, 1995; Walsham, 2006), and the process of data analysis included:

- Transcribing of data collected
- Sorting and categorisation (coding) of data
- Developing intra case themes relating to governance and trust
- Making cross-case comparisons

During the field work, raw data was recorded as field notes in interviews, focused group discussions

and participant observations. The recorded information included the designation (official capacity) of the participants and their specific responses to the questions, and their specific reflections on issues of trust towards other relevant stakeholders. The copies of relevant documents mentioned in the interviews, group discussions and participant observations were also collected for the document analysis. Copies of the electronic communications (e.g. email) were downloaded and saved for the analysis. Later (usually at the end of each working day) those were transcribed as field notes and were expanded with relevant background information from other sources such as the analysed documents. Interviews were conducted in both English and Sinhala languages, which was later translated into English during the transcribing phase. Some examples for this process were, observing the governance dialogues during NFOSHS meetings and transcribing the conversation as field note adding explanatory excerpts from National eHealth Policy and extracted text from the forum posts.

Followed by the transcription phase, the data was sorted (coded) according to identified themes (Hsieh, & Shannon, 2005) and aligning them with research questions. During the coding phase, I rearranged the data to categories searching for patterns. The three broader categories were PE, governance and inter-organisational trust. Within each main category, discerning regularities or similarities in the data was noted and sub-categories identified. In the PE category, data was further grouped into the stakeholder interactions of growing PE (admittance to PE) and expulsion of an organisational actor from PE; stakeholder categories (internal, external) and; longitudinal evolution of the PE. Within the governance category, coding was further refined into hierarchical governance, governance towards orchestration (poly-centric approach), central form of governance, networked form of governance; orchestration mechanisms - licence, decisions, variations of coordination (non-coordinated, formal-impersonal, formal-interpersonal and informal-interpersonal) and variations of control (self-control, output control, behaviour control and clan control). In the trust category, the refinement was for the inter-personal trust, personal trust towards an organisation, inter-organisational trust, the observation of strengthening of trust, weakening of trust and behaviour of conveying trust (boundary spanning behaviour).

The case study approach included within-case data analysis and identifying cross-case patterns (Eisenhardt, 1998). Data from participant observations, interviews, focus group discussions and document analysis was compared and contrasted (Reeves, Kuper & Hodges, 2008) to get an in-depth understanding of governance trajectories and influence of trust in the multiple FOSS implementation decisions. To discern the governance trajectories of PEs, intra-case themes selected were, whether the stakeholder network in a PE was growing or weakening with the governance

decisions. For example, the DHIS2 for MCH network weakened with initial governance approaches, and when governance was mediated through boundary spanners, the network began to grow stronger. Similarly, the longitudinal nature of inter-organisational trust was also a thematic focus for the within-case analysis. The observation of growing inter-organisational trust between FOSS implementers and MOH resulting in less tension in HHIMS implementation network can be given as an example for the results of intra-case analysis.

The cross case comparisons were made to identify the differences of governance trajectories shaped by the inter-organisational trust and tension within the PE when the focus of governance shifted from centralised to poly-centric. For example, in paper 1, I discussed how the DHIS2 for MCH network developed more tensions over a period compared to the HHIMS implementation network, which negatively affected the governance trajectory of the DHIS2 for MCH projects. The cross-case analysis also tried to identify variations of governance decisions based on the types of coordination and control mechanisms involved. For example, when DHIS2 for MCH and HHIMS governance trajectories are compared, latter had more formal control and coordination mechanisms resulting in a lesser tension building in the network. Finally, these themes were aligned with the conceptual framework for building a deeper understanding of and reflecting on the findings.

3.3 Author's role in fieldwork

I played several, sometimes overlapping roles during this study, such as an observer, interviewer, FOSS HIS implementer and evaluator. Following is a list of different roles I played in the different projects during my research.

Project	Role
HHIMS	HIS evaluator Observer Interviewer
DHIS2	Observer Interviewer FOSS implementer and trainer
NFOSHS	Observer NFOSHS member

Table 3.6: Author's roles in different projects

In the DHIS2 implementation exercises I was engaged in the participant observations positioning myself as a 'participant-as-observer' (Gold, 1958), where I fully functioned as a member of the implementation setting through being assigned to PGIM and HISSL implementer teams. The other members participating in the HIS implementation were aware that I was an observer cum researcher. Observations were made while contributing to DHIS2 customisations and implementations for the Tuberculosis programme and MCH implementation in the Southern Province. In these settings, both focus group discussions and interviews were used along with participant observation. During the DHIS2 implementation in the North Western Province, interviews helped to collect data on the perceptions of central health managers and administrators of MCH programme, DMOs and other peripheral health staff such as midwives. During Tuberculosis eRegistry project I was mainly observing within my coordination role and as a volunteer for the HIS implementation. Whereas in the Nutrition Monitoring project with a strong contribution as a HIS implementer and a field level trainer, I had the opportunity to observe both the central as well as peripheral level interactions in the PE.

In the HHIMS project, I first participated in HIS evaluation activities representing the MOH. Hence, I played the role of 'participant-as-observer' during this phase familiarising myself with the FOSS implementation governance decision-making process from the perspective of a FOSS client (healthcare organisation). I participated in the HHIMS customisation and implementation activities with the FOSS implementer team for a deeper understanding of the implementation governance process from the 3rd party FOSS service provider. However, in HHIMS implementation exercises, I chose to be an 'observer-as-participant' since my expertise as an HHIMS implementer was minimal. There, as an 'observer-as-participant' (Gold, 1958) my observations were with minimal participation in implementation activities understanding implementers' concerns regarding the decisions of governance taken by the health managers and administrators. During this process, I was able to interview both HIS implementers as well as health managers/administrators and to conduct group discussions with HIS implementers regarding the FOSS implementation governance trajectory.

I was fortunate to be appointed as a member to the NFOSHS with access to the foundation's online discussion forum. Hence, I had the opportunity to observe the decision-making process towards establishing the NFOSHS, attend its meetings and to interview members of the NFOSHS working council. Similarly, I was able to analyse the ongoing governance discussions in the NFOSHS online forum as an 'observer-as-participant'.

The FOSS HIS implementer role I played in some of the cases took the form of an internal

implementer (e.g. for Tuberculosis and Respiratory Diseases eRegistry, working with the Tuberculosis Programme team as a volunteer) and in some other cases as an external implementer (e.g. DHIS2 for MCH implementation, representing the PGIM and HISSL as a 3rd party not-for-profit entity). Hence, these multiple roles gave me an opportunity to understand both the internal and external concerns and perspectives in FOSS HIS project governance. However, my focus during the study was to observe the HIS project governance in the FOSS implementation attempts. Hence, my expertise on the selected FOSS projects (i.e. whether I am a participant-as-observer or an observer-as-participant) did not affect the quality of data. However, the FOSS implementer role consumed more time, which, otherwise, could have been used for observations. However, it provided me a profound understanding of stakeholder functionalities, expectations and responses.

Also, I performed the observations of the project governance processes by getting involved in the respective PEs through the representative organisations; HISSL and the PGIM - and not as an independent researcher. I was bound by the project management decisions of the organisations I was employed in the implementations, without making my research interests the priority.

3.4 Ethical considerations

I faced several ethical issues during this study. One consideration concerned the gap which often exists between the expressed purpose of the research and the broader agenda of the field researcher (Walsham, 2006). In this research, trust was a subject of study, but was also the basis on which I gained access to conducting fieldwork. For example, in some data collection sessions, I observed lingering trust amongst the stakeholders through their actions towards each other without this being explicitly mentioned as the object of study.

Another issue which both Madden (2010) and Walsham (2006) highlight is of deciding what materials are to be included and excluded in writing the thesis, due to privacy and confidentiality considerations. With my different roles in participant observation, I had access to internal organisational information otherwise only available to members of the organisation. However, due to the sensitive nature of some of the information and the repercussions that might create if identifications of the informants are revealed, I have not included them in my thesis, probably losing some of the richness of the insights gained.

Chapter Summary

This chapter has described the research design and methodology adopted in this thesis. The research design followed a qualitative research approach with the focus on understanding the social meanings of the dynamics of FOSS HIS implementation software ecosystem with governance and inter-organizational trust in focus. The study was conducted in the preventive and curative health sector organisations involving HIS implementation initiatives to gain a better understanding of the FOSS implementation governance process under different conditions. Positioning myself in the qualitative tradition, I followed the case study approach organising the findings around three cases. The data collection methods included participant observations, semi-structured interviews, group discussions and document analysis. The study was informed by the interpretive tradition aiming at understanding the world by focusing on social and cultural context. The unit of analysis was the organisational networks. The data analysis process included the steps of transcribing of data, coding, developing themes and performing intra-case and inter-case comparisons. During the research, I played different roles, from observer to HIS implementer. These roles provided me with a better understanding of all aspects of FOSS HIS governance from various angles.

Chapter 4 - Related Research

This chapter presents related literature and the theoretical framework of the thesis. The first section describes the key concepts underpinning this study, relating to Platform Ecosystem (PE), FOSS, governance and trust. The second section elaborates on how I drew upon these different concepts to develop a holistic conceptual perspective to study the PE surrounding FOSS HIS implementations and to understand the influence on inter-organisational trust in the governance process.

4.1 Theoretical Underpinning

This study broadly focuses on the literature on PEs and FOSS, particularly relating to the influence of inter-organisational trust on the governance process. Specifically, the stakeholder governance approaches in PE and FOSS implementation processes and influence of the trust on governance trajectory in both these contexts was looked at. Hence, this thesis draws from four broad domains- PEs, FOSS, governance and trust. For this purpose, I brought in concepts around governance and trust from different domains of study such as management, organisational studies and IS research. Drawing upon these different set of concepts, this thesis seeks to build a deeper conceptual understanding of the stakeholder governance process in FOSS implementation by conceptualizing FOSS as a PE. Hence, the thesis tries to conceptualize the FOSS implementation governance with the aid of the PE orchestration, which is the platform owner's attempt to control and coordinate the stakeholders by 'gently but invisibly nudging' to maintain the evolutionary trajectory of the platform in a desirable direction (Tiwana, 2013). The thesis further tried to understand the role of trust in the context of FOSS implementation taking PE orchestration as an analogy for the control without the coordination through ownership or authority (ibid). The trust, in FOSS context would be an important consideration due to the facts that FOSS platform allows itself being replicated (forking) by 3rd parties and, traditional governance mechanisms are less effective in the multi-sector stakeholder network in the early phase of FOSS implementation.

4.1.1. Key concepts used in this thesis

As mentioned in chapter 1, I examined FOSS from a PE lens in this thesis trying to understand the roles of key stakeholders and the shifting focus of governance in the new context. Similarly, the role of trust in PE governance around FOSS implementation stage was another focus.

Hence, I introduce the following key concepts underpinning this thesis.

FOSS implementation: The term *implementation* is used as a collective term to encompass a diverse range of activities in association with making FOSS work in practice, including:

- open source configuration - optimising the performance of the system
- customisation - creating data entry forms and visualisations using features already made available in a FOSS platform
- component development on FOSS platform - developing custom components on top of the FOSS code base by adding new features to the platform as new modules or apps
- support - upgrading to a newer version of the FOSS platform, post-implementation maintenance and disaster recovery
- server hosting - hiring or configuring web and database servers to host FOSS platforms
- advocacy - FOSS awareness and supporting related policy formulations
- building networks - supporting FOSS developer and implementer networks
- end-user training - training employees of the client organisation to use the platform for the routine activities of the organisation

Platform Ecosystems: "*A software platform, a set of internal and external developers and a community of domain experts in service to a community of users that compose relevant solution elements to satisfy their needs".* (Bosch & Bosch-Sijtsema, 2010, p 70)

Governance: *All the structures and processes that coordinate and control an organisation's resources and actions.* (Meyer, 2004)

Trust: *A party's willingness to accept vulnerabilities, but with an exception or confidence that it can rely on the other party.* (Lewicki, Tomlinson & Gillespie, 2006). Informed by this definition, *inter-organisational trust* was interpreted as the degree of trust placed on the partner organisation by members of a focal organisation (Zaheer, McEvily & Perrone 1998).

4.1.2 Platform Ecosystems

IS research is currently emphasising the use of a PE perspective (Elbanna, 2010). PE is an emerging trend within the software industry, implying a shift from closed organizations towards more open structures. PE is considered to "consist of a software platform, a set of internal and external developers and a community of domain experts in service to a community of users that compose relevant solution elements to satisfy their needs" (Bosch & Bosch-Sijtsema, 2010, p 68). In this PE

perspective, the networked community of organisations base their relations to each other on a common interest reflected in the central software technology (Hansen, 2011). Hence, the central software is developed, maintained and evolved through a collaboration of the software platform developers, other 3rd party (component) developers and several layers of actors customising and configuring the software product (Dittrich, 2014).

The PE has been conceptualised as a way to construct a large software system on top of a software platform by composing components developed by actors both internal and external (Manikas & Hansen, 2013). However, this differs from traditional IS outsourcing in that, the actor commissioning the implementation of the software ecosystem does not necessarily own the platform software produced by the contributing actors. The lead firm who owns the software platform is referred to as the platform owner or the keystone organisation (Tiwana, 2013). In the traditional PE conceptualisation, the platform owner plays the role of the keystone organisation and controls the PE. Tiwana (2013) further elaborates that PEs highlight the role of the internal developer as the platform owner and hence representing the *keystone organisation*. In this conceptualisation, PE requires the platform owner to deliberately govern its evolution and this governance approach is described as orchestration. While conceptualising the PE as an organisation (contrary to the *platform as an architecture* conceptualisation), Gower (2014) described PE governance to play out as a collaboration.

PE and Information Infrastructure (II) reflect many common and overlapping elements, such as the characteristics of being open, shared and socio-technical. Heterogeneity (Hanseth, 2000), a characteristic of IIs, arguably provides a sense of contradiction between PE and II. According to Hanseth and Monteiro (1998) the concept of II is not strictly defined, but is rather characterised by several aspects, including heterogeneity. The concept of II can be based on heterogeneous technologies and also allows for the seemingly similar functions being implemented in different ways. Manikas and Hansen (2013), in contrast, argue that a PE is built up on a primary technology focus. Hence, in contrast to II, PE can be considered to be less heterogeneous. PE is based on a one central technology, which is the platform (Nielsen, 2016). In addition to the heterogeneity, in early conceptualisations of II it was considered as a physical artefact and a passive sub-layer (Star & Ruhleder, 1996). The PE was considered to consist of a physical artefact as well as its users (Bosch & Bosch-Sijtsema, 2010).

4.1.3 FOSS in LMIC context

FOSS is a globally recognised software development practice, which is not merely the free access to

the software source code (Gwebu & Wang, 2011). The value of open source is based on several key concepts[7] . These include the free access to the software source code with the permission to modify and redistribute the code and its derivatives with a technology neutral licence. FOSS has increasingly started to appear in enterprise scale HIS implementation projects competing with proprietary software, especially in the public sector of LMICs (Chamili, et al., 2012). Many IT executives believe that the organisational adoption of FOSS is inevitable because of its process, cost and performance advantages to the firm (Gwebu & Wang, 2011).

Due to the technological and financial limitations inherent in a LMIC context, FOSS has increasingly become an important resource in the global south (Twaakyondo & Lungo, 2008). This is not only because FOSS reduces licensing costs, but also because it promotes indigenous technological development by allowing access to the source code which can aid the enhancement of local knowledge (Câmera & Fonseca, 2007). Benefits of FOSS include, but are not limited to, vendor neutral technology through the availability of source code and reduced the Total Cost of Ownership with no licence fees. Vendor neutrality further contributes to the reduced cost of maintenance and competitive costs for software customisation and component development. Also, open source provide flexibility in end user training and reduces the risk of losing legacy data when migrating to a newer software version or solution as compared to a proprietary software (Meystre & Müller, 2005). However, due to limitations of technical and financial resources, FOSS adoption in LMIC health sector context often demands the participation of multi-sector stakeholders. Governance of these stakeholders becomes an important challenge.

4.1.3.1 Commercial FOSS

The FOSS phenomenon has undergone a significant transformation from its free software origins to a more mainstream, commercially viable form, which is referred to as ‘Open Source 2.0’ (Marsan, Paré & Wybo, 2012). Under this new business model of ‘second-generation open source’, the FOSS development process has become less ad-hoc (community centric), migrating towards strategic planning and a stronger revenue focus.

During the transformation to FOSS version 2.0, the interpretation of the word ‘free’ in FOSS has got more esoteric, beyond its common meaning of ‘being without financial commitments’. This is often misinterpreted by FOSS users and in fact, is subject to criticisms (May, 2006). Under this new business model, only the basic forms of FOSS artefact is offered free of charge and further technical

7 Open Source Definition; https://opensource.org/osd

support for advanced customisations, such as developing new components based on the FOSS framework, remains a commercial proposition. Customers have to pay for customising an FOSS platform to align generic features to specific organisational business needs (Fitzgerald, 2006; Riehle, 2007) and for capacity strengthening support.

Such customisation related services critically influence the FOSS adoption in enterprises, and tend to be beyond the FOSS developer firm's capacity against the growing demands. Hence, FOSS developer firms have to look towards 3rd party service providers to support customisation and related services (Krishnamurthy, 2003). Several open source business models have been proposed to describe these emerging stakeholder relationships (Markus, 2007), which represent more the custom-built software development process than the earlier Bazaar model of earlier (Ebart, 2008). Single-vendor Commercial Open Source Model and Service/Support Commercial Open Source Model proposed by Dixon (2009) and Third Party Service Provider Model proposed by Krishnamurthy (2003) were central among these new emerging models. In the Single-vendor Commercial Open Source Model, an extension from the FOSS developer firm emerges and provides the product related services, which Dixon (2009) referred to as 'productisation', implying creating a specific software product using the generic platform. In the Service/Support Commercial Open Source Model, instead of the FOSS firm, 3rd party 'service providers' emerge around the FOSS platform to deliver 'productisation' related services. Whereas, in the Third Party Service Provider Model, 3rd party service providers use the generic platform the FOSS community releases and creates a custom software using the FOSS core following a similar approach to custom software development.

4.1.3.2 FOSS as a platform

FOSS is considered as a viable candidate to build a PE from the perspectives of effective implementation, development methodology, business model, governance and legality. It promotes extending the FOSS code repository by 3rd party developers with open source licenses to create a software ecosystem around the FOSS artefact produced by the core development firm. However, how this plays out in practice have not been topics of systematic research (Kilamo, et al., 2012). FOSS provides the transparency of development and capability to build more complex systems out of freely available source code. This provides an opportunity to rapidly construct a PE without large initial investments (Walton, 2002).

The platform architecture consists of a stable base (the platform core, owned by the keystone firm), interfaces and modules to deliver specific functionalities built by independent developers (Tiwana,

2013). Hence, the PE can be seen comparable to commercial FOSS models where 3rd party developers add functionalities to the FOSS with free access to the its code repository. FOSS can be more precisely theorised as an "Application-centric PE" which is a platform based on a software application which is designed to provide routine functionalities to its users (Bosh, 2009). The Total Cost of Ownership of FOSS can be understood in comparison to platform-application integration cost and 3rd party component development cost, even if the FOSS code base provides free access to itself.

4.1.4 Governance and PEs

Governance has been the subject of study in many disciplines, including political science, sociology, law, IT, business administration, marketing, economics, health, management as well as geography and history (Kersbergen, & Waarden, 2004). These studies have elaborated multiple forms of governance mechanisms, such as, collaborative governance, multi-level governance, public-private partnerships, community organisations, corporate governance, market mechanisms, new public management and top-down methods involving governments and state bureaucracy. Similarly, many governance structures have been identified including institutions, networks, markets and the State (Bevir, 2008; Kersbergen, & Waarden, 2004). Today's firms are moving in to new governance approaches, such as steering committees, instead of more traditional methods, such as governance through oversight (Meyer, 2004).

Governance involves the processes of decision making in a formal or informal organisation through laws, norms, power, or language (Bevir, 2012). In this thesis, governance refers to 'all the structures and processes that coordinate and control an organisation's resources and actions' (Meyer, 2004). It includes making and enforcing rules and relating to processes and decisions that seek to define actions, grant of power and verification of performance (Fukuyama, 2013). Governance is a legal necessity in today's firm and is a way to use resources effectively. More importantly, governance is a must for the control and coordination of the organisation, (Meyer, 2004). It provides the organisation with a sense of community against the fragmented organisational structure creating a sense of solidarity and cohesion (Papadopoulos, 2002). Governance supports the organisation to achieve its business goals (Simonsson & Johnson, 2006), and is a pre-requisite for putting in place an integrated policy making capacity needed to drive sustainable development and inclusive organisational growth within finite boundaries (Clark, 2012). Effective governance is a means of risk reduction as well (Ahrens, & Rudolph, 2006).

Conventional hierarchical governance is challenged in multi-sector networks such as of building

commercial FOSS based applications. Hence, the governance mechanisms observed in IT projects (Hirschheim, Heinzl & Dibbern, 2007) and especially the remotely outsourced software development (Sabherwal & Chaudhary, 2006) take the form of coordination and control. The coordination, which is defined as "integrating or linking together different parts of organisation to accomplish a collective set of tasks" (van de Ven, Delbecq, & Koening, 1976; 322), includes non-coordination, formal and informal coordination. The control is defined as "… the organisation's attempt to increase the probability that employees will behave in ways that lead to the attainment of organisational goals" (Henderson & Lee, 1992; 757). Four modes of control identified are self-control, clan control, output control and behavioural control. (Sabherwal, & Choudhury, 2006) This is summarised in the table 4.1 below.

Coordination	Non coordination	No coordination mechanism exists
	Informal-interpersonal	Informal coordination among individuals
	Formal-interpersonal	Individual dependant, yet formal coordination
	Formal-impersonal	Non-individual dependant formal coordination
Control	Self control	Monitoring the self
	Output control	Monitor and evaluate output by a manager
	Behavioural control	Monitor and evaluate team members' behaviour by a manager
	Clan control	Monitoring the team by the members of the team

Table 4.1: Governance mechanisms in IT projects

Out of these modes, self-control and clan control are considered as forms of informal control mechanisms whereas output and behaviour control represent more formal methods. Clan control is more evident in the early phases of IT projects coexisting with an informal governance structure.

However, later it can be replaced by formal mechanisms indicating that governance mechanisms can undergo changes and evolve from none to mature governance models.

4.1.4.1 Governance approaches in PE

PEs can be theorised as governance mechanism through its rules and constraints, creating inducements and otherwise shaping behaviours (Boudreau, & Hagiu 2008). Tiwana (2013) suggests that it is the architecture rather than authority and contracts that provide coordination in a PE. Gawer (2014) proposes the alliance or cooperation as the means which provide control in PEs.

PEs can be conceptualised as a network of organisations where the inter-organisational relationships are based on a common interest in a central software technology (Hanssen, 2012). Such networks are cooperative endeavours and comprised of autonomous organisations (Provan and Kenis, 2008). Since networks are not legal entities, the legal imperative for governance is not naturally present in such networks. However, a network can be seen as a governance approach which ensures that participants engage in collective and mutually supportive action, conceptualised as collective action (Constantinides & Barrett, 2014). In such poly-centric governance, multiple governing units will appear at different scales, compared to traditional mono-centric governance. Poly-centric system exercises considerable independence to make norms and rules within a specific domain. Centralisation, which is defined as a locus of authority to make decisions affecting the organisation (Pugh, et al., 1968), is not uncommon in network organisations. The centrally controlled (brokered) network organisation is described as a lead organisation-governed network and is coordinated by a dominant, single participant (Provan & Kenis, 2007).

Tiwana (2013) has conceptualised PE governance as a loosely-organised yet a brokered governance model. In this model, the related platform owner's attempt to bring the organisational network to order against the 'waning' authority is described as an orchestration[8]. During this process, attempts are taken to ensure the integration of the outputs of diverse ecosystem participants through orchestration rather than tightly controlling the ecosystem. The command-and-control structures work well in traditional organisations due to legitimate hierarchical authority of employer over employee. However, in PEs no such direct authority exists since there is no hierarchical authority of the platform owner on 3rd party contributors (e.g. App developers).

The orchestration of PE enacts through the three dimensions of platform governance - decision rights, control mechanisms and pricing (Tiwana, 2013). Decision rights implies the authority or the

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responsibility for decisions prevailed by the App developers and the platform owner. The decision rights can range from centralised to decentralised and take the form of App decision rights and platform decision rights. Four control mechanisms are associated with PE and responsible for goal convergence and coordination with App developers. Those include gate-keeping, metrics, process control, and relational control. Pricing mechanisms include incentives for 3rd party contributors' participation and licensing. Table 4.2 below summarises the different dimensions of the platform orchestration with their governance mechanisms.

Decision Rights	Strategic decisions or implementation decisions (decision horizon)	
Control Mechanisms	Gate-keeping	Platform owner decides who are allowed into the PE (input control)
	Metrics	Reward/penalty based on performance targets of Apps
	Process Control	Reward/penalty based on adherence to prescribed PE process
	Relational Control	Shared norms and values (clan control)
Pricing	Incentives, integration cost and licence decisions	

Table 4.2: Three dimensions of platform governance in PEs

4.1.5 Role of trust in PE governance

Trust is defined as a party's willingness to accept vulnerabilities, but with an exception or confidence that it can rely on the other party. (Lewicki, Tomlinson and Gillespie, 2006). There are three dominant characteristics of trust common to most conceptualisations, vulnerability, risk and expectations (Edelenbos & Klijn, 2007). McEvily, Perrone and Zaheer (2003) have also highlighted the willingness to accept vulnerability based on positive expectations about another's intention or behaviour as being key in trust based relationships. In inter-organisational contexts, trust can exist as inter-personal trust between individual actors in partner organisations or as inter-firm trust between two organisations (Zaheer, McEvily & Perrone, 1998). Individual actors who play a key role to propagate trust between organisations are referred to as boundary spanning agents (Perrone,

Zaheer & McEvily, 2003). While exchanging with another organisation, they place their trust in it, and move back into their own organisation and propagate the trust towards the organisation they were in exchange, and internally amongst colleagues of their own organisation.

With the emergence of the network organisation, the classic hierarchical governance has been increasingly challenged, requiring alternative models of governance (Ribbers, Peterson & Parker, 2002). Although our knowledge on these issues is still limited, there is evidence to support the importance of trust in developing robust governance processes (Kezar, 2004). Inter-organisational trust, which is defined as "the extent of trust placed in the partner organisation by the members of a focal organisation" Zaheer, McEvily and Perrone (1998, p142), has been identified as a key determinant in maintaining the fabric of a network organisation (Sørensen & Torfing 2009; Uzzi, 1997). While acknowledging trust as a key aspect in inter-organisational relations, Provan and Kenis (2008) have highlighted that the distribution of trust is critical in the governance of networks. They have also argued that networks face tensions between the need for administrative efficiency and inclusive decision-making. Gallivan, (2001) has argued that, while various control mechanisms can help in governing autonomous agents, trust is a key determinant of control (and hence, governance) processes.

Trust has been discussed in association with PE implementations. Hurni, and Huber (2014) had highlighted the role of inter-organizational trust in the PE relationships, which may exist in the form of the trust of an employee of an organization towards the platform vendor. This study was designed around the coordination between huge multi-national platform vendors and small complementor companies and it investigated the role of trust as a coordinating mechanism in PE governance. During this study, they have identified the inter-organizational trust as necessary pre-condition for coercive and reward power in PE context. In this study, Hurni, and Huber (2014) proposed the inter-organizational trust as an alternative to legal coordination of partnerships in PEs. Schreieck, Wiesche, and Krcmar (2016) have also highlighted the role of trust in PE context. Basole, and Karla (2011) have also argued for the unique influence trust is having over PE governance beyond the role of inter-organizational trust on the conventional network organization.

4.1.5.1 Trust in HIS

Trust is influenced by the national culture and the norms and values of the organisation (Doney, Cannon & Mullen, 1998). Trust is a familiar concept in healthcare organization in personal as well as and inter-organisational relationships (Alexander, Comfort & Weiner, 1998), and in maintaining the integrity of partnerships in networks (Ross et al, 2010, Zaheer, McEvily & Perrone, 1998). Trust

is critical in determining the end user's experience and their willingness to take up an e-health innovation initiatives (Shuvo et al, 2015). In an organisational context, trust has been identified as an important factor in HIS success with an important focus on the contracts between healthcare institutions and the software firm (Brender et al 2006). In the health sector, inter-organisational trust is more visible in the governance of public-private partnerships, volunteer organisations, communities and individuals with informal contracts (Alexander et al, 1998; Michell & Shortel, 2000). Inter-organisational trust is especially important in the early phase of HIS implementations where multi-sectoral stakeholders operate based on mutual understandings (Miranda & Kavan, 2005).

Brender et al. (2006) argues that trust is an important factor for HIS success even after consolidating the inter-organisational relationships with formal contracts. Trust between software vendors and hospital managers are attributed to the HIS implementation success in custom software development process (Rahimi, Vimarlund & Timpka, 2009). It has been argued that trust (or lack of trust) could be manifested in the HIS implementation context in various issues such as, sources of funding, outsourcing of system development and implementation and in selecting of software vendors and IT service providers (Randeree, Kishore & Rao, 2005; Kopala & Mitchell 2011; Spriggs, et al., 2012). Croll & Croll (2007) have mentioned that trust in e-health is fragile than in other industries. Trust among nodes of distributed developers and public health partners are shown to be important in multi-sector stakeholder software development tasks (Moreno-Sanchez et al, 2007).

Trust positively affects healthcare stakeholders, not only in IS development, but also in using HIS (Tung, Chang & Chou, 2008).

4.1.5.2 Role of trust in the context of governance

Miranda & Kavan (2005) have highlighted the significance of non-contractual mechanisms, such as trust in an IS governance context. Trust is especially important in the early phase of IS implementation and around outsourcing arrangements. Heeks (2002) describes trust in a certain technology as a new state of rationality, understanding which is essential in minimising IS failures. Trust has been identified as a risk factor in collaborative software development involving multiple organisational units in many domains, including the corporate health sector (Mohtashami, et al, 2006). However, trust has not been analysed in LMIC settings with a particular focus on FOSS implementation governance.

Creed et al., (1996) argue that, in a network organisation, where traditional control mechanisms are

generally ineffective, the requirement of trust is high. The orchestration of PE (Tiwana, 2013) was also theorised as an occasion where the traditional hierarchical governance mechanism is challenged. There are three dominant characteristics of trust - vulnerability, risk and expectations (Edelenbos & Klijn, 2007). Vulnerability refers to, the open and vulnerable position an actor is willing to assume, expecting the other actor to refrain from being opportunistic behaviour. The risk is the ambiguous and unpredictable situations an actor is willing to embark upon with the belief that the other party can be trusted. The trust presumes a stable positive expectation of the intentions and motives of the other actor, which is the third characteristic of the trust Edelenbos & Klijn (2007), describes. Trust reduces unpredictability because one can anticipate the behaviour of the other actor. During PE orchestration, the keystone organisation expects a similar degree of control to hierarchical governance against the vulnerability conveyed by the independent nature of the stakeholders being orchestrated against the risk of the independent actors who might refuse to comply with the keystone organisation.

Trust becomes important in the context of FOSS by being a key denominator affecting the implementation decision. From the end user perspective, trust plays an important role in FOSS applications rather than in proprietary software (Boulanger, 2005). A classic example for inter-organisational trust was provided by Doney and Cannon (1997) taking the buyer-seller relationship as the case. They describe the comparable analogy for PE to understand trust in the orchestration process. In this model, Doney and Cannon (1997) investigate the buying firm's trust towards the supplier firm and the buying firm's trust towards the sales person and sales choices. They have found that characteristics of the firms involved, such as supplier firm's reputation and sales person's expertise and characteristics of the relationship, such as its length and the role of the sales person in influencing the purchasing decisions.

4.2 Conceptual Framework

In this section, I present my conceptual framework, which seeks to understand PE governance in FOSS implementation in a LMIC context and; the role of trust in PE orchestration in FOSS implementation. For this purpose, I extend the vendor focus orchestration of Tiwana (2013) to the FOSS implementation context by highlighting the key differences of PE governance when the platform becomes open source. As discussed early in this chapter, the multi-sector stakeholder governance aspect has not been much discussed in the FOSS implementation context in the current literature, including in the existing FOSS business models. Aligning with the capability of FOSS to behave as a PE, I explore the possibility of PE governance comparatively to understand the

stakeholder governance in FOSS implementations.

The traditional PE is mainly commercially driven, whereas FOSS is considered as a public good (Johnson, 2002). Hence in the PE context, the 3rd parties are driven by commercial incentives providing specific service allowed by the platform owner. In FOSS platforms, the commercial incentive is not so explicit and the 3rd party contributes are permitted by the open source license to 'innovate' beyond the control of the platform owner. This is a major difference I consider in applying the PE governance (orchestration) idea in the FOSS context. With the shift of governance mechanisms from traditional centralised to a poly-centric focus (Spinellis, & Giannikas, 2012) during the PE orchestration, there is the potential of rising tensions in FOSS implementation networks. Hence, the conceptual framework attempts to understand the role of inter-organisational trust in maintaining the fabric of the FOSS implementation PE against the changing governance focus.

As various authors (Hurni, & Huber, 2014) highlighted, the inter-organization trust has a unique role in PE context. This is not merely due to the fact that the stakeholders in FOSS implementation context tend to behave as a network organization in their inter-organizational relationships. Since the inter-organizational trust is a key facilitator in the governance of network organizations, FOSS platform having a similar organizational architecture could relate to the significance of inter-organizational trust in FOSS implementation context. However, when FOSS becomes a PE, several inherent properties of FOSS highlight mechanisms which may seek inter-organizational trust to support the orchestration of FOSS PE. FOSS licensing is one such element which may adversely affect the orchestration of FOSS platform without the presence of strong inter-organizational trust among stakeholders.

For example, several FOSS licenses allow duplication of the a FOSS code repository. This freedom is in fact, extending to forking of the FOSS code base, creating new platform from an existing platform (Ven & Mannaert, 2008) provides an option to refuse orchestration by creating a new PE out of existing FOSS project. Similarly, the governance of traditional PE (orchestration) is done by the platform owner. However, when FOSS is considered as a PE the platform orchestration is transferred to, or has to be shared with the client who commissions the FOSS implementation. Hence the orchestration mechanisms such as gate-keeping and metrics may not operate in the same way they serve in the traditional PE. Such key deviations have been considered in the proposed conceptual framework to understand the FOSS governance through an PE lens.

4.2.1 FOSS business models informed governance framework

Establishing key stakeholder groups and control mechanisms (formulating the strategy/policy, remediation and communication) are major components of the FOSS governance processes (Kemp, 2010). It has been shown that a major reason for FOSS rejection by top management is the failure to align the FOSS system to the organisational business model/requirements or reservations about the lack of pre and post implementation support (Goode, 2005). According to Heeks (2002), bridging the gap between generic HIS design and the domain actuality is an important consideration in the implementation process. Within the emerging FOSS 2.0 paradigm, customisation and "productisation" are important steps in adopting FOSS solutions (Fitzgerald, 2006). The 'second-generation FOSS' is where developer firms generate revenue from complementary IT services supporting business practices. These may include further customising the FOSS artefact to address organisational business requirements, component development on the FOSS platform, implementation and post-implementation services.

In this paradigm shift, various FOSS business models have been coined in the literature (Markus, 2007). FOSS business models help implementation governance by identifying prospective stakeholder expectations and engagements. They also facilitate communicating the policies and strategies to stakeholders and establishing quality control measures during the governance process. The community centred FOSS development model referred to as Bazaar (Ebart, 2008) was one in which FOSS development took place in a highly unstructured manner. Developers released a minimally functional code to the general public in advance and then modified the code base according to the feedbacks which could often attract other developers. The bazaar method of development has been proven over time to have several advantages such as building upon the work of others. This model was more focused on FOSS development than customisation and commercialisation. Later there were several models proposed to describe commercially focused FOSS projects such as the Single Vendor Commercial Open Source Model and Service/Support Open Source Model by Dixon (2007) and the Third Party Service Provider Model by Krishnamurthy (2003).

In the current FOSS context, the process of FOSS customisation can be more closely represented by the Single Vendor Commercial Open Source Model (Dixon 2007). FOSS projects which are managed by a single firm is known as single-vendor FOSS (Riehle, 2012) and a substantial part of the software and majority of the resources are provided by a firm which manages the FOSS development process. In this model, the main exchange occurs amongst software developers, product management, the support team, and the customer. According to this model, the commercial

FOSS firm manages the software development and productisation single-handedly.

To supplement the Single Vendor Commercial Open Source Model, Dixon later suggested the Service/Support Commercial Open Source model (Dixon, 2009). It is comparable to the 3rd party implementers' role in enterprise-scale FOSS implementations. Krishnamurthy (2003) has also proposed several FOSS models and the Third Party Service Provider Model which is more compatible with FOSS 2.0 paradigm. In this model, supportive entities beyond the FOSS developer firm emerge around the FOSS project in supporting implementation. The FOSS customisation and related services are the single revenue stream in this model. In many cases, these third party service providers are local and hence, may be able to provide on-site assistance which is usually not possible by the FOSS developer firm or volunteer developer community support such as mailing lists or user groups.

The FOSS business models discussed above are compatible with PE principles. The service provider firm may choose a stable FOSS release which can be considered as the software platform, and can create custom software modules or Apps, which could be integrated with the platform for extended functionalities with value addition. In addition, these commercial FOSS approaches provide trustworthy business models with higher flexibility against generic FOSS architecture and less technical vulnerability during implementations.

Configurable IT implementation, such as FOSS and PEs, involve not only internal stakeholders, but also a network of external stakeholders such as software vendors, external contractors or system integrators, independent consultants, product extension vendors supporting ICT capabilities (Pozzebon and Pinsonneault, 2005). Manikas and Hansen (2012) have identified the orchestrator (platform owner), niche players (component developers), external actors (e.g. 3rd party/external developers and community), vendors (or resellers) and customer (end user) as the main actors involved in PE relationships. According to Dittrich (2014) software platform developers and 3rd party component developers are both important in configurable software development in a PE. Tiwana (2013) describes the platform owner, who is the infrastructure developer; 3rd party developers, who concentrate on service development instead of infrastructure: and users as the key stakeholders in association with PE orchestration.

The early FOSS development model, Bazaar (Ebart, 2008) only accommodated the core developer team (lead by committers), volunteer developer community and end users. However, with the comoditisation of infrastructure FOSS, independent software suppliers (3rd party service providers) play a key role in further customisation of the software to support the organisational business needs (Ven & Manneart, 2008). Emergence of the 3rd party service providers has made it possible for the

FOSS client organisation to consider outsourcing the implementation to external FOSS suppliers (Nagy, Yassin & Bhattacherjee, 2010). Dixon (2007; 2009) had mainly proposed the client firm, the commercial FOSS company, FOSS community and 3rd party service providers in his FOSS business models. Krishnamurthy (2003) has proposed FOSS (developer) community, distributors, and 3rd party software/service providers as the key stakeholder categories in commercially supported FOSS models.

FOSS business models (Dixon, 2009; Krishnamurthy, 2003) discussed in this chapter were based on the technical and financial exchange, among stakeholders instead of governance of the stakeholder community. Hence the supportive actors who did not directly participate in the exchange but had the potential to influence the governance of the FOSS implementation were not represented. Gwebu & Wang (2010) has proposed several FOSS user groups who are not depicted in the previous FOSS business models. The mainstream market is the *non-developer community members*, i.e., those users who are exclusively FOSS members. The ordinary FOSS users were introduced as the *non-developer non-community members*. The penetrated niche market encompassed the *developer community members*, i.e., users who are both developers and community members. As software developers, they possess advanced technical skills and tend to perform tasks that cannot be satisfied by standard functions offered by commercial software packages or generic FOSS products. These special categories of more technical savvy stakeholders help to improve the FOSS application and broaden its use (Ousterhout, 1999; von Hippel, 2001).

In formulating a conceptual framework, stakeholder categories representing a PE can be compared to that of the FOSS implementation as summerised in the table 4.2 below. In more generic terms, the FOSS developer firm plays the role of software platform developers and the 3rd party FOSS service firms/implementers play the role of the platform component developers. This could be useful as a lens to understand the orchestration in FOSS implementation context.

PE dimension	FOSS dimension
Software platform developers/platform owner	FOSS developers (FOSS firm)
External actors (Nice players)	FOSS developer community
Third party component developers	FOSS implementer/ 3rd party service providers
End-users	End-user

Vendor (value-added reseller)	FOSS implementer/ 3rd party service providers
Client	Client organisation

Table 4.3: A comparison of stakeholder categories in commercial FOSS and PE

4.2.2 Inter-organisational trust in the PE context

Inter-organisational trust has been identified as the key determinant in maintaining the fabric of the network (Sørensen & Torfing 2009), and an essential component in maintaining the integrity of the network organisation in healthcare partnerships (Ross et al, 2010). Many constructs of trust which have been described (McEvily and Tortoriello 2011) including competence, integrity and benevolence. Brender et al. (2006) argue that trust is an important factor for the HIS success even after consolidating the inter-organisational relationships with legal contracts.

Trust based contracts play an influential role in IS outsourcing projects even after legal contracts are formulated (Miranda & Kavan, 2005). Research by Koh, Ang and Straub (2004), Sabherwal (1999) and Willcocks and Kern (1998) confirm the significance of trust based informal governance arrangements in IS outsourcing. The broader governance mechanisms may include a IT project steering committee as well as stakeholder groups, and also be integrated within a wider and formal organisational governance arena. Creed et al (1996) have argued that in the network organisation where traditional control mechanisms are generally ineffective, the requirement for trust is high. Arguably, this is a comparable scenario to PE orchestration. In the FOSS context as well, from an end user perspective, trust was a key concern, since users tend to perceive FOSS and proprietary software in different ways in terms of ownership, credibility and support (Boulanger, 2005).

Analysing the marketing domain, Doney and Cannon (1997) argue that the purchase choice of a buying firm depends on their level of trust of the supplier firm and the sales person. IS research emphasises that trust amongst the nodes of distributed developers and public health partners are crucially important (Moreno-Sanchez et al, 2007). Trust between FOSS developers and healthcare actors need to maintain the transparency of decisions (Biondich, 2008) and positively cultivate trust amongst the partners (Tung, Chang & Chou, 2008). The model proposed by Doney and Cannon (1997) suggests a dependency between the purchasing decision and the buyer firm's trust of the sales person and buying firm's trust of the supply firm. Several supply firm factors, such as, its reputation and sales person factors, including his/her expertise are found to affect the trust among

these stakeholders. Similarly, relationship characteristics, such as the time period of the relationship with the buyer firm, found to have an effect on the buying firm's trust on supplier form or the sales person. When FOSS exchange is considered, the organisation commissioning the FOSS implementation plays the buyer firm's role. FOSS supply is done by the platform developer firm, whereas essentially the 3rd party component developers sell their product on the FOSS platform. Hanssen (2012) had proposed the keystone-centric PE model and in this model, he highlights the relationship among supplier, customer and 3rd party developer in the PE context.

In this backdrop, I propose a combination of these two models as a framework to study the inter-organisational trust in FOSS implementation ecosystem to understand how trust plays out in platform orchestration. In Hanssen's model (2012), the exchange takes place directly between customer and 3rd parties as services and; indirectly, between supplier and 3rd party through platform strategy and customer and supplier through platform. In Doney and Cannon (1997) model, the trust between the buyer firm and supplier firm and the trust between the buyer firm and sales person has been explicitly represented. However, it indicates that the relationship between the supplier firm and the sales person influence the overall trust in the environment through indirect mechanisms, such as delivery performance which depends both on the supplier firm and the sales person. In this context, it is possible to argue that the buying firm, the supplier firm and the sales person in Doney and Cannon (1997) model is respectively comparable to the customer, the supplier and the 3rd parties in Hanssen's (2012) ecosystem model. Hence, this can be the reference point to apply the inter-organisational trust for the stakeholder framework suggested in the table 4.3.

4.2.3 Aligning the conceptual framework with research objectives and research questions

The conceptual framework helps theory to inform the data collection and analysis. Hence, this section discusses how the conceptual framework liked research questions to the empirical analysis. In summary, my conceptual perspective is informed by the following concepts discussed in this chapter.

- Commercial FOSS business models: This differentiates FOSS development from implementation and allows understanding the diverse participation in the empirical context.
- FOSS as a PE: Component and app development on FOSS core enable it to behave as a software platform beyond customisability.
- Governance as orchestration: With the independent stakeholder network that is being created around FOSS implementation, the broker of the network fails to maintain the traditional

hierarchical governance. Borrowed from the PE discourse, the orchestration provides an alternative lens to understand the governance attempt in FOSS implementation network.

- Shifting focus of orchestration in PE of FOSS: A key difference between the traditional PE discussed in the literature and PE around FOSS implementation is the keystone organisation role shifting from the platform developer to client organisation. This may generate new dynamics in FOSS implementation ecosystem, which might not be seen in traditional PEs.
- Influence of inter-organisational trust in FOSS PE orchestration: As traditional governance fades away, inter-organisational trust emerges to retain the diverse actors within the network. This provide a lens to investigate the response of the network to its orchestration.

The empirical work of this thesis seeks to understand PE governance in FOSS implementation in LMIC contexts and the role of trust in PE orchestration in FOSS implementation. The data gathered through the participants' observations, interviews, focus group discussions and document analysis was centred on multi-sector stakeholder interactions in FOSS implementation focusing on the governance behaviours and perception of trust among them and the possible influence of inter-organisational trust on governance trajectories.

Extending the current FOSS business models in the conceptual framework helps to investigate the research question, 'Who are the actors and what are their inter-relationships comprising a platform ecosystem around a free and open source based health information system implementation in a low and middle income country setting?'. FOSS implementation governance is seen comparable to PE orchestration as the basis to investigate the research question, 'What are the governance modalities in free and open source implementation ecosystem in the low and middle income country context?'. The research question, 'How does trust play out in the orchestration of platform ecosystem around free and open source implementation?' could be aligned with the combined understanding of the Buyer-seller relationship model by Doney and Cannon (1997) and the Keystone-centric PE model by Hanssen (2012) in the conceptual framework.

The theoretical understanding of the governance structure based on the PE orchestration provides an opportunity to refine the observations around the stakeholder interactions in the FOSS HIS implementations. Inter-organisational trust is important in understanding the stakeholder governance trajectory against the tension created by the changing governance focus from a hierarchical control to an orchestration, which otherwise might rip apart the multi-sector stakeholder network organisation.

Chapter Summary

This chapter discussed the theoretical underpinning of the thesis. The chapter was built around the four seemingly independent concepts, governance, FOSS, PE and inter-organizational trust. It focuses on the possible governance mechanisms which can exist in the FOSS HIS implementation PE. Further it elaborates and differentiates PE governance with FOSS implementation governance. The chapter also highlights the inter-organisational trust as a key construct in understanding the dynamics of the interactions in the FOSS implementation ecosystem.

Followed by this, the chapter presents the conceptual framework leading to the discussion presented in this thesis. In conclusion, this chapter reveals the deficiencies of the current understanding FOSS implementation governance models suggesting improvements to FOSS HIS implementation ecosystem based on the empirical practice.

Chapter 5 - Research Findings

This chapter summarises the empirical findings from papers which I include in my Kappa. The first part of this chapter presents the summary of each paper which describes its key findings. In the second part, I present a synthesis of the findings from individual papers and discuss how these relate to the overall research questions posed in the thesis.

5.1 Summary of individual papers

Following are the five papers included in this thesis.

5.1.1 Paper I: Hewapathirana, R., & Rathnayake, S. (2014). How health managers' trust towards FOSS implementers changed and shaped HIS implementation trajectories: An empirical study of selected FOSS HIS implementations in Sri Lanka. International Journal of User-Driven Healthcare (IJUDH), 4(1), 17-32.

In a LMIC context, implementation of FOSS HIS demands participation of diverse organisational actors, typically operating in a network form of governance model. This paper attempts to reflect on how trust influences governance of this network, based on two FOSS HIS implementation projects in Sri Lanka. One of these projects is the implementation of the electronic medical record system HHIMS, whereas the other focused on the implementation of the public health IS, DHIS2 under MCH programme of the MOH, Sri Lanka. The longitudinal comparative case study helped to understand how health managers' trust towards FOSS implementation and other stakeholders changed over a period of time and shaped the implementation governance trajectories of the respective projects. This paper identified the inter-personal trust (trust between actors of stakeholder organisations) and inter-organisational trust (trust of actors of one organisation towards the other organisation) as the key to influence the governance of the organisational network around FOSS implementation. The paper also differentiates the static view of trust from the process view of trust, which may be an important aspect in longitudinal studies on trust.

Sri Lanka has a centrally governed healthcare system, which can also be seen as a brokered network with the MOH as a dominant actor. The State health sector is equipped with a well-established and time tested paper based record system, which MOH hesitates to experiment with and is conservative in partnering with external stakeholders. Hence, this paper contributes to the argument that trust process is influenced by national culture and the norms and values of the socio-cultural organisation (Doney, Cannon & Mullen, 1998).

In this paper, the inter-organisational trust between health care managers and FOSS implementers

were observed longitudinally and interpreted under the broader perceptions of several trust constructs. The trust constructs are a key concept to which this paper contributed. The competence, integrity and benevolence were the trust constructs used in this discussion based on the work of McEvely & Tortoriello (2011) which was also found to be aligned with the IS implementation. The paper describes trust as a process which evolves from an initial trust to on-going trust; shaping HIS implementation trajectories with time. Contrary to the static view of trust, the process view of trust consists of trust creation, development and maintenance (Khodyakov, 2007). According to Calton & Lad (1995), it is particularly important to understand the evolving network, such as PE, that consists of autonomous and independent entities. This study being longitudinal in nature, helped author to understand some process dynamics of trust, such as influence of trust on network trajectory shaped by the actions and interactions of FOSS implementers.

Based on the argument that the trust was a key determinant in maintaining the fabric of the network (Uzzi, 1997) where hierarchical governance fades away, this paper highlights the inter-organisational trust dependant relationship between the FOSS client (health care) organisation and external FOSS implementers (FOSS developer firm and 3rd party implementation firms) in HIS implementation ecosystem. The important role of trust was observed during the field work, especially given that health managers were largely unaware of FOSS and related concepts, and; had prior expectations only on custom software development projects, which are having different dynamics compared to FOSS HIS commissioning/development projects. At various steps during the lifespan of each project, inter-organisational trust was noted to shape the implementation trajectories with its influence on governance decisions. The trust itself seemed to vary in intensity in response to the decisions and actions of the participant of stakeholder organisations.

The boundary spanning behaviour (Perrone, Zaheer & McEvily, 2003) of HIS implementers seemed to strengthen trust and inter-organisational relationships among the client organisation, HIS implementers and FOSS developer firm. Strengthening the client organization's trust towards FOSS artefact and FOSS developer firms, the boundary spanners observed to move across the health domain to the FOSS domain playing a vital role to cultivate trust in implementation ecosystem.

At the central level, health managers' trust towards FOSS implementation was more influenced by the broader, programme-wide issues such as, financial model of software agreements, FOSS licences, reputation of the funding agencies and the ownership of software source code. Whereas at the peripheral level, health managers were more concerned about the feature of the FOSS HIS and flexibility of the HIS for it to be aligned with the health institution's business practice during the trust building process towards the FOSS implementation. Empirical evidence showed that the

central health managers/administrators have higher potential to alter the FOSS HIS implementation trajectories, especially with the brokered network in Sri Lankan context, than the peripheral health managers. This indicates the influence of top-down approach in FOSS implementation over the bottom-up approach.

Further, this paper highlights some best practices that FOSS implementers may adhere to, which might help in improving inter-organisational trust in FOSS HIS implementation ecosystems. These included having frequent interactions with the end users of the HIS, maintaining technical, financial and social transparency, and having a technically competent boundary spanning agent to strengthen the cross-domain inter-organisational interactions. Even if the initial trust was low, with the help of repeated and on-going interactions with health sector stakeholders, the FOSS HIS implementers could improve the trust in the implementation ecosystem and contribute to make the governance trajectories favourable securing a successful implementation. The work leading to this paper confirms the observations of Gulati (1995) that inter-firm trust consolidated in long term ties influence the contractual decisions within the network. This is a useful finding for the practical contribution of this thesis, which may help FOSS practitioners to migrate from trust-based contracts to legal contracts.

5.1.2 Paper II: Roshan Hewapathirana. (2015). Network governance in open innovation adoption: Case study from health domain. Roshan Hewapathirana, 13th international conference on social implications of computers in developing countries, Negombo.

This paper analyses selected FOSS implementations in the State health sector of Sri Lanka to understand the various governance mechanisms which operate in association with FOSS implementation ecosystems. Hence, the main contribution of this paper to the thesis is the broadening of the understanding of governance modalities that could exist in FOSS implementation. In addition, this work tried to understand the FOSS component development, which is an integral aspect of PEs, from the health sector perspective using an open innovation lens.

Due to technological and financial limitations in LMICs, FOSS is increasingly being considered for HIS implementation efforts. Although FOSS HIS potentially contributes to local innovation, its generic design may demand further customisation as required by specific business needs of health programmes. This customisation called for the participation of various non-health sector stakeholders to the FOSS HIS implementation process in the LMIC context. During the initial phases of FOSS implementation which is supported by a network of stakeholders, the governance process is informal and challenging. It required a sensitive approach to establish a trusting

relationship among multi-sector stakeholders. This longitudinal case study empirically examined three FOSS HIS implementation projects over four years duration, especially focussing on the dynamics around governance decisions. In this paper, the IS governance was conceptualised as a combination of coordination and control of the network participants (Hirschheim, Heinzl & Dibbern, 2007). During this research, several coordination options observed and those include, non-coordination, informal - interpersonal, formal - interpersonal and formal - impersonal. The control mechanisms observed included self-control, output and behavioural control by an officially designated role and clan control, which is a group, controlling themselves.

For FOSS HIS implementation to succeed, both formal and impersonal coordination mechanisms were required at an early stage of the implementation process. However, it was noted that clan control was typically the natural choice in the network, especially in its early phases organised through personal visits, group meetings and informal conversations. Later, this was noted to be formalised with legal contracts and impersonal coordination mechanisms, which helped to strengthen the FOSS HIS institutionalisation process by avoiding personal dependencies. Interpersonal as well as impersonal mechanisms of coordination were found to be effective under formal control compared to informal - interpersonal coordination mechanisms. Within formal coordination mechanisms, impersonal coordination yielded more stable outcomes in terms of governance decisions. Similar observations were made with respect to behavioural and output control (e.g. on-site coordination, project management plans, and periodic communication) which were seen to be more effective than self-control or clan control mechanisms. Output control mechanisms, such as monitoring of interim deliverables was valuable in a multi-sector network since it allowed stakeholders to evaluate the progress on the development of software artefacts in an ongoing and incremental manner. Not only the means of control and coordination mechanisms, but also the extent of them fluctuated with time in the observed implementation trajectories. This points towards a governance structure suggestive of orchestration seen in PEs. Further, the observations of the study indicated that the MOH was less aware of the concepts of FOSS governance (Kemp, 2010). Hence, they adopted ad-hoc approaches in FOSS implementation governance, which were mostly borrowed from their experiences in custom software development.

FOSS HIS developer firms, inherently, try to generalise the FOSS design by limiting the available features to most commonly requested functionalities to support a range of health programme settings with minimal effort. Due to the uniqueness of business processes (highly evolved clinical care pathways and health programme administration/monitoring strategies), the generic FOSS design was comprehended as a weakness of the IS design and appeared to be less desirable in

gaining the trust of the MOH in the Sri Lankan context. However, in combination with FOSS methodologies, further customisation demonstrated competitive technological and financial advantages to the health programme. Pre and post implementation support were identified as major barriers to adopt FOSS in empirical contexts. This emphasised the need to extend the stakeholder network to include the regional and global open source development communities to seek technical support more effectively. Similarly, hidden cost, which is a misunderstanding of Total Cost of Ownership, and fear of possible unauthorised access of health data by external stakeholders, especially FOSS developers and implementers, were serious considerations during the decision making in implementation governance. The ownership of the 3rd party component on FOSS platform was also seemed to be a debatable issue in the empirical context.

5.1.3 Paper III: Siribaddana, P. A., & Hewapathirana, R. (2016). Using training as a tool for cultivating communities of practice around Health Information Systems in low and middle income countries: A longitudinal mixed method study. The electronic journal of information systems in developing countries, 73.

It has often been argued by researchers that providing training per se would not lead to successful implementation of HIS, particularly in LMIC contexts (Mutale et al, 2013, Braa, Monteiro & Sahay, 2004). In such settings, it has been shown that, it was necessary to create support networks (Braa, 2004) to institutionalise the HIS implementation. Particularly, creating domain and technology 'hybrids', has shown to help bridging the gap between the technology and health sector. This paper discusses the role of 'hybrid' implementers in the multi-sector stakeholder network (beyond organisational boundaries), by studying a group of MO-HIs undertaking DHIS2 training and consolidating their interactions with the global FOSS implementer community. These hybrids extend their role beyond health institutions' functional limits as boundary spanning agents (Perrone, Zaheer & McEvily, 2003) traversing health and FOSS HIS domains. Hence, this paper contributes to the thesis by highlighting the roll of implementers and their boundary spanning behaviour across their own domain (health sector, in this case study) and technical community (global DHIS2 implementer network).

Networking interactions around HIS implementation included amongst HIS implementers; between HIS implementers and clinical/health sector stakeholders, and; between HIS implementers and the global and regional FOSS expert communities, which include implementers and developers. To enable such support networks, organisations try to adopt the cultivating communities of practice (Wenger, McDermott & Snyder, 2002) approach. This paper argues that by facilitating participation

and encouraging relationship building, HIS training can be used as a tool to build such communities of practice in multi-sector stakeholder networks. In this process, it is imperative to manage the 'participation' of HIS implementers, who are members (employees) of the organisation through facilitation and identifying organisational champions, who serve as boundary spanners, to lead the formation of communities of practices.

This paper gathered empirical evidence from a FOSS HIS training initiative aimed at a group of 'hybrid' implementers, who were primarily medical graduates trained in health informatics. The training included DHIS2 implementation projects with provincial and health programme-wide scopes. The FOSS public health IS, DHIS2, was included in their academic curriculum, but the trainees did not have opportunities to acquire technical skills to perform advanced DHIS2 customisations with the hands-on training while attending health programme needs. Hence, this group of emerging implementers were not experts enough to convey the required trust in DHIS2 to the MOH to take adoption decisions, raising the need for extensive training on DHIS2.

This study initiated, in combination with an advanced DHIS2 training programme aimed at creating the implementers with expert technical skills, such as creating custom forms and dashboards. The paper points out that a training programme can help to trigger the formation of an effective community of practice around FOSS implementation in a networked manner. Such networking showed to consolidate the confidence in implementation mediators in themselves, and to help in developing trust in the FOSS artefact among these implementers to strengthen their boundary spanning role. The discussion within the online platform (Launchpad9) generated new links between these local implementers and regional/global developers and implementers, and helped them to develop their own strategies in engaging with the global community. This training also facilitated networking among local implementers, which help them to build on each-other's capabilities and expertise. For example, one implementer might be good at server configuration, while another might be good at creating custom forms.

The local implementer group organised themselves as a locus within and beyond their organisation's stakeholder network. They were keen on maintaining the links they built during the training programme as extensions to their existing networks. This helped them to expand their sense of belonging to this global community, which in the long run would enhance their trust in FOSS HIS, which they could convey to their employer, MOH, influencing HIS implementation decisions. The feeling of 'globalness' encouraged the implementers to be proactive in network building and learn from experiences of the others who were having similar contexts. In a summary, it helped

9 https://launchpad.net

them to improve their skills in customisation, and to gain and build trust among the community members. The more they felt comfortable within and across these networks, these boundary spanners could contribute to the processes of institutionalisation of FOSS HIS.

5.1.4 Paper IV: Roshan Hewapathirana, Sundeep Sahay. (2017). Open Source adoption in health sector: Understanding the stakeholder relationships in a resource constrained setting. The Electronic Journal of Information Systems in Developing Countries, 81.

This paper took the FOSS 2.0 paradigm, which is the commercially viable model in providing support in large scale FOSS implementation as the lens to understand HIS implementation and governance in health domain. This longitudinal case study (from 2011 to 2014) was empirically positioned around two FOSS HIS implementation projects in an effort to establish a FOSS governance body in the State health sector of Sri Lanka. The paper contributes to FOSS governance discourses by suggesting an alternate model to understand the enterprise scale FOSS HIS implementation ecosystems in LMIC settings. The single Vendor Commercial Open Source Model and Service/Support Open Source Model by Dixon (2007) and; the Third Party Service Provider Model by Krishnamurthy (2003) are the leading FOSS business models to understand such HIS implementation ecosystems.

The positioning of stakeholders in the network which constitutes the PE is vital to the success of FOSS HIS implementations. Hence, the paper began with a discussion identifying several categories of multi-sectoral participation in FOSS HIS implementation ecosystems. With the empirical evidence, the client organisation (who commissions the implementation), FOSS developers firm and implementers (FOSS customisation agents, 3rd party or employees of the client organisation) were the three key stakeholder groups identified in this network. Around this core exchange, it was possible to identify several supportive stakeholders. The first group was directly involved with the health care domain and referred to as ‘internal’ stakeholders in this paper. They included health sector regulatory bodies, such as NFOSHS. The second group was not directly involved with the health domain and referred to as the ‘external’ stakeholders. These actors could have a global focus (e.g. international funding agency and global standardisation bodies) or a local focus (e.g. national IT regulatory committees) based on their operational interests and functional scopes.

Within the FOSS 2.0 practice, FOSS developers and implementers could provide the core product (FOSS platform) and the whole product respectively to client organisations. The FOSS implementers were also supposed to provide end user training and implementation related technical

consulting services. The implementers could be an internal employee of the client organisation or a 3rd party individual or entity. They may reflect boundary spanning behaviours conveying technical and domain expertise across the health and IT domains during a FOSS project. Similarly, these boundary spanners strengthen the client organisation's trust towards the FOSS implementation process. During this study, it was evident that 'external' supportive stakeholders had a certain influence in shaping initial implementation trajectories even though they are not directly a part of the health domain. As an example, globally positioned (international and regional) funding agencies could exert a control over the HIS client organisations through their reporting requirements. Whereas, the 'internal' supportive stakeholders, such as local health authorities (eHealth Steering Committee), could exert its influence through standards and guidelines and health policies (National eHealth Standards and Guidelines/Policy).

The paper argues that the FOSS business models proposed in the current body of literature, such as the work of Dixon (2009) and Krishnamurthy (2003) are not adequate in understanding the possible vast range of stakeholders categories in FOSS HIS implementation ecosystems in the LMIC context. Hence, in this paper I argue that there is a need for alternate conceptualisations to understand FOSS governance. As a solution, we proposed a model to understand the various stakeholder representations in FOSS HIS implementation ecosystem.

According to the empirical experience, several aspects need to be improved in existing FOSS business models in order to understand governance dynamics. With the empirical evidence, the coordination between key stakeholder groups was found to influence the FOSS implementation trajectory. Hence, drawn upon the existing theoretical understanding, we propose an extended model to analyse FOSS implementation governance (see figure 5.1).

The stakeholder groups identified as the essential categories included, the core FOSS development team (e.g. HISP global team), implementers (e.g. 3rd party implementers) and FOSS client organisations (e.g. health programme administrators of the organisation commissions the implementation) and the FOSS community (volunteer implementer/developer community). Apart from these actors who are directly associated with the FOSS product, it is possible to identify two major *auxiliary* stakeholder categories (internal and external) that influence the FOSS implementation trajectory. The Internal Auxiliary Stakeholders consist of local health administrators and policy-makers such as NFOSHS. Global standards enforcing bodies and international development partners (e.g. funding agencies) could be categorised under the External Auxiliary Stakeholders.

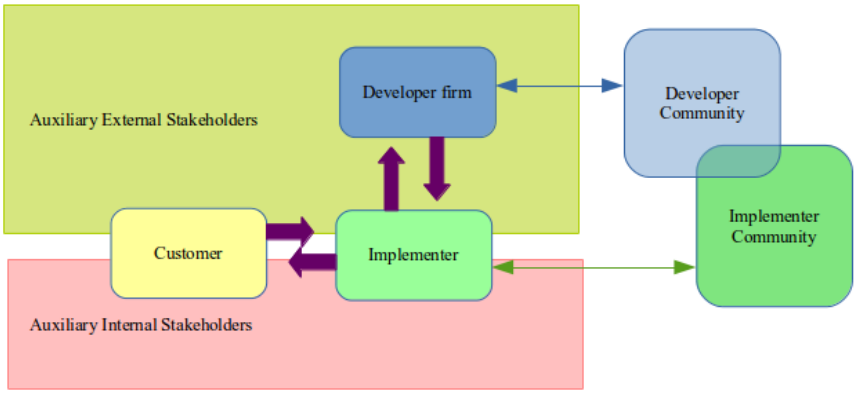

Figure 5.1: Various stakeholder groups in FOSS 2.0 implementation in the health sector

In this model, the main interaction between the client firm and implementers is that the implementer is supplying the 'whole product' (customised FOSS solution) to client firm in exchange of payments for the service of the implementers. The main interaction between the FOSS developer firm and implementers is, that the developer provides the FOSS platform to implementers and; the implementers in exchange, may (or may not) provide various services (such as, FOSS bug reporting, channelling user requirements to FOSS firm) to FOSS firm. The paper also highlights the knowledge exchange (two-way arrows in the figure 5.1) between FOSS developer firm and the developer community and; between FOSS implementers and implementer community. As explained in this model, funding agencies have the ability to control and coordinate (local) HIS implementation as well as (global) FOSS development depending on the scope and the model of the project financing. Coordination is prominent and essential between implementers and clients, and in some instances between FOSS developer firm and implementers. The paper further argues that it is important to make the distinction between customers (corporations) and community (consisting of individual members) since community members have the potential to persuade their employers to become a prospective client organisation.

5.1.5 Paper V: Hewapathirana, R., Amarakoon, P., and Braa, J. (2017). Open Source software ecosystems in health sector: A case study from Sri Lanka. In international conference on social implications of computers in developing countries (pp. 71-80). Springer.

Compared to the traditional software project perspective, software ecosystem is an emerging trend within the software industry. This paper analyses a FOSS HIS implementation in Sri Lankan

context to understand the stakeholder participation in the implementation network and its governance approaches outweighing the effect of the stakeholders being independent from each other. Theoretically, the paper positions itself in the PE which typically consists of a software platform, internal and external developers, domain experts and a community of users that compose the relevant solution elements (Bosch & Bosch-Sijtsema, 2010). Empirically the paper was framed within a FOSS HIS implementation in the State health sector of Sri Lanka for nutrition monitoring, where the mutli-stakeholder participation was an essential requirement to face the domain challenges.

A PE is a means to construct a large software system on top of a software platform by composing components developed by actors both internal and external to the implementation domain. The general composition of a software ecosystem is the software firm (framework developer), (3rd party) software suppliers, client firm, intermediaries and client firm's customers. The paper aligns PE concept to the FOSS paradigm, which is a well-established practice to manage both software development and distribution. FOSS permits access to the software source code, together with the permission to modify the source code as well as to redistribute the derived works. Hence, this paper argues that FOSS, especially with its commercial FOSS tradition, has a similar degree of stakeholder model to PEs where, FOSS developer firm look to 3rd party service providers (FOSS implementers) in implementation.

In this study the software platform used was the DHIS2 and the solution element was the nutrition monitoring and intervention tracking system. The internal developers are the HIS implementers employed by the Nutrition Secretariat and the external developers included DHIS2 implementation team funded by UNICEF and the 3rd party software firm who developed the mobile and web components. Domain experts were the DMOs and Divisional Secretariats who supervised the nutrition assessment and interventions under the supervision of MOH and the Nutrition Secretariat. The community of users mainly included midwife from health sector and Village Committee members representing the non-health sectors.

In this study, the most important requirements leading to the inception of the implementation ecosystem was the need for the field level nutrition surveillance and the tracking of the multi-sector nutrition interventions enabling a collaboration across domains. This stakeholder integration in the PE emerged on top of the new components developed on FOSS HIS creating new stakeholder dependencies. Otherwise, these actors would have operated in isolation with fragmented information flows. The leading or central organisational actor in this PE, who is also known as, central referent organisation, was the Nutrition Secretariat, which later transferred to the external

HIS implementer. It was evident that the presence of FOSS implementers and 3rd party component developers are essential for a viable FOSS ecosystem to emerge in LMIC contexts. The FOSS firm and domain experts (client organisation) alone were not sufficient to form an implementation ecosystem. The HIS project was in constant negotiation of boundaries within the PE. In this case study, the technical negotiation was observed across the boundary between local and global FOSS HIS development networks. Apart from the technical negotiation, a domain understanding was also exchanged between health and non-health domains since nutrition had its roots beyond health sector, such as education, social status and agriculture practices. These domain specific negotiations take place in the Village Committee with the participation of the midwife and non-health sector actors such as social service worker or agriculture extension officer. The midwife functions as a domain specific boundary spanning agent in the nutrition intervention domain, freely moving between the health and the non-health sector. In the technical space of the PE, DHIS2 implementers functioned as ~~a~~ technical boundary spanning agents, bridging the gap between FOSS developer firm/community and the 3rd party component developers.

In summary, a PE has internal and external stakeholder networks which could be either domain specific or technical. In particular, a FOSS platform need to have a central FOSS platform developer and custom components developed that are extending generic FOSS functionalities to address domain needs. It is important to apprehend the role of the FOSS implementers, which a client firm can employ to customize a FOSS platform. Whether internal or external to the client organisation, the FOSS implementer may have boundary spanning roles bridging the FOSS firm and the 3rd party component developers. Identifying the 'central referent organisation' (also known as keystone organisation), who orchestrates the participation of different stakeholders, was an important step in facilitating the stakeholder interactions in the PE. However, the role of the central referent organisation may be played (shared) by different organisations during the PE evolution. The role of 3rd party developers was also noteworthy for a viable PE around a FOSS implementation.

5.2 Aligning the research questions and the papers

As seen from the five papers presented, they were addressing the research questions in different combinations. Hence, this section will guide the reader on the relevance of the research papers to each research questions. The table 5.1 will list the research questions and illustrates how the various papers contribute to each research question.

Research Question	Paper
RQ 1. Who are the actors and what are their inter-relationships comprising a platform ecosystem around a free and open source based health information system implementation in a low and middle income country setting?	Paper I, III, IV and V
RQ 2. What are the governance modalities in free and open source implementation ecosystem in the low and middle income country context?	Paper II, IV
RQ 3. How does trust play out in the orchestration of platform ecosystem around free and open source implementation?	Paper I, III, IV

Table 5.1: How do the papers contribute to answer research questions?

5.3 Synthesis of empirical findings

The empirical findings presented through the five papers contribute to the objective of the thesis, which are, *to understand the platform ecosystem governance in free and open source implementation in the public health sector of a low and middle income country context and; to understand the role of trust in platform ecosystem orchestration in free and open source implementation*.

Table 5.1 below maps the arguments and contributions of each paper with respect to the research questions posed in this thesis.

Title of the paper	Answers to research questions
Paper I - How Health Managers' trust towards FOSS Implementers changed and shaped HIS implantation trajectories: an	**RQ 1**: This paper analysed the empirical material to identify core user groups around FOSS HIS implementations, and suggest user categories such as, FOSS implementer, developers and client (FOSS implementation commissioning) organisation

empirical study of selected FOSS HIS implementations in Sri Lanka	as key stakeholders. It further discusses the exchange of the stakeholders in relation to the inter-organisational trust to understand the behaviour within the HIS implementation network. Boundary spanning agents is another concept this paper contributed towards the thesis, which play a crucial role in cultivating trust within the network and strengthening PE. **RQ 3**: This paper explored various aspects of trust in relation to the empirical evidence, and highlighted in long term partnerships, trust needs to be conceptualised not only as a static construct but also as a process with a fluctuating nature. Further it tried to elicit trust constructs from the empirical material, such as competence of partner organisations. It also discusses the different forms of trust such as inter-personal trust between individual actors in partner organisations to inter-firm trust between individual actors in trust or organisation towards trustee organisation. The paper further elaborates how the inter-organisational trust helped to keep the stakeholder adhered to the network against the week governance structure resulted by the independent nature of the actors.
Paper II - Network governance in open innovation adoption: Case study from health domain	**RQ 2**: This paper discusses the exchange of the key actors involved in FOSS HIS implementation, namely, the developers, implementers and the client organisation. Further it highlights the role of the other (supportive) stakeholders, such as funding agencies in the FOSS implementation ecosystem. The paper contributes to the thesis with its discussion on various FOSS governance approaches. It analyses the IS governance mechanism with a control and coordination perspective. Further it uses empirical evidence to show how coordination ranges from non-coordination to informal/formal coordination and how self-control, clan control, output control and behavioural control influence the FOSS governance

	trajectory in the PE.
Paper III - Using training as a tool for cultivating communities of practice around HISs in low and middle income countries: A longitudinal mixed method study	**RQ 1**: This paper mainly focuses on the role of implementers in FOSS HIS context. It focuses on the special form of implementers, referring to them as 'hybrid' implementers', those who are from health backgrounds, later trained on HIS implementations. They were conceptualised as boundary spanners, who link the health organisation to the FOSS community. The paper also highlights how these implementers developed unique mechanisms to build links with the regional and global FOSS community, based on empirical materials. **RQ 3**: In this paper implementers' trust has been conceptualised as confidence they kept on the FOSS community. During their boundary spanner role, the implementers build their identity and position them in the implementation network. A trusting relationship with the developer community helps these 'hybrid' implementers to gain self-confidence and position them strongly as an internal implementer.
Paper IV - Open Source adoption in health sector: Understanding the stakeholder relationships in a resource constrained setting	**RQ 1**: This paper conceptualises FOSS implementation based on commercial FOSS perspective. It brings several FOSS business models to the discussion and highlights their inadequacy in understanding FOSS implementation in HIS domain. Thereof, in relation to enterprise scale FOSS HIS implementation, the paper proposed several stakeholder categories, including Auxiliary Internal and Auxiliary External stakeholders, those did not appear in previous conceptualisations, yet necessary to understand the empirical context. Further this paper develops a model to understand the FOSS stakeholders in HIS implementation ecosystem taking the exchange among stakeholders to consideration. **RQ 2**: This paper highlights the difference of the governance focus in FOSS development to that of FOSS implementation

	and the non-hierarchical nature of FOSS implementation governance. It discussed four control mechanisms viz. self control, clan control, output control and behavioural control, in relation to the empirical materials. Building upon the empirical experience, the paper identifies the output control mechanisms, such as interim deliverables, as a facilitator in PE governance in FOSS HIS implementation. It also highlights the importance of establishing the formal and impersonal coordination mechanisms at an early stage to facilitate institutionalisation of FOSS HIS independent of personal interests and influences. **RQ 3**: This paper discusses the role of inter-organisational trust in the context of exchange in FOSS implementation ecosystem. The boundary spanners function across the health and FOSS domain as well as within the FOSS domain between developer and implementer communities, cultivating trust in the multi-stakeholder network. The three key actors participate in the trust based governance in this PE were FOSS developer firm, implementer and the client organisation. The paper also emphasise the influential role played by the external stakeholders, such as funding agencies, standards development organisations, in this trust-based governance trajectory.
Paper V - Open Source software ecosystems in health sector: A case study from Sri Lanka	**RQ 1**: This paper analyses the empirical evidence in PE lens to understand the multi-sector stakeholder participation. It further discusses the stakeholder participation in relation to the platform nature of FOSS. In this regard, it elaborated how software platform created stakeholder dependencies which were not present before establishing the ecosystem around FOSS implementation. Further, it elaborates the role, played by the 3rd party developers in extending the capabilities of the HIS by means of externally developed modules and apps on FOSS core. The paper also brought in empirical evidence to discuss the

	shifting role of keystone organisation (central referent organisation) in PE. It also contributed to the thesis by highlighting the boundary spanning behaviour across the health and FOSS domains as well as, between health and non-health stakeholders within the nutrition monitoring activities.

Table 5.2: Summary of the contributions of each paper towards the research questions

Chapter Summary

The papers presented in this section lead to an understanding of the dynamics of interactions surrounding different actors in FOSS HIS implementation ecosystem. Building upon the fact that during the early phase of FOSS HIS implementation, the governance is mostly informal and takes the form of a network approach, the papers presented highlight the necessity of adopting a sensitive approach in HIS implementation governance. The papers explore the role of trust within the loose governance structure, which is similar to the orchestration in PEs attempting to keep the multi-sector stakeholder network intact. For this purpose various manifestations of trust, such as inter-personal and inter-organisational trust were brought in with different trust constructs.

Summarising, the research findings this chapter has highlighted how inter-organisational trust shapes the governance trajectory of the PE around FOSS implementation. This ultimately affects stability of the PE around HIS implementation. Further, the discussions highlight the role of boundary spanners and various boundary spanning behaviours of PE actors, such as FOSS implementers. Paper IV proposed an extended model to understand various stakeholder interactions in enterprise scale FOSS implementations based on the existing FOSS business models. The proposed model identified key stakeholder groups involved in FOSS HIS implementation and how they shape implementation trajectories.

The next chapter builds upon these findings to contribute theoretically to current IS and FOSS discourses.

Chapter 6 – Analysis and Discussion

This chapter presents the analysis and the discussion of the empirical findings with the aid of the conceptual framework presented in Chapter two of this thesis. In the first section, I analyse the empirical evidence to answer the research questions, relating who are the actors and their inter-relationships comprising a platform ecosystem around a free and open source based health information system implementation low and middle income country setting; and, what are the governance modalities in free and open source implementation ecosystem in low and middle income country context: and, how does trust play out in the orchestration of platform ecosystem around free and open source implementation. In the second section, I discuss the findings in relation to the objectives of this research, which included, understanding the PE governance in FOSS implementation in a LMIC context and; understanding the role of trust in PE orchestration in FOSS implementation.

6.1 Analysis

With the empirical evidence, I noted that when FOSS is used in the organizational context, it could appear in two broad levels at work practice. The relatively simpler first level is the *end-user level*, where an individual may download a FOSS tool directly from the repository for individual use. Use of a FOSS office tool by a DMO to present the statistics during the monthly review meeting is an example of this category. The more advanced, second level is the *enterprise level*, where an organisation will mediate the adoption of the FOSS tool for its users with necessary customisations. The DHIS2 and the HHIMS implementations come under this category.

This enterprise level FOSS adoption may take place with or without further customisation of the FOSS code base. According to the empirical evidence, the enterprise level of adoption was not very effective with the support of the FOSS developers or a 3rd party implementer due to the complex nature of organisational business requirements and the organisation-wide training associated with implementation. My thesis focused on the enterprise level FOSS implementation.

6.1.1 Actors and their inter-relationships in FOSS implementation ecosystem in a LMIC setting

The State health sector, on which my research was based on, is a resource limited setting, both technologically and financially. The MOH is not adequately equipped with IT personnel nor can they afford the high end IT equipment over priority of the clinical supplies and diagnostic

equipment. Hence, it requires the assistance of several other stakeholders such as funding agencies and HIS implementers to realise health sector computerisation efforts.

Understanding the dynamics of interactions surrounding the different actors of this PE was considered an important aspect in understanding the FOSS implementation governance (Riehle, 2009). Hence, with the help of my conceptual framework, I analysed the empirical evidence gathered to understand different stakeholder categories around the FOSS implementation. Within the enterprise-scale FOSS implementation as well, there existed individuals who come in to contact with FOSS due to the organisational decision of opting for FOSS HIS. They are not previous FOSS user community members and most certainly not FOSS developers. Some of them, such as midwives or DMOs were ordinary FOSS users, but few others were health administrators and managers who directly influenced the decision to commission the FOSS HIS implementation in the organisational context.

In the 2nd generation FOSS, developer firms such as HHIMS team, seemed to play two roles in implementation. As presented in Paper I, the first role is to create the software as the FOSS firm, and the second is to participate in the pre-implementation customisation. This is particularly important in implementing a generic FOSS artefact where the core software needs to be aligned with the business needs of the customer organisation. For example, the HHIMS team developed the core HIS for different hospitals, and then a smaller team visited the hospital to discuss further customisation of the HHIMS core for specific hospital needs such as, printing clinic books. For an implementation with a local or limited scope, this strategy seemed to suffice. However, against the growing need for diverse range of implementations, the capacity of the FOSS developer firm was limited, such as the situation of DHIS2 core team with a continuously growing list of countries with a vast number of diverse health programmes.

Due to the limited capacity of the developer firm to engage in productisation, opportunities for external implementers are created in FOSS implementation, as discussed in the Paper IV. In the empirical context, these FOSS implementers played an essential role in the PE. Hence, client organisations, such as health institutions, sometimes got the service of implementers through the mediation of another supportive entity (e.g. getting the service of HHIMS team through ICTA). In other occasions, the organisation commissioning the HIS directly employed the implementers (the Nutrition Secretariat employing HISSL as DHIS2 implementer). In both these occasions, this can be seen similar to the outsourcing (Hirschheim, Reinzl, & Dibbern, 2007) software development. As per the empirical observations in the Tuberculosis programme, attempting in-house FOSS customisation seemed to require considerable resources and expertise, which the health sector is usually not able to support. In supporting the further customisation approach, the globally

positioned FOSS developer community was also promoting the implementation through 3rd party local service providers (e.g. HISP network with its country including HISP nodes as local implementers). Hence, empirical evidence presented in Papers III and IV suggested that the expert implementers were an important stakeholder category in enterprise scale FOSS HIS implementations. In FOSS acquisition by the organisation, this group can play a vital role by deciding the appropriate software version, type of licence suitable for the organisational needs, the alignment of the FOSS supply chain to organisational project timelines and further customisation of the FOSS artefact.

Several deficiencies of the current FOSS business models have been highlighted in Paper IV. One of the key aspects lacking in current FOSS business models is that employees of the client organisation who are assigned for the customisation and implementation of FOSS artefacts. They can be introduced as *internal implementers* to differentiate them from the 3rd party implementers and examples of them include MO-HI of the Tuberculosis programme and MO-HI in Southern Province implementation of DHIS2 for MCH. They are mostly, non-developer FOSS community members who are in exchange with global FOSS community. Their influence on the HIS implementation trajectory was augmented by the fact that they were employed by the client organisation. With their access to both the client organisation and FOSS community, this category of users can also be conceptualised as the boundary spanners (Perrone Zaheer & McEvily, 2003), who traverse different domains during their usual functions (e.g. implementers between health and FOSS communities).

In the empirical context, it was evident that there were many stakeholders around a FOSS implementation who were neither FOSS community members nor a direct user of the HIS. In an enterprise-wide FOSS implementation in the health sector, this group consist of stakeholders such as funding agencies, development partners or high level policy-makers and standards development organisations. These stakeholders are found to play an influential role in decision-making and hence, on the FOSS implementation trajectory. The role of these supportive stakeholders has often been overlooked in the existing FOSS discourse. Hence, in Paper IV, I proposed the term ‘auxiliary’ to these stakeholders for further analysing their role in the implementation process. These auxiliary stakeholders can broadly be grouped into internal and external auxiliary based on whether they are part of the implementation domain (the health system, in this study) or outside of it.

The auxiliary internal stakeholders, even though playing a supportive role, belonged to the business domain, but were not directly involved with the business process itself. For example, the central health authority (MOH) and the health sector regulatory bodies, such as the eHealth Steering Committee and NFOSHS. The scope of authority exerted by the auxiliary internal stakeholders was

always local. Hence, the globally positioned FOSS actors, such as core FOSS firms were beyond the jurisdiction of the auxiliary internal stakeholders. However, they demonstrated to have direct control on the implementation trajectory through various mechanisms, for example, NFOSHS with FOSS procurement guidelines.

The other category of supportive stakeholders is auxiliary external, which operates external to the business process of the organisation which commissioned the FOSS implementation. The funding agency GFATM and the WHO were some of the entities found during this study who could be categorised under the auxiliary external stakeholders with indirect influences on the FOSS implementation trajectory. The auxiliary external stakeholders could be global, such as GFATM in case of Tuberculosis programme, which requested integrated DHIS2 implementation encompassing Tuberculosis, HIV and Malaria data flows. Similarly, the auxiliary external actors could influence local actors such as the ICTA responsible for IT procurement under guidelines of the National eGovernment Policy.

Hence, according to my experience I could infer that the current FOSS models are inadequate to understand the spectrum of stakeholders involved in multi-sector PE around FOSS implementation. There were several FOSS actors whose role and influence could not be explained through the existing models. Similarly, in PE literature as well, only the key actors, namely the platform developer, client and the 3rd party software developers are highlighted even though there are many others that contribute to the ecosystem. Hence, based on the empirical evidence, I would like to suggest several other roles to be included in such models, as illustrated in table 6.1 below.

Proposed stakeholder roles	Examples from empirical cases
Client organisation	Health institution – e.g. hospitals Health programmes - e.g. Tuberculosis programme
Individual FOSS users who are employees of the client organisation	Health manager who uses a FOSS HIS, Midwives
FOSS developers firm	HISP global team, HHIMS core team
Developer community	DHIS2/HISP global developer community
Implementer community	DHIS2/HISP global implementer community

3rd party implementers who are employed by client organisation (external implementers)	HISSL, HHIMS implementation team
Implementers who are employees of the client organisation (internal implementers)	MO -HIs of Tuberculosis programme
Supportive stakeholders internal to the business domain (Auxiliary internal stakeholders)	eHealth Steering Committee, NFOSHS
Supportive stakeholders external to the business domain (Auxiliary external stakeholders)	Funding agency such as GFATM, WHO (both as a development partner and a standard development entity), ICTA (as a standard development entity of National eGovernment policy)

Table 6.1: List of members in identified stakeholder categories.

During the empirical study, I observed that, even though external to the organisational business process, the Auxiliary External stakeholders demonstrate their authority not only over on implementation process but also on FOSS development both locally and globally. The effect of the global medical terminology standard SNOMED CT[10] on the software architecture and implementation of HHIMS is an example of this influence. When the HHIMS was re-developed from its pre-cursor, Multi Disease Surveillance system, developers decided to retain the SNOMED CT support as its medical terminology standard. Hence, they had to design the software architecture of the HIS so that it supported fetching the diagnosis codes from the embedded terminology repository. Even though it is very comprehensive, SNOMED CT was a commercial (non-free) terminology standard. Hence, the HHIMS developers decided to keep the SNOMED CT support as an optional feature of the HIS that could have an added value in long term perspective. However, due to its non-free nature, SNOMED CT module was seen as a hidden cost by the MOH during its evaluation. For this reason, MOH refused to accept HHIMS as a prospective candidate for the State health sector for several years. This illustrates how a global standards development body might affect the platform architecture as well as implementation decisions.

The GFATM's request to integrate Tuberculosis, HIV and Malaria data to a single system was

10 http://www.ihtsdo.org/snomed-ct

another example to understand the influence of Auxiliary External players. Perhaps due to its global relevance, GFATM is focusing on the three diseases, Tuberculosis, HIV and Malaria under its funding scheme, which in Sri Lanka functioned as separate vertical health programmes. During a post-customisation evaluation meeting, the funding agency's proposal to integrate the data streams was tabled, but all three programmes opposed the suggestion at the beginning. However, later, Tuberculosis and HIV programmes agreed to share only high level indicators and minimum essential patient information to identify Tuberculosis and HIV co-infections. The DHIS2 customisation accommodated necessary changes for future integration. Hence, the globally positioned Auxiliary External stakeholders should also be respected for their ability to influence implementation trajectory through the FOSS developer firm, implementers or client organisation with their indirect mechanisms. Funding agencies and development partners may influence through financial contribution and reporting requirements, whereas the standards development organisation may influence through various technical and health standards.

6.1.2 The *governance modalities in a FOSS implementation ecosystem in LMIC context*

FOSS governance has been described at two broad levels in the literature. One level relates to the governing the FOSS development, which encompass the software development project and volunteer FOSS developer communities being managed (O'Mahony & Ferraro, 2007). The other level refers to the process of FOSS acquisition by the client organisation (Kemp, 2010), which was the focus of my empirical observations and hence, this thesis as implementation governance.

For the purpose of this analysis, governance is defined as all the structures and processes that coordinate and control the organisation's resources and actions. Hence, I have used the conceptual framework in a control and coordination lens to understand the governance modalities in Paper II In these diverse inter-organisational contexts, governance aims at the coordination of resources and interests of stakeholders to achieve a common objective rather than executing a formal and hierarchical governance structure. For example, in the HHIMS case study, the ICTA was an independent government entity, outside the jurisdiction of the MOH. Hence, as the key organisation which drove the HHIMS development, the ICTA, had the autonomy to control its architecture and support any hospital to implement the HIS, independent from the MOH. However, to succeed in the implementation, it cooperated with the MOH seeking its permissions for implementation, the prioritization of user requirements and to reschedule development timeline. Similarly, in the PE around nutrition monitoring, the non-health sector stakeholders cooperated with those from the health sector to achieve the common objective of identifying the households at risk, even though

they could have done it independent of the Midwives, which were considered before the negotiations.

At the beginning of all the projects presented in this thesis, as discussed in Paper II, the control and coordination mechanisms were informal and interpersonal. For example, the DHIS2 was selected for the nutrition surveillance project after a personal recommendation and the HHIMS implementations propagated from an institution to another, introduced mostly through personal ties. In some projects, the coordination process matured to formal-interpersonal and later to the formal-impersonal such as the HHIMS project and DHIS2 for Tuberculosis and Nutrition Monitoring, while in some others it stayed at informal level. The empirical evidence also indicated that the HIS implementation process was easily institutionalised in programmes where formalisation of the control and coordination was reached sooner. As highlighted in the papers, the informal-interpersonal coordination together with clan control included personal visits, meetings, phone calls, emails and small group meetings as governance mechanisms. HHIMS project, as presented in Paper I, and the DHIS2 for nutrition monitoring project, as presented in Paper V, demonstrated strong governance from early stages. The project management team was appointed with the participation of institutional members and stakeholders external to the implementation domain. The behavioural control mechanism, such as project review meetings, conference calls and on-site coordination, appeared when the project matured. Toward the institutionalisation of HIS implementation, projects demonstrated strong output control efforts such as change control mechanisms (mediated by health managers form the institutions), problem queries, follow-ups and client involvement plans, periodic reviews and interim deliverables (included in formal contrast through tender procedures).

The direct governance approaches observed in the Sri Lankan context, such as project reviews, stakeholder meetings, and other governance bodies instrumentalised to address client organisations' potential feelings of vulnerability and loss of control in migrating from custom software development to FOSS implementation. Health managers and administrators were sensitive to the changing organisational governance structure and power dynamics, and the need to establish inter-organisational trust and central control. With the multi-sector participation, the hierarchical governance structure, which is the traditional governance mechanism of the MOH appeared to collapse and alternate (and indirect) governance mechanisms started to evolve. MOUs, tender procedures and FOSS licences were among these new governance modalities which were observed during this study.

MOUs were among the early governance approach as an attempt to transit from trust based contracts towards more formal contracts. It was noted that the MOUs with not-for-profit external technical implementers, such as the university sector, which draws upon students as developers,

help and enable the FOSS client to do in-house development as well as provide MOH with the bargaining power to negotiate with profit driven third party implementers. However, MOUs, require many administrative procedures, some of which may even prevent the progress of implementations. For example, the DHIS2 implementation for MCH once required signing a tripartite MOU among provincial health authorities of North Western Province, HISSL and HISP India which could never materialise due to administrative constraints. Hence, the practicality of creating MOUs remained questionable, even though it was a necessary element of migrating towards the formal governance.

Steering Committees are becoming particularly important as a form of governance mechanism due to its inherent ability to facilitate multi-sector stakeholder involvement in governance. In my empirical context as well, several steering committees could be identified, with the direct as well as indirect influence on FOSS governance trajectories. For example, the HHIMS steering committee and National Nutrition Council were two steering committees that operated with multi-sector stakeholder participation, directly assisting the governance of respective projects. Whereas, the National eHealth Steering Committee, which indirectly governed the implementation trajectory of all FOSS implementations through the influence of national technical and procurement standards.

The governance initiatives such as NFOSHS, acted as FOSS incubators and sought to nurture the participation of FOSS community while functioning as a governance body. The steering committee mechanism appeared to be stronger than MOUs, however the composition and objectives of the committee needed to be closely aligned with the health programme needs. However, it is important to make a clear distinction between a volunteer community based FOSS development and commercially driven FOSS development, and to distinguish clearly between acquisition and development agendas in setting up steering committees in implementation ecosystems. The model followed to launch the NFOSHS was based on a volunteer community mediated FOSS development and which failed to consider the FOSS 2.0 compatible model where third party implementers are important in the acquisition process. This ultimately led to the failure of the NFOSHS initiative since MOH could not manage a group/community of FOSS developers where there is no hierarchical governance structure. Hence, in attempting the enterprise FOSS implementation governance in health sector, the waning nature of hierarchy needed to be accepted and mitigated by the MOH.

Although not considered as a formal governance modality, tenders and FOSS licences were also used in controlling and coordinating stakeholder participation in my empirical context. Tenders were used in governance as they helped to shape software requirement specifications, and better manage expectations of stakeholders and as a means to control participation of 3rd party developers/suppliers. The output control methods such as interim deliverable plans were

supplemented by tender procedures where specifications were clearly defined and monitored. However, for the tender procedures to be effective, the FOSS requirement specifications must be prepared prior to calling for tenders. In some instances, preparation of the software requirement specifications was also included in the tender as a part of the deliverables, which might lead to disputes between FOSS clients and implementers at a later stage. In contrast to all the aforesaid governance modalities operated by FOSS client organisation, the licence was another modality imposed by the developer form, used by the client to control participation around FOSS implementation and enable a social framework for collaboration.

6.1.3 Trust *playing out in the orchestration of PE around FOSS implementation*

Trust was an important aspect shaping the governance dynamics, as reflected in the following quote from the head of the Country Coordinating Mechanism of the GFATM, who was a former head of the MOH:

"… If you want to introduce anything [referring to IS] to the Sri Lankan health sector, the only way you can achieve it, is by gaining their trust. Otherwise, they may simply agree to all you say, but nothing will happen after you walk out of their door. …"

I recollect a statement of a prominent medical trade-union leader to the media that MCH records could be possible evidence against Sri Lankan government following its 30 year war against terrorism. A report (IMADR, 2016) by *The International Movement Against All Forms of Discrimination and Racism* would be an example of such use of public health information out of the relevant context. Drawing upon statistics on malnutrition from the war stricken North and East and the rest of the country, the article argues that there has been discrimination towards the ethnic minority by the State: "There have been push backs in human development indicators in the North and East that 46% of children aged 3-59 months are underweight in comparison to 29% in the rest of the country. Only 46% of the population in the North and East has access to safe drinking water compared to 62% in the rest of the country". Due to this kind of 'undesirable use' of health information, in the course of my empirical work, I have frequently noted the protective behaviour of health managers and administrators towards the access to HIS by the parties outside the State health sector.

Who are the funding agencies and what is their general reputation?, what are the motives of the 3rd party technical support specially in the context of 'donating' a free software which is going to hold very sensitive health information were important concerns. Hence, the State sector medical administrators and managers were hesitant to consider accepting 3rd party implementers, system

integration or sharing indicators with NGOs, especially internationally operational NGOs. These reasons for mistrust had to be understood by the implementers, especially if they were outside the implementation domain.

The fear of data loss or unintended access to data was a key concern of health programmes in trusting or not HIS implementers. The DHIS2 implementation for MCH was a prominent case where the State health actors hesitated to trust the external implementers based on the possible unintended access to data. Not only between MOH and the non-health sector stakeholders, but in some occasions even among health sector stakeholders themselves, such issues surfaced. One such instance was when the Tuberculosis programme refused to share data with the HIV or Malaria programme even though it was a reporting requirement by the funding agency, GFATM. After a series of discussions, the Tuberculosis and HIV programmes agreed only to mutually share their high level indicators and essential data set to identify Tuberculosis and HIV co-infections. This request was seen as permitting 'unwanted access' to Tuberculosis data, which could possibly compromise patients' confidentiality. The Tuberculosis programme was not prepared to place their trust on the HIV programme (and vice-versa) on its ability to safeguard the privacy of the full set of patient data in an integrated HIS.

The FOSS financial model was another key concern in shaping mutual trust between external stakeholders and the State health sector. "What is the 'catch' in giving software free?" or "Will there be any 'hidden' cost?" were major concerns among health administrators during the early discussions. Main reason for this could be the fact that they were used to the custom software development process where the procurement/development cost was very explicit. They were further confused by the total cost estimates of prospective FOSS implementation. Hence, the misunderstanding around the Total Cost of Ownership (short term and long term costs involved with the acquisition of 'figuratively free' open source HIS) estimation was difficult for them to comprehend.

6.1.3.1 Trust in HIS context

Trust has been identified as an important factor for HIS success even after consolidating the inter-organisational relationships with legal contracts (Brender et al., 2006). This could be attributed to the multi-faceted nature of possible ethical and organisational issues that can arise in FOSS HIS implementation. For example, in the nutrition monitoring project, the formal agreements were signed between the funding agency and HISSL as the implementer. However, still trust seemed to matter in shaping product delivery, implementation and the use of data. Further, as discussed in the

paper V, MOH was refusing to allow access to health data by the non-health-sector stakeholders in the village committees, as stated by the MOH that they cannot trust (specially male) non-health sector members of village committees to not exploit sensitive information of the affected families.

As presented in Paper I, trust can be inter-personal between individual actors in partner organisations or inter-organisational between actors belonging to the two firms. The initial phases of the FOSS implementation process commenced with people centric approaches based on inter-personal trust and later matured to more organisational centric approaches. The DHIS2 implementation in the Tuberculosis programme best demonstrated this during the study. Initially, the DHIS2 was introduced to the Tuberculosis programme by the MO-HI appointed to the programme where the initial piloting was driven based on his personal trust in DHIS2 and the support he got from the HISSL and HISP India. Later, he was able to convince the health managers of the Tuberculosis programme to depend on the DHIS2 and HISSL. Finally, through the support from the funding agency, GFATM, trust towards DHIS2 became an organisation-wide phenomenon which helped in DHIS2 being institutionalised successfully within the Tuberculosis programme. This process illustrated how inter-personal trust diffuses within the organisation and subsequently matures into strong inter-organisational trust.

In the FOSS implementation context in Sri Lanka, the technical competency of the FOSS implementers, prior experience with them, their interactions with former clients and previous outcomes were key considerations shaping trust. In the HHIMS case study, whether the FOSS developers and implementers were trustworthy was a key issue voiced during most of the project steering meetings. As Paper I illustrated, the ‘trust’ in this case had several perceptions, such as whether the implementers were sufficiently competent and transparent in their operations; and whether they had a genuine intention to make a positive change in health outcomes beyond making financial gains.

Projects, such as for HHIMS and the Tuberculosis programme, which demonstrated high or improving levels of trust within the network slowly entered the institutionalising phase. The project which demonstrated weak or deteriorating inter-organisational trust failed to thrive, such as the MCH project. However, trust was not a static construct and could change towards achieving better outcomes. The ongoing trust in the Tuberculosis programme was an example of managing it from a sensitive state where the MOH rejected the DHIS2 for MCH to the institutionalisation of the same DHIS2 in Tuberculosis programme context. So, it is safe to mention that the action of the implementers may change the trust dynamics with implications on the governance trajectory.

It was evident that, especially in HHIMS project, with time, inter-organisational trust seemed to grow stronger amongst the key stakeholders, and slowly extended to the auxiliary stakeholders as

well. Initially trust emerged at an individual level, and slowly diffused in the stakeholder organisations and then more broadly within the network. Similarly, eroding trust creates a higher tension in the network which may lead to more centralised governance and some stakeholders being rejected from the network, such as in the case of MCH implementation. It can be inferred that as inter-organisational trust erodes, decision-making becomes more centralised. The opposite effects will be seen when inter-organisational trust grows and networking is strengthened.

6.1.3.2 Implementers as boundary spanners in cultivating trust

In the empirical setting, some individual actors appeared to propagate trust between organisational actors. These individual actors who traversed different domains and helped to consolidate trust are referred to as boundary spanning agents (Perrone, Zaheer & McEvily, 2003) have been earlier identified in research (Nyella, Nguyen, & Braa, 2010; Miscione, & Sahay, 2007; Braa et al., 2007). The FOSS implementers seemed to play the most significant role in this regard, playing boundary spanning roles. Paper IV highlights employees of the client organisation and third party FOSS implementers for their prominent boundary spanning roles.

As discussed in Papers III and IV, FOSS community members can be employed by the client organisation, such as by appointing a MO-HI with DHIS2 training to a vertical health programme. Driven by their personal interest towards the FOSS HIS, these employees, who may also be FOSS volunteers, may function as a boundary spanner within the organisation cultivating trust towards the HIS implementation initiative. The same boundary spanner may open up new channels for the healthcare organisation to expand the PE by inviting prospective stakeholders, such as external implementers to the implementation process. These internal implementers became important in influencing the network trajectory with their boundary spanning role, apart from supporting the implementation on behalf of their employer. They tended to enhance trust between the FOSS developer/implementer firm and the healthcare institution and strengthen platform orchestration based on the links they have already developed.

Supportive networks, including regional and global expert communities, of various knowledge domains are also relevant in this regard, as discussed in Paper V. It appeared that the FOSS implementation network can organise itself to merge with the regional and global expert communities expanding the span of the network. In association with the DHIS2 implementations I studied during this study, a group of internal implementers interacted with the regional and global DHIS2 expert community and these implementers started to make links with external communities bringing expertise into their network.

It was also noted that, increased levels of implementers trust in the FOSS artefact and the developer firm (or community), enhanced the confidence of the boundary spanning role of the implementers. Else, initiating an FOSS customisation was always seen as taking a risk. For example, trusting the FOSS artefact against the risk of possible incompatibility with the organisational needs and lack of support from the global developer firm were outstanding concerns. When implementers receive a positive response from the developer community, they tend to trust the developer network to support them in implementation related technical issues. The MO-HI responsible for the HHIMS at Tuberculosis programme implementations provided examples of the relation between trust and confidence, with positive implications on the PE.

When a FOSS project inherently facilitates forking (creating a new FOSS project reusing code of an existing FOSS repository), the FOSS firm as platform owner carries a unique risk which is not present in other (commercial) PEs. Making the FOSS codes available to 3rd party implementer/developers under FOSS licences makes the firm vulnerable for creating prospective competitors (Lerner & Tirole, 2002). Two major incidents of forking were, Ubuntu Linux being forked in to Linux Mint[11] and OpenOffice being forked in to LibreOffice[12]. In 2012, Ubuntu Linux distribution was forked into Linux Mint by the Ubuntu community over a dispute on its desktop environment design. Similarly, in 2010, OpenOffice was forked by the contributors over a dispute on FOSS license being used. Since the 3rd party contributors are not allowed to access platform source code, the risk of forking is not there in the commercial platforms even though this is a possibility in FOSS platforms. Hence, orchestration by the FOSS firm builds a sense of trust, with the anticipation that implementers will not create a competing product using the existing repository.

6.2 Discussion

Tiwana (2013) has introduced PE as an architecture led governance approach, where the architecture, the platform, the interfaces and modules developed on the platform are key constituents. My thesis reinforces the argument that FOSS is a viable candidate on which to build a PE (Kilamo, et al., 2012). The FOSS artefacts considered in this research, the HHIMS and DHIS2 both have a generic software core as the platform. The core teams have developed several essential modules together with custom Apps which by default are bundled together with every release. DHIS2 further possesses an Application Programming Interface similar to PE is provided through which 3rd party software components (custom web and mobile apps) can communicate with the

[11] http://www.theregister.co.uk/2012/12/30/linux_in_2012/
[12] http://www.osnews.com/story/23843/OpenOffice_Forked_Into_LibreOffice

DHIS2 core. Hence, the embedded modules, bundled apps and custom web and mobile apps can be conceptualised as modules comparing the DHIS2 to the PE architecture. In HHIMS as well, 3rd party contributors extend the software core in producing new modules for extended functionalities.

6.2.1 Understanding the PE governance in FOSS implementation in LMIC context

Several open source business models have attempted to describe stakeholder relationships in FOSS implementation as discussed in chapter 4 (Dixon, 2009; Krishnamurthy, 2003). After going through this body of literature on FOSS, it was possible to identify a gap between the existing business models and domain specific practices during implementation. Hence, arguably current conceptualisations need to be improved to accommodate the stakeholder categories (see table 6.2) involved with a FOSS implementation for a holistic understanding of the PE.

Empirically observed roles	Equivalent roles available in the existing FOSS business models (Dixon, 2009; Krishnamurthy, 2003)
Client organisation	Customers/Client organisation
Clients (individual)	Clients
Individual FOSS users who are employees of the client organisation	-
Developers (FOSS firm)	Commercial Open Source Company – Software Development team
Developer community	Community
Implementers (employed by the FOSS firm)	Commercial Open Source Company – Productisation team
Implementers who are employees of the client organisation (internal implementers)	-
3rd party implementers who are employed by client organisation (external implementers)	-
	-

Auxiliary internal stakeholders	
Auxiliary external stakeholders	-

Table 6.2: A comparison of the stakeholder categories of current FOSS business models and empirical evidence

Without being comprehensive, existing FOSS business models (Dixon, 2009; Krishnamurthy, 2003) are capable of describing some but all of the stakeholder interactions observed in my empirical work. In conventional FOSS models, the main exchange takes place between the core FOSS developer community and the client. However, with the emergence of the FOSS 2.0 paradigm, the enterprise-scale FOSS implementations closely resemble custom software development with the 'productisation' of the FOSS software core in the PE approach. Hence, apart from the architectural similarity, the second generation FOSS demonstrates comparable similarity to PE in user involvement as well.

The emergence of the service/support team around FOSS implementation is a key phenomenon in such initiatives. Apart from the FOSS developer and customer, the 3rd party service provider is an essential actor in this ecosystem. Even though, initial steps towards implementation might be assisted by the FOSS community to a limited extent it is more practical to provide this ongoing customisation support by a dedicated technical team specialised in the particular FOSS HIS. There are support groups which are emerging around many enterprise scale FOSS projects and the entire HISP network around DHIS2 was formed mainly by these independent service providers (Braa, Monteiro & Sahay, 2004). For example, various DHIS2 implementations in India and Bangladesh lead to the emergence of support entities around those implementations, respectively as HISP India and HISP Bangladesh.

After analysing these stakeholder interactions, Paper IV proposed a model to understand PE governance in FOSS implementation (figure 6.1 below). In this conceptualisation, auxiliary external stakeholders possess the ability to influence the client firm, implementers as well as the developer firm, whereas auxiliary internal stakeholders' scope of influence is limited to the client firm and implementers. According to the empirical evidence, the main interaction between the client firm and implementers are of the latter supplying the 'whole product' (customized FOSS solution) to the client firm in exchange of payments for implementation services rendered, such as software bug reporting, channelling user requirements shaping future developments, and advocacy. I highlight the

knowledge exchange (two-way arrows in figure 6.1) between the developer firm and community mainly in the form of source code and bug fixes, and between implementers and the community.

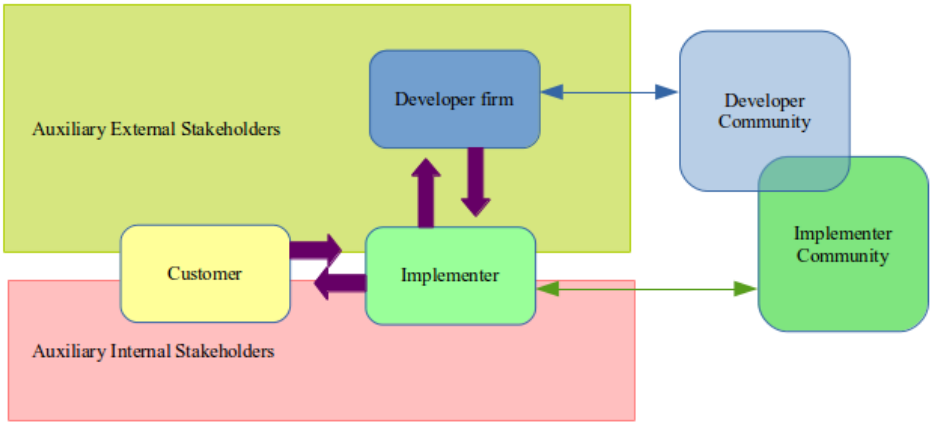

Figure 6.1: Proposed model to understand the user interactions around FOSS implementation ecosystem.

In the model proposed in Paper IV, I have suggested disintegrating the software development and productisation functions as two independent activities, where development and implementation services may or may not be provided by the same entity. This conceptualisation is different from the existing models for FOSS development. In practice, there are many projects maintained by the FOSS firm where the developer community plays a minor role in providing peer reviews, documentation support and translations with the release cycles. Often there is the need for an implementer community to emerge (e.g. DHIS2 implementation forum) when there is a need for extensive customisation on an ongoing basis. There can be certain overlaps in the developer and implementer communities as indicated in the figure 6.1, to represent the exchange of knowledge and expertise between these two groups.

6.2.1.1 Traditional PE governance vs. FOSS Implementation governance

With the emergence of FOSS 2.0, where external stakeholders extend the open source core to custom domains, the FOSS implementation paradigm is reaching a status of a PE. According to Bosch and Bosch-Sijtsema (2010), a PE consists of several categories of stakeholders, which include the internal and external developers, domain experts and community of users. Distributed

FOSS development welcomes enhanced user participation. In PE, governance has been theorised as an orchestration of these stakeholders under loose control and coordination mechanisms. Whereas FOSS implementations in the health domain are still struggling between, the need for traditional hierarchical (and centralised) governance and the reluctance to accept the waning centralisation in network governance. In this backdrop, I argue that orchestration is an effective form of governance for FOSS implementations where a multi sector approach is required.

However, in comparing FOSS implementation governance to PE orchestration, I observe several key differences. One of which would be the shift in the role of the keystone organisation, from platform owner in a traditional PE to client organisation commissioned implementation in the FOSS 2.0 ecosystem. With this new status of equilibrium, FOSS implementation as a PE reaches a new level, which I compare with traditional PE in table 6.3 below, taking the DHIS2 as the example.

Governance approach	**Traditional platform**	**Commercial FOSS as a PE**
Orchestration of PE	Platform Owner (HISP)	Organisation commissioning FOSS implementation (Client Organisation, Ministry of Health)
App decision [decision rights]	Platform Owner (HISP)	Bundled apps - HISP Custom Apps- Ministry of Health as client organisation
Gate-keeping	Platform owner (HISP by controlling DHIS2 blueprints and development trunk and API) – controlling third party developers	Client organisation, Ministry of Health (selecting implementer, choosing apps to be implemented/custom developed, control over funding agencies, opting for standards)
Metrics	Performance targets of bundled apps	Business Goals (health outcomes, national policies) for custom apps
Process control	Platform Owner – by controlling release process	Platform owner (HISP) – software releases

		Client Organisation – implementation project management bodies and steering committees
Relational control	Platform Owner – controlling 3rd party developers	Trade-off between hierarchical and poly-centric
Pricing	Mainly the integration cost and app pricing	As FOSS licences and Total Cost of Ownership

Table 6.3: Comparison of traditional and commercial FOSS.

With this comparison, it is evident that in the FOSS implementation context, decision rights lies with the organisation which commissions the implementation process (e.g. MOH) instead of the platform owner (the FOSS developer firm) who plays the central authority in Tiwana's PE model. Pricing is another key difference, where in commercial PEs, pricing includes the App integration costs and might be controlled by the platform owner. Since the core FOSS artefact is distributed free of charge, the concept of pricing amounts to the Total Cost of Ownership described in the FOSS acquisition context. Similarly, the FOSS licence the developer firm opts for, in the open source core will act as a restriction for 3rd party involvement in extending the core to domain needs. 3rd party contributors are not permitted to use more restrictive licence (e.g. from GPL[13] to LGPL[14]) or remove the open source licence in re-distributing FOSS artefact is an example of such restrictions.

6.2.2 Understanding the role of trust in PE orchestration in FOSS implementation

With growing maturity of inter-organisational relationships, it has been argued that inter-personal trust needs to diffuse within the organisation as consolidated inter-organisational trust (Seppänen, Blomqvist & Sundqvist, 2007). However, in the empirical setting, it was noted that only some projects were able to reach this stage, and which reached this stage exhibited strong ecosystem-wide diffusion of trust and institutionalisation.

13 https://www.gnu.org/licenses/gpl-3.0.en.html
14 https://www.gnu.org/licenses/lgpl-3.0.en.html

6.2.2.1 How trust influences FOSS implementation governance

Trust has been coined as a valid denominator in collaborative software development. Similarly, trust based contracts play an influential role in IS outsourcing projects even after legal contracts are formulated (Brender et al., 2006). Trust also serves as an important determinant of governance processes (Gallivan, 2001). Most actors involved in the network of FOSS implementation at the early stage were legally independent, and mutually agreed to cooperate to achieve a common goal. This is comparable with PE orchestration. Vertical health programmes have the authority over peripheral health facilities, and provincial departments of health are legally independent from the line ministry. Similarly, external auxiliary stakeholders are also independent agencies from the jurisdiction of health administration processes. In most cases, these independent relationships were governed through trust-based contracts in the initial phase of implementations, which required more sensitivity to develop than legal contracts.

With the comoditisation of enterprise scale FOSS, trust based relationships of key stakeholders are crucial to facilitate FOSS HIS 'marketing'. A Total Cost of the Ownership based perspective of enterprise FOSS can be seen as comparable to a traditional sales process. Doney and Cannon (1997) have theorised that the purchase choice of a buying firm depends on buying firm's trust in the supplier firm and the buying firm's trust in the sales person. I would like to argue that this conceptualisation can be adopted to the FOSS domain to represent the relationship among the FOSS developer firm, implementers and the client organisation. The FOSS adoption decision of the client (health care) organisation depends on its trust in the of FOSS developer and implementer firms, similar to the supply firm and sales person respectively. The key trust based relationship exists between the implementer and the client organisation (the healthcare institution/programme), which helps to frame the understanding of user interactions around the FOSS HIS implementation ecosystem (figure 6.1). Further, Hanssen (2012) has also proposed a similar relationship among supplier, customer and the 3rd party in the keystone-centric PE model, which is also confirmed in my empirical analysis.

6.2.2.2 Boundary spanners role on trust

The boundary spanner concept has been coined in several academic discourses (Nyella, Nguyen, & Braa, 2010; Miscione, & Sahay, 2007; Braa et al., 2007), including in the process of cultivating trust. In most cases, internal implementers emerged as organisational champions and facilitated the diffusion of trust towards the FOSS artefact and external implementers, first amongst the immediate team working on the implementation and later organisation-wide. The MO-IC of HHIMS

implementation and the MO-HI who was entrusted to manage the DHIS2 implementation in the Tuberculosis programme were examples for such behaviours.

However, the emergence of a very strong organisational champion was also not desirable in some cases as they led to over-dependence on the champion. Contrary to the helpful role of boundary spanning organisational champion (Zaheer, McEvily, & Perrone, 1998), in some cases, they could be seen as threats to the existing organisational power structure and control with their newly emerged influential roles. Hence, boundary spanners are helpful, even though the very dominant champions may turn out to be counter-productive.

Chapter Summary

This chapter has proposed a conceptual framework to understand enterprise-scale FOSS HIS implementation governance based on the PE governance (orchestration) and inter-organizational trust. The key feature of this perspective is disintegrating the development and productisation functions as two non-interdependent activities during the FOSS life cycle. The perspective covers the interactions of both the internal and external stakeholders as well as actors directly and indirectly involved in HIS implementation decisions.

My thesis reemphasizes the boundary spanning role of FOSS implementers as a way to institutionalise HIS. It concludes with the role of trust in managing the tension in multi-sector stakeholder networks with the help of early governance mechanisms. Further, the thesis contributes to the discussion of how inter-organisational trust shapes the governance trajectory of multi-sector stakeholders in FOSS implementation PEs and their relationship over time.

Chapter 7 – Contributions

This chapter highlights the theoretical and practical contributions of the research, discussed respectively in the subsequent two sections.

7.1 Theoretical contributions

The key theoretical contributions focused on the PE nature of FOSS in enterprise-wide HIS implementations and the influence of inter-organisational trust in governance processes. Firstly, this thesis proposes a FOSS stakeholder participation model to understand governance processes to help bridge the knowledge-practice gap with respect to FOSS 2.0 based HIS implementation. This model helps to expand the scope of stakeholders involved and their influences, through a focus on platform orchestration. Secondly, the thesis helps to theorise the role of trust at the organizational and inter-organizational levels with respect to governance of implementation processes.

7.1.1 Understanding PE governance in FOSS implementation

This thesis helps to theorise the FOSS artefact and stakeholder interactions using a PE lens which includes aspects such as access to source code facilitating 3rd party involvement in expanding the software and its functionalities. This helps to focus on understanding governance orchestration, crucial to understand the role of user participation in enterprise-scale FOSS implementations which requires multi-sector stakeholder participation. Orchestration requires a change from a hierarchical approach to something more fluid. In drawing upon a PE lens, I could contrast the keystone firm of traditional PE from that of the FOSS platform. In traditional PE, the keystone organisation which orchestrates the participation of other actors in the PE is played by the platform developer. However, in FOSS implementation, the orchestration is mainly done by the client organisation which commissions the FOSS implementation. Still the FOSS firm as the platform owner retains its capability to enable the orchestration partially, but not as prominently as in traditional PEs. The thesis highlights that the keystone role can even be shifted/exchanged or shared between client organisations during the implementation trajectory (see Paper V). The other main challenge to orchestration is the freedom that a FOSS licence provides to create a new platform through reusing its code base by *forking the open source repository* (May, 2006).

In this thesis, I extend the vendor focus orchestration of Tiwana (2013) by highlighting the key differences of PE governance when the platform becomes FOSS. In the FOSS PE, new regulatory

mechanisms such as licencing and Total Cost of Ownership work together with traditional pricing mechanisms to enable revenue for 3rd party firms. The thesis thus contributes to the IS literature by presenting FOSS implementation dynamics through a PE perspective, which has not been done in IS research up to date.

With the emergence of FOSS 2.0 paradigm, several business models have been proposed to understand implementation. However, empirically I observed several gaps between existing enterprise FOSS business models and current practices. By modelling new stakeholder relationships, including developer firm and broader developer community, implementers and the implementer community, FOSS customer and external and internal auxiliary actors, I have tried to bridge some of these gaps (see Paper IV). The proposed model distinguishes between the development and implementation roles which can be performed either by the FOSS firm or a by a 3rd party service entity. Figure 7.1 below illustrates the proposed extension to the existing FOSS business models.

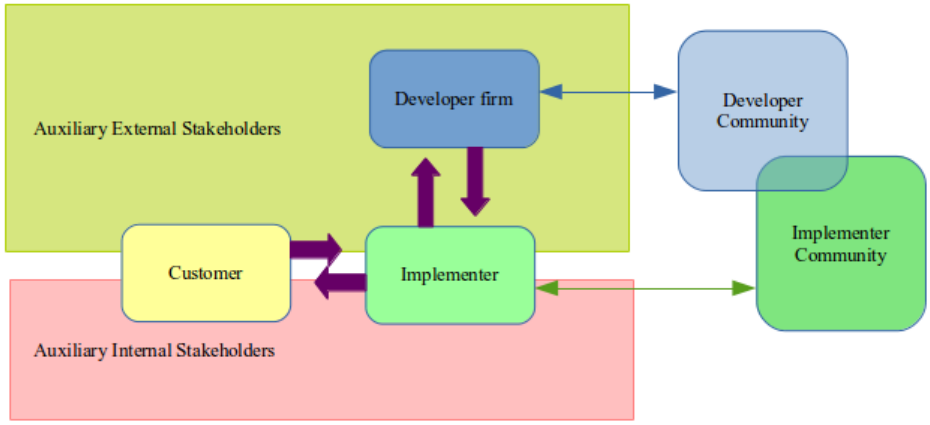

Figure 7.1: Proposed model for FOSS stakeholder network governance

The model proposed need not be limited to the health domain but has implications also to other sectors where FOSS implementation is involved. A key focus is on making available the FOSS platform to 3rd party implementers by the FOSS firm in exchange of various services (such as, software bug reporting, channelling user requirements shaping future developments, promoting FOSS platform among prospective clients). It is also possible to highlight the knowledge exchange

(two-way arrows in figure 7.1) between developer firm and the developer community mainly in the form of source code and bug fixes and; between implementers and the implementer community in the form of implementation approaches. There can be overlaps in the developer and implementer communities as indicated in figure 6.1, in the exchange of knowledge and expertise between these two groups.

In this model (Figure 7.1), the internal and external supportive actors have been introduced as Auxiliary Internal and Auxiliary External stakeholders, which previous models have not considered. However, the Auxiliary Internal stakeholders such as local regulatory authorities may influence customer organisation and local implementers through direct governance mechanisms such as circulars, guidelines, local (organisational) standards, policies and direct supervision. Similarly, Auxiliary External stakeholders such as development partners and funding agencies may have indirect influences over customers (healthcare organisation) and local implementers through programme specific funding and routine reporting requirements. Silva and Figueroa (2002) highlight the power and politics exercised by international agencies in implementing IT in developing countries. Other research have highlighted the donor-recipient conflict as the reason for unsuccessful HIS systems in the African context (Braa & Heldberg, 2002; Mosse 2004). Hence, supportive actors can play a crucial role in institutionalising a HIS implementation process.

Paper IV has theorised the formation of networks around FOSS HIS implementations and elaborated the effect of control and coordination on various stakeholders. Paper V has examined FOSS implementation through an ecosystem lens. Paper I and IV have discussed the effect of boundary spanning agents on governance trajectories. While paper I elaborates on trust cultivating behaviour of boundary spanning agents, paper IV contributes in building a deeper understanding of the mechanisms exercised by different categories of stakeholders as boundary spanning agents, including their dichotomous behaviour (Dixon, 2009). Hence, this thesis contributes by extending the organisational boundary spanning dynamics (Perrone, Zaheer, & McEvily, 2003) to the FOSS HIS domain.

The model proposed in this thesis (figure 7.1) contributes to the existing understanding on FOSS as a PE with a domain specific perspective, with the potential of extension to other domains.

7.1.2 Understanding the role of trust in PE orchestration in FOSS implementation

The shift of governance from traditional centralised-focus to orchestration is seen as less administratively efficient and contributes to a rising tension in the implementation network. In such a scenario, inter-organisational trust can help to resolve tensions among networked participants and

prevent the network from falling apart. Hence, this thesis identifies inter-organisational trust as a vital component in the orchestration of multi-sector stakeholder networks. As discussed in chapter six, in traditional PEs, platform owner has the exclusive right for orchestration, while in a FOSS implementation platform, many governance decisions are taken by the client organisation which commissions the FOSS implementation. As a result, the platform developer has to share some of their privileges and orchestration exclusivity with the client organisation.

In this landscape of governance through orchestration, several key considerations, other than losing control, have been highlighted for the FOSS to become a PE. These include pricing becoming a less crucial denominator in orchestration and forking tendencies possible leading the keystone organisation to rely on inter-organisational trust in orchestration. Hence, trust becomes a significant consideration in FOSS implementation platforms compared to that of a traditional PE. The relevance of trust comes from the ability of the FOSS platform to be forked (create new repository using the code base), which is not possible in non-FOSS platforms. Doney, and Cannon, (1997) have described the buying firm's trust of the supply firm and the sales person in the traditional buyer-seller relationship. In this thesis, a comparable analogy is seen through the assistance of the keystone-centric PE (Hanssen 2012). The thesis thus seeks to extend the traditional buyer-seller relationship model (Doney & Cannon, 1997) to theorise the influence of trust in FOSS implementation governance and identify key areas where tensions can develop during orchestration. Key relationships identified are between the organisation which commissions the implementation, the implementer and the developer firm, understanding which are instrumental in synthesising the proposed FOSS governance model (figure 7.1). This helps to provide a novel lens to investigate the core relationship of FOSS implementation and user perspective of PE.

Figure 7.2 highlights these important trust based relationships between the healthcare authority (client organisation) and the HIS implementer; and between the HIS implementer and the FOSS developer (arrow with a solid-line in Figure 7.2). However, the health programme's trust towards the FOSS firm influences strengthening these core relationships (arrow with a dashed-line in Figure 7.2). These dynamics are reflected in Figure 7.2 below.

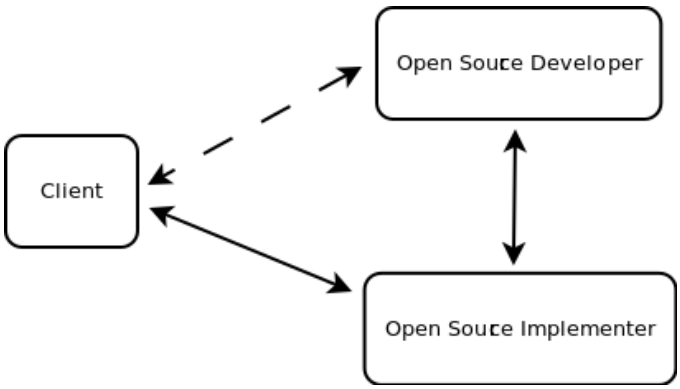

Figure 7.2: Key inter-organisational trust based relationships

There are risk factors unique to FOSS implementation which calls for a higher level of inter-organisational trust between parties as compared to traditional PEs, including:

- Between the client and the FOSS developer: the uncertainty of FOSS releases, mismatch of features offered on FOSS artefact and the business requirements of the health progamme.
- Between the client and the FOSS implementer: the risk of implementation failures beyond the control of implementers (such as developers abandoning the FOSS project), high Total Cost of Ownership.
- Between the FOSS developer and the implementer: developer community/firm abandoning the projects, delayed releases, possible forking of the FOSS code base.

When trust weakens, tensions rise in the network requiring more centralised governance. The implementation commissioning client (health care organisation) becomes the key-stone organisation and trust from their perspective becomes important to understand for a successful orchestration. The Total Cost of Ownership becomes one such important factor which often contradicts the notion of 'free' in FOSS. The uncertainty of the cost model adversely influences trust relations between the health administrators and implementation mediators. The fear of data loss (data access beyond authorised limits by implementers) is another trust mitigating factor which reinforces the findings of Edwards, et al. (2007) that data ownership is key in building tensions in information infrastructure development.

7.2 Practical contributions

Understanding tensions between hierarchical governance and orchestration, formal and informal

control and coordination mechanisms and the role of boundary spanning agents may help in resolving disputes during FOSS implementation governance. Trust mitigating factors relating to ambiguous Total Cost of Ownership, unauthorised access of code base and the nature of initial contracts need to be properly understood and addressed. Empirically, the study aims to contribute to consolidate new and on-going HIS implementations in Sri Lanka and more broadly within the broader global HISP network by building a deeper understanding of trust based issues, and how these can be strengthened.

7.2.1 Practical contribution to HIS implementation in State health sector in Sri Lanka

This thesis identifies the health institution or the programme as an emerging FOSS client organisation which needs to interact with a range of health and non-health sector actors. FOSS based implementation is a relatively novel and poorly understood concept to the State health sector of Sri Lanka, and this has led to setbacks in the efforts to introduce DHIS2 in Sri Lanka. Insights developed through this thesis can help to overcome some of these obstacles and better plan for the institutionalization of systems. This understanding of the multi-sector stakeholder network and the roles of implementation mediator are important in this regard, especially to promote the boundary spanning role of internal implementation mediators to strengthen trust. Building inter-organisational trust and legitimacy are important functions of the implementation mediators.

These insights helped to steer governance trajectories of DHIS2 implementation for the Tuberculosis eRegistry and Nutrition Monitoring programmes towards successful institutionalisation. In the Tuberculosis eRegistry initiative, a multi-sector stakeholder network was facilitated comprising the National Tuberculosis Programme, MOH, HISSL, PGIM, HISP India and HISP Vietnam, the global HISP community and the Global Fund. Enabling this network also made it possible to initiate a dialogue with the AIDS Programme as well to design data flows to manage co-infections of Tuberculosis and AIDS. The National Tuberculosis Control Programme included information needs for its annual planning, including allocating resources for equipment and manpower. A boundary spanner was identified and made responsible to strengthen the communication among multi-sector stakeholders. A similar approach was taken in the Nutrition Monitoring Programme, including stakeholders from both the health and non-health sectors.

The MCH system implementation, which was not a success previously, was re-initiated. With the new approach, DHIS2 was accepted for island wide implementation in 2017. In this approach, a new stakeholder network was created including provincial and central health authorities, HISSL and the PGIM, and formal communication channels were established between them. Learning from the

Tuberculosis programme, internal implementers were identified and promoted as boundary spanners, helping to smoothen the governance trajectory. With this experience, HISSL approached the central healthcare authority to support computerisation of the entire MCH data flow using DHIS2, and the customisation was subsequently done successfully. A project steering committee was appointed including representations from the central healthcare authority, HISSL and PGIM, enabling discussions on managing the tension arising from the central control of the MCH programme and the need to strengthen participation of supporting stakeholders. This helped to build trust of the central healthcare authorities towards implementers. The steering committee coordinates customisation with regular meetings, a process facilitated by an internal champion functioning as the boundary spanning agent between central healthcare authority and the external implementers. The DHIS2 implementation at the Tuberculosis eRegistry and Nutrition Monitoring Programmes serve as examples of success stories in trust building and enabling effective implementation..

Figure 7.3: DHIS2 for MCH training session.

I was able to contribute to the HHIMS project by enabling a new partnership between HISSL and ICT Authority to broaden implementation to 300 other state hospitals. Project governance emphasizes networking with the formation of an inter-ministerial committee on IT, and plans to establish a MOU between the MOH and ICTA. Another project benefited by this networking approach was the DHIS2 implementation in Non-Communicable Disease programme. Initially,

there were tensions between the health programme and the implementation mediators, which was strategically managed by placing a boundary spanner who helped diffuse this tension enabling the health programme to become electronic from the first quarter of 2016. Adoption of DHIS2 as the National Disaster Management IS was also helped by these insights involving the important role of the boundary spanning agent.

7.2.2 Contribution to HISP network and global HIS community

The findings of this thesis will be useful for the other members of HISP network and development partners, especially in identifying and mitigating trust-related issues. The proposed network model identifies actors important in the early phase of negotiations, including those who are less obvious but can make a dramatic difference. Hence, correctly positioning these actors in the multi-sector stakeholder network and addressing their concerns are key to effective institutionalisation. Globally, some actors exercise their influence both on implementation and development level directly and indirectly, and these influences need to be sensitively cultivated (see Figure 7.1).

Understanding FOSS as a PE may help global HISP team to work closely with local HISP nodes as well as to make use of local stakeholders to expedite DHIS2 adoption in countries. Also, strengthening a user interaction perspective helps to develop trust based relationships between implementer and the global HISP team as the platform owner. It is also helpful for the global HISP team to understand the need to shift the role of the keystone organisation from the FOSS developer firm to local health authorities to reduce conflicts and enable rapid institutionalisation.

As illustrated in figure 7.2, building a trust based relationship between the developer and implementer firms is an important consideration to understand the multiplicity of expectations of the different stakeholders. In applying the buyer-seller trust model proposed by Doney and Cannon (1997) to FOSS HIS practice I argue that the FOSS developer and the implementer demonstrate a similar degree of trusting behaviour as a traditional supplier (comparable to FOSS developer firm) and a seller (third party FOSS implementers). As argued in paper III, the FOSS firm should strengthen the trust of implementers through improved support and a responsive approach (e.g. issue tracking and frequent release cycles).

In today's international health system development efforts, funding agencies spend a large sum of money, but tend to fail to yield HIS implementations beyond pilot studies. Strengthening trust based multi-stakeholder relationships can go a long way in addressing this lack of successful efforts.

Chapter Summary

In this chapter, several important arguments have been put forward, including conceptualising FOSS as a PE and emphasizing the role of inter-organizational trust in the governance of FOSS implementation. However, there are several key differences in FOSS as a platform, compared to the traditional PEs, and the thesis identifies platform orchestration to enable stakeholder governance. The empirical findings suggest differentiating FOSS developer and implementer governance processes, while understanding the overlaps in practice. Hence there is the need to extend the governance model to accommodate other stakeholders. Further, this work contributes to understanding the role of inter-organisational trust in the PE and the effect of boundary spanning agents on governance through formal and informal control and coordination mechanisms. Practical implications for the State health sector of Sri Lanka and for the global HISP network have also been highlighted.

Chapter 8 - Conclusions and Recommendation

This chapter presents the conclusions, recommendations, and possible future research avenues arising from this research.

8.1 Conclusions

This study aimed at understanding PE governance in FOSS implementation in the public health sector of a LMIC context and; the important role of trust. This section presents the conclusions from the study and how these may be useful for other settings, especially within the HISP network. However, in applying the governance framework to other LMIC contexts, it is advisable to consider the centralised nature of the state health sector in Sri Lanka, and how this may differ with existing structures in other countries.

8.1.1 The perception of FOSS implementation in health domain

Typically, health administrators and managers embark on FOSS implementation with prior expectations similar to custom software development. They tend to expect the FOSS implementation to provide them with similar flexibility as the custom development process. In this context, the health programme managers fail to apprehend the generic nature of the FOSS software design (Gizaw, Bygstad, & Nielsen, 2016.) and possible design-reality gaps (Heeks, 2006) between FOSS functionalities and health programmes business process needs. This may breach the trust in subsequent stages of implementation.

The meaning of ‘free’ in FOSS is largely misunderstood, as health managers believe they don’t need to make any financial commitments towards customisation and training. When the expectation of free becomes ‘not-free’, it leads to a breach of trust amongst the health managers towards FOSS products, processes, and the people behind it. The access to source code is free, but technical support and customisation remains a commercial proposition. Hence the FOSS business model is sometimes described as a strategy of ‘giving away the razor to sell blades’ (Isaac & Park, 2004). In FOSS implementations, the cost for user support and maintenance may exceed the cost of a proprietary software license for the same purpose (May, 2006).

Total cost of ownership is an important reason for mistrust in FOSS. From the perspective of health managers/administrators, they are not interested in mere FOSS philosophy; instead they demand a ‘whole product’ which can help them in addressing their business needs. FOSS often conveys the message of a totally ‘free software’ and when implementation requires substantial financial

commitments, it is a genuine source of misunderstanding and break down of trust. The 'cost' of acquiring software is a familiar concept in the software industry where the cost of licensing or purchasing is only a part of the Total Cost of Ownership. FOSS does not have a purchase price but does have many of the other costs of software installation. FOSS however gives freedom to control the software which is an important part of being 'free'. Hence, it is important to understand and justify FOSS implementation costs upfront, and how it compares to the costs of a proprietary system.

8.1.2 FOSS customisation as a PE with multi-sector participation

Multi-sector participation plays a major role in FOSS HIS implementations, not only in Sri Lanka but also in other LMIC contexts. The multi-sector network around implementation is different from what exists in Enterprise Architecture. Zachman (1997) has described the boundary of the enterprise architecture as a self-contained set of business functions and assets, all integrated in support of a common mission or a set of objectives. Hence, in enterprise architecture, the network is limited to the business scope and rules of the organisation and the underlying control structures which is referred to as the *natural integration boundary* (Zachman, 1997). Since in FOSS HIS implementation, the stakeholder network consists of organisational actors beyond the business scope and control of the jurisdictional authority (e.g. vertical healthcare programme) and the natural integration boundary of the enterprise architecture, this network is conceptualized as a PE. This network is mainly decided by the non-contractual agreements, with trust based relationships being prominent. A PE based conceptualisation shifts the traditional hierarchical governance towards one based on trust involving a process of orchestration. In this scenario, the central healthcare authority plays a decisive role in structuring the PE as compared to traditional PEs. Here, the platform owner has to share the orchestration rights with the client firm which commissions the implementation. Shifting the hierarchical governance to the orchestration and keystone organisation from platform owner to client may contribute to tensions within the implementation network. The PE around FOSS implementation differs from the traditional PE, not only due to the keystone responsibilities being shared amongst the developer and customer firms, but also due to their being no license costs and the potential ability to fork the platform.

The multi-sector participation involves several key roles. The core developer firm, implementers and client firm (commissioning entity) are three key stakeholders in this network. Implementers may include individuals from the FOSS firm as well as, employees of the client firm or a 3rd party individual or an entity. The auxiliary stakeholders could be internal or external, depending on the

scope of their interests and authority in the PE. With regard to promoting participation in the PE, it is necessary for the internal implementers to become aware about their working context through insights from people who they can relate to. They should also feel that they belong to a society beyond their work practices (global network of implementers), with feelings of 'globalness' which encourages internal implementers to be proactive in network building and learn from experiences emanating from similar contexts.

8.1.3. Need for strengthening the boundary spanning role of implementers

Organisations need to develop their internal expertise in adopting and managing FOSS enterprise solutions. The lack of such expertise increases costs of implementation, maintenance and support leading to a higher Total Cost of Ownership as compared to proprietary solutions. Lack of awareness towards FOSS governance was a major issue in Sri Lanka. As the case study around NFOSHS indicated that these bodies need to be appropriately positioned and directed to achieve objectives and to avoid failures.

In a domain with entrenched hierarchical forms of governance, shifting towards orchestration may itself be a source of tension to central administrators. The trust-building role of intermediaries is significant, especially those situated in the major stakeholder organisations. Intermediaries also have an effect over initial conditions of the network organisation, which can either be stabilising or destabilising. The reason for this is the provision in the FOSS license to replicate the code repository under a new owner (forking). In this context, the role of the implementer as a boundary spanning agent may strengthen inter-organisational trust between participating organisations, thereby reducing tensions amongst them.

8.1.4 FOSS project governance and implication of inter-organisational trust

The focus of trust is different amongst different medical administrators/managers. At the central level, health managers are more concerned with broader issues such as costs, licensing, ownership and possible unauthorised access to code. On the other hand, peripheral level health managers are more concerned about the feature-richness and flexibility of the HIS.

This thesis highlights several best practices implementers can follow to improve inter-organisational trust, including the need for frequent interactions with system users, maintaining technical, financial and social transparency; organising a readily deployable and technically competent implementation team and cultivating the boundary spanning behaviour. The role of trust is higher in orchestration

than in hierarchical governance approaches. Even if initial trust is low, with repeated interactions with health managers, the implementation team can positively cultivate on-going trust. Pre and post implementation support is important in building trust. Hidden cost models and unauthorised access to health information by external FOSS implementers tend to mitigate trust.

Formal and impersonal coordination mechanisms should be set up at an early stage to facilitate the institutionalisation of the HIS, avoiding personal dependencies. Interpersonal as well as impersonal mechanisms of coordination are effective under formal control compared to informal and interpersonal coordination mechanisms. Within formal coordination mechanisms, impersonal coordination yields a more stable governance trajectory than person dependent means such as interpersonal coordination. Similar observations are made on behavioural and output control (e.g. on-site coordination, project management plans, periodic communication) leading to successful open innovation compared to self-control or clan control mechanisms. Output control mechanisms, such as interim deliverables are valuable in allowing health stakeholders to evaluate the software artefacts incrementally. Tender processes can also serve as an effective governance tool.

Control is exerted on the FOSS development project through funding agencies and other external stakeholders through funding and scope defining mechanisms. Coordination is prominent and essential between implementation mediators and clients and in some cases between core developers and implementers. This study demonstrates the importance of adhering to strict institutional/programme procedures and guidelines (not only in information handling, but also monitoring mechanisms) in developing a stable PE to support HIS.

8.2 Recommendations

The PE provides a necessary lens to analyse user interactions and PE orchestration helps provide the basis to understand multi-sector stakeholder governance. However, this thesis also suggests several differences of FOSS PE to traditional PE. Since FOSS is non-commercial focus, there is the possibility of forking the platform and keystone responsibility is being divided between the developer and customer firms.

The findings of this research may be relevant beyond the health sector where FOSS is involved. What is important to understand is the different stakeholders involved, processes of governance and the evolution of trust or not. There are typically three main stakeholders involving the client, the developer and implementer firms, playing different roles. Studying these groups and interactions becomes the analytical focus in studying FOSS implementation projects, irrespective of the sector.

8.2.2 Directions for further research

Based on the findings of this research, two major avenues for further research are highlighted.

1. Investigating PE in more detail in FOSS implementation projects.
2. Investigating the micro-issues of trust in the FOSS implementation governance
3. Extending the model to other non-health settings.

This thesis has proposed a PE orchestration lens to understand governance in FOSS implementation. It may be beneficial if approach is further studied in different domains other than the health sector for a more comprehensive understanding.

The thesis focuses on macro scale analysis of trust issues in the FOSS HIS implementation process. Therefore, it is recommended to study also micro level issues relating to trust to get a deeper grasp of the influence of trust in FOSS implementation networks. Future studies can focus on the interplay between multi-stakeholder network trajectories and various forms of trust and different trust elements. While this study adopted a qualitative approach, further quantitative elements may supplement the findings. Use of mixed method approaches with a larger sample size may help to generalise the findings to overcome some limitations of sample size restrictions inherent to the case study approach (Sandelowski, 1995).

The study was mainly based on a centralised network organisation of the state health sector in Sri Lanka. So, it would be interesting to study similar stakeholder interactions in de-centralised (shared form of governance) networks in other LMIC settings to compare the findings with the centralised stakeholder network. This will allow applying the findings of the research without being restricted by the network structure with the ability to generalise the proposed model to a range of settings.

Chapter Summary

This chapter has presented the conclusions of this thesis. It has highlighted the demand for the 'whole product' in enterprise FOSS implementation and the dilemma of FOSS customisation against custom software development. Similarly, it has highlighted the theoretical as well as practical significance of boundary spanning agents in FOSS implementation context.

The discussion proposes using PE as a lens to understand the stakeholder governance around FOSS implementation. The chapter also recommends using the proposed model and theoretical contribution of the thesis beyond the FOSS implementation network to custom software development in the health domain to strengthen stakeholder participation and institutionalisation of the implementation efforts. Similarly, it argues that some of the findings presented in this thesis are

applicable to the software development domain in general, beyond health. Finally, the chapter has identified some future research directions which emerge from this thesis.

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Appendices of Publications

I

How Health Managers' Trust Towards FOSS Implementors Changed and Shaped HIS Implantation Trajectories:
An Empirical Study of Selected FOSS HIS Implementations in Sri Lanka

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ABSTRACT

In developing countries, implementation of FOSS health information systems demands participation of diverse organizational actors and, can be considered similar to software outsourcing exercise. The multi sectoral actors operate in a network form of governance model where psychological and social contracts are important in maintain the fabric of the network organization. Inter-personal and inter-organizational trust is a key constituent in psychological and social contracts in IS outsourcing. This article attempt to reflect the empirical evidence of trust based governance of the network organization around 2 FOSS HIS implantation within the state health sector with an inter-organizational trust lenses. The longitudinal case studies try to understand how health managers' trust towards FOSS implementors changed and shaped HIS implementation trajectories with long term repeated interactions during two HIS implementations in Sri Lankan context.

Keywords: *Free and Open Source, Health Information System,Inter-Organizational Trust, Network Organization, Normative Implementation Environment Evaluation*

INTRODUCTION

In developing country perspective, implementations of free and open source health information systems (HIS) demands participation of many organizational actors in a networked manner (Puri, Sahay, & Lewis, 2009). This multi sectoral participation is necessitated mainly due to the lack of HIS related technical competencies in healthcare organization and comprised of heterogeneous actors, including healthcare managers and administrators, free and open source software (FOSS) developer communities and FOSS implementors. FOSS implementors often provide their services in the form of well-organized entities around customization

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and implementation of large scale information systems and identified as implementation mediators (Puri, Sahay, & Lewis, 2009). FOSS implementation exercises can be comparable to an Information Systems (IS) outsourcing project. Bridging the health care organization and FOSS developers, implementation mediators play a significant role in the HIS implementations (Twaakyondo & Lungo, 2008).

The multi-sectoral actors participating in the network organization of HIS implementation are often independent from each others (Braa & Hedberg, 2002) and in the early phase of FOSS implementations operate outside formal contracts, based on psychological and social contracts. This persistent, and structured set of autonomous firms and agencies are referred to as a *network governance* by Jones, Hesterly and Borgatti (1997) and engaged in creating products or services based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinates and safeguard exchanges. Inter-organizational trust has been identified as a key determinant of the fabric of the network governance (Uzzi, 1997). In the network governance around FOSS HIS implementation, the most interactive inter-organizational trust relationship can be seen among the healthcare organizations and HIS implementation mediators. Trust has been identified as an important denominator in IS outsourcing projects (Heiskanen, Newman, & Eklin, 2008) hence expected to have similar value in FOSS HIS implementations as well. Miranda and Kavan (2005) further emphasize this suggesting that even after making the formal contract, the cooperation continues mainly according to a psychological contract in IS outsourcing. Trust is theorized as a construct by some authors with trust dimensions such as competence, benevolence and integrity (McKnight, Choudhury, & Kacmar, 2002), whereas others prefers to consider it as a process. It is argues that treating trust as a construct or a variable is a weakness in trust discourse due to the changing nature of the composition of the trust in the society. Hence the process oriented view of trust emphasizes its creation, development and maintenance (Khodyakov, 2007).

This comparative analysis was carried out to investigate how health managers' trust towards FOSS implementors changes and shapes the HIS implementation decisions. One of the studied HIS project was Hospital Health Information Management System (HHIMS) and the other was a customization of District Health Information System 2 (DHIS2). In evaluating these HIS initiatives at department of health level to grant permissions for piloting and scaling, it was observed that the inter-organizational trust appeared to play a key role affecting the implementation decisions by the central health care authorities. Based on these empirical findings, the paper organizes as follows: the theoretical development section discusses the literature on network organization emphasizing inter-organizational trust in the forms of a construct and a process. The research method section describes the data collection and analysis process as longitudinal case studies, followed by narrations of two case studies based on two large-scale FOSS HIS implementations attempted with multi-sectoral participation in Sri Lanka from mid-2010 to mid-2012. The discussion reveals how trust was established in the two projects being considered. Finally, the paper reflects the findings, while special attention was given to the normative implantation environment analysis described by Chen (1989).

THEORETICAL DEVELOPMENT

Network Organization

Network organization is a form of co-governance (Kooiman & Jentoft 2009) and is defined as a select, persistent, and structured set of autonomous firms engaged in creating product or service based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinate and safeguard exchanges (Jones, Hesterly, & Borgatti, 1997). The network governance is a main form of governance in network organization and characterized by, being a clusters of organizations with non-hierarchical collectives of legally separated units (Alter, & Hage, 1993), having long-term recurrent

exchanges that create interdependencies (Larson, 1992) and demonstrable lateral and horizontal patterns of exchange(Powell, 1990). A network organization can be frequently identified in health sector (Ansell & Gash 2007; Exworthy, Powell & Mohan, 1999), more prominently in relation to public health initiatives (Alexander, Comfort & Weiner, 1998). The centralization, which is defined as the locus of authority to make decisions affecting organization (Pugh, Hickson, Hinings, & Turner, 1968) could be seen in network governance and referred to as brokering of the network organization (Provan & Kenis, 2007). When brokered, network governance is known as *lead organization-governed network*, coordinated by a dominant, single participant.

The inter-organizational trust has been identified as the key determinant in maintaining the fabric of the network governance (Sørensen & Torfing 2009), and it is particularly applicable to health sector as well (Ansell & Gash 2007). The trust based social and psychological contracts play an influential role in IS outsourcing projects even after the legal contracts were formulated (Miranda & Kavan, 2005). Trust is a familiar concept in healthcare organization in terms of individual and inter-organizational relationships (Alexander, Comfort & Weiner, 1998) and an essential component in maintaining the integrity of the network organization in healthcare partnerships (Ross, et al., 2010). Evolved from the patient-physician relationship, the concept of trust has become significant concept influencing HIS implementation (Mandl, Simons, Crawford, & Abbett, 2007). In organizational context, trust has been identified as an important factor in HIS success than the literal focus on the contracts between healthcare institution and software firm (Brender, Ammenwerth, Nykänen, & Talmon, 2006). Further, Creed, Miles, Kramer and Tyler (1996) mentioned that, in the network governance, where traditional control mechanisms are generally ineffective, the requirement for trust is high. In the context of health sector, the inter-organizational trust is more visible in the governance of public-private partnerships where state health sector frequently interacts with private sector, volunteer organizations, communities and individuals with informal contracts and mutual trust (Alexander, Comfort & Weiner, 1998; Michell & Shortel, 2000). Trust has been identified as a risk factor in collaborative software development involving multiple organizational units in many domains, including cooperate health sector (Mohtashami, Marlowe, Kirova, & Deek, 2006).

Inter-Organizational Trust

Inter-organizational trust is a familiar concept in FOSS (Stewart & Gosain, 2001), and coined as the key determinant in maintaining the fabric of the network governance (Uzzi, 1997). Also, it has been identified as a major denominator in IS outsourcing (Heiskanen, Newman, & Eklin, 2008). Trust is a positive concept and involves two parties; trustor and trustee. Inter-organizational trust has been described by various authors with different conceptualizations and dimensions (Seppänen, Blomqvist, & Sundqvist, 2007). Most conceptualizations of trust is based on, dealing with risk and accepting vulnerabilities (Newell & Swan, 2000; Edelenbos & Klijn, 2007). For the purpose of this study trust was considered as:

The willingness of a party to be vulnerable to the action of another party based on the expectation that the other will perform a particular action that is important to the trustor, irrespective of the ability to monitor or control the other party (Norman, 2002).

According to Zaheer, McEvily, and Perrone (1998), in inter-organizational context, trust can exists as inter-personal trust between individual actors in partner organizations or as inter-firm trust between individual actors in trustor organization towards trustee organization. However in later stages of inter-organizational relationship, inter-personal trust believes to diffuse within the trustor organization as consolidated inter-organizational trust (Seppänen, Blomqvist, & Sundqvist, 2007).

Aforesaid individual actors who play a key role to propagate trust between organizations are referred to as boundary spanning agents (Perrone, Zaheer, & McEvily, 2003) and play a major role in establishing inter-organizational trust in the network organization. Within the scope of this study, inter-organization trust is considered mainly as "*the extent of trust placed in the partner organization by the members of a focal organization",* based on the work of Zaheer, McEvily and Perrone (1998). Trust is a multifaceted construct and there are many aspects to trust, individually or in combination gives rise to different dimensions of trust. In analyzing organizational trust researches from 1990 to 2010, McEvily and Tortoriello (2011) had proposed a framework for measuring trust, mainly comprising of competence, benevolence and integrity while identifying those as the most frequently coined constructs of trust in contemporary literature. As defined by Mayer and Davis (1999), *competence* is that group of skills that allow a party to have influence within some domain. *Integrity* defined as the trustor's perception that the trustee adheres to a set of principles that the trustor finds acceptable and *benevolence* is the extent to which a trustee is believed to want to do good to the trustor, aside from an egocentric profit motive.

Trust as a Process

Contrary to the widespread notion of trust as a construct, some considers trust as a process consists of trust creation, development and maintenance (Khodyakov, 2007). This is particularly true in evolving network organizations among autonomous and independent entities (Calton & Lad, 1995). To understand the trust process, Lee and Choi (2011) has coined the concepts of *initial trust* and *ongoing trust* considering the temporal factor and historical element in development and maintenance of trust. Gulati (1995) has shown that inter-firm trust consolidated in long term ties influence the contractual decisions of alliances. The common features in trust building process suggested by different authors; calculative, predictive, relational, identification and cognitive processes and reputation and capability (Komiak & Benbasat, 2008). The four staged trust process and outcome model suggested by Johns (1996) consists of assimilation of information about potential trustee and the relevant situation; decision making with information processing; trusting relationship; and the consequences of entering in to a trusting relationship in context-specific situation. Initial trust also drew much attention in the discourse on the trust process (McKnight, Cummings, & Chervany, 1998).

RESEARCH METHOD

This study begins with the assumption that, there is a causal link between inter-organizational trust among multi-sectoral organizations participating in FOSS HIS implementation project and the governance decisions of FOSS HIS implementations by health managers. The research question the analysis in this paper based on is,

How health managers' trust towards FOSS implementors changes and shapes HIS implantation trajectories?

To explore the research question, a comparative case study research strategy was adhered to (Yin, 2003). Two cases of FOSS HIS implementations were chosen from the state health sector of Sri Lanka namely, Hospital Health Information System (HHIMS) for curative healthcare institutions and District Health Information System (DHIS2) for public health institutions. The two cases were selected for being large scale projects, beyond the purview of a single healthcare institution with the participation of multiple stakeholders. Authors engaged with cases prospectively and longitudinal observations on two HIS implementations were recorded during a period of three years duration from mid-2010 to mid-2012. Unit of observation for the study was organizational and inter-organizational. Later, the findings were analyzed with inter-organizational lenses. In the reflection of findings, special attention

was given to the normative implantation environment analysis suggested by Chen (1989).

However, considering the organization as unit of observation pose the challenge of key-respondents' views while collecting organizational level data on perception of trust. It was assumed that the perception of health management in a health institution or programme reflect the collective perspective of the health institution or the programme, and as a result, the views of top managers could be held as reliable source of organizational-level data (Gaur, Mukherjee, Gaur, & Schmid, 2011). So, the opinion of health administers and managers, those who are able to recognize and assess the strategy within the organization boundaries weighted more in interpreting the information extracted from interviews, focus group discussions and other communications.

DATA COLLECTION

The focus of data collection was on health managers' perception of trustworthiness of FOSS HIS implementation mediators. The health managers interviewed consisted of HIS end users (e.g. Medical Officers of health, Medical Officers – In Charge) as well as super users (e.g. Consultant Community Physicians, Programme/Hospital Directors, Regional Directors of Health Services). Some of the super user health managers and administrators were mainly responsible for managerial decisions in implementation projects with minimal interaction with the HIS and customizations (e.g. Provincial Directors of Health Services, Deputy/Programme Director Generals of Health Services). They however were more influential in implementation decisions. Also, the health managers from both central and peripheral level were included in the study (See Table 1).

During the implementation projects, authors interacted with the healthcare workers who were HIS end users with non-managerial/administrative roles (e.g. Medical Officers, Nurses, Public Health Nursing Sisters, Public Health Midwives and Development and Programme Assistants). The interviews conducted with the non-managerial/administrative users are mainly focused on usability aspects of the systems and hence considered to have limited value in this discussion.

The data was mainly gathered on the views on trustworthiness beliefs, competence, benevolence and integrity, based on the framework of measuring trust recommended by McEvely and Tortoriello (2011). To collect data on these issues, the research took a multi-method approach (Mingers & Brocklesby, 1997), employing three main data collection methods; series of semi-structured interviews with the health managers, focus group discussions and relevant document collection, including project steering and evaluation meeting minutes and email communications. The semi-structured interviews and focus groups were selected for gathering the qualitative data that will provide insight into the health managers' perception of trustworthiness of FOSS HIS implementation mediators.

The starting point of data collection were several HIS review meetings conducted by Ministry of Health and FHB in 2010. In 2011

Table 1. Number of interviews and focus group discussions with health managers and administrators

Position	Number of interviews/ focus group discussions	Number of subjects
Central health managers	8	31
Programme/Institutional health managers	16	28
Provincial health managers	12	23
Total	**36**	**82**

and 2012, data were collected by attending implementation meetings and pilot site visits with interviews and participant observations with a focus on health managers' perception of inter-organizational trust. In this phase of research, a total of 36 semi-structured interviews and focus group discussions were conducted on changing perception of trust towards FOSS HIS implementation mediators at different phases of the implementation projects. Out of the health managers viewpoints, 45% can be considered as solely super users perspective and 55% were mainly end users perspective towards the concerned HIS implementation mediator teams. The interview questions focused on how health managers perceived the trustworthiness of FOSS HIS implementation mediators and interpreted in terms of *competence* (having the skills that allow a party to have influence within some domain), *benevolence* (extent to which a trustee is believed to want to do good to the trustor, aside from an egocentric profit motive) and *integrity* (trustor's perception that the trustee adheres to a set of principles that the trustor finds acceptable).

DATA ANALYSIS

The study is conducted as an interpretive case study (Walsham, 1995). A qualitative data analysis was performed with post data collection reduction (Miles & Huberman, 1984). The event listing is the key data display method used in this study and the level of analysis is inter-organizational. Analyzing within-case data and searching for cross-case patterns (Eisenhardt, 1989) have been performed during the data analysis. In both within the case and cross-case analysis, the main aim was to identify the trustworthiness beliefs of health managers and to interpret it in terms of inter-organizational trust towards FOSS HIS implementation mediators. The within-case analysis focuses on variations of perceptions of trust and implementation decisions. The cross-case analysis tries to compare variations of trustworthiness beliefs and implementation trajectories in two FOSS HIS projects concerned.

CASE DESCRIPTIONS

Hospital Health Information Management System

The electronic medical record system, Hospital Health Information Management System (HHIMS) is the FOSS descendant of the electronic patient information system, Multi-Disease Surveillance project (MDS). The MDS system was implemented by the Austrian and Swiss Red Cross Societies during the period, 2006-2009 in 27 state owned hospitals (23 provincial and 4 line-ministry hospitals) in Eastern province of Sri Lanka after 2004 Asian tsunami. With the success of the MDS in the Eastern province of Sri Lanka, the MDS implementors brought the system to the attention of Ministry of Health suggesting it to be expanded to the rest of the island. Ministry of Health reviewed the system with the technical expertise of Postgraduate Institute of Medicine (PGIM), University of Colombo and did not agree with the licensing of the MDS system, which was free to be implemented in tsunami affected areas of the country, but not FOSS. The main issues identified in the evaluation were the ownership of the source code of the MDS system, and non-FOSS nature. The system being requested to be implemented in Kegalle district was the turning point of the project. The Regional Director of Health Services (RDHS), Kegalle submitted a proposal to ICT Agency of Sri Lanka (the single apex body involved in ICT policy and direction for the nation) requesting financial and technical support for implementing the MDS system in two base hospitals. According to ICTA guideline proposal was revised to convert MDS in to FOSS and implementing the new FOSS HIS in selected hospitals. MDS team was invited to develop an open source HIS and the new electronic health record system with a FOSS license was baptized as Hospital Health Information Management System (HHIMS).

HHIMS (version 1.0) was a very successes pilot project in Karawanella base hospital, and subsequently Provincial Department of Health Services (PDHS), and the Regional Director

of Health Service Kegalle supported for the replication of HHIMS in another three district hospital in order to improve health information management. Parallel to the release of HHIMS, the local maintenance team of MDS organized as a FOSS development and implementation team. There were several review sessions for the HHIMS implementation conducted by the Ministry of Health with the participation of central, provincial and institutional health managers, representatives of ICTA and PGIM. Despite being PDHS Sabaragamuwa and RDHS Kegalle were very convincing about the HHIMS, ministry of health hesitated to approve HHIMS to be scaled up and implemented island wide. Instead, it authorized ICTA to pilot HHIMS in 5 more hospitals in three 3 districts to evaluate security and usability of the system. The next episode of HHIMS development started with ICTA financially and technically supporting District hospital Dompe to enhance the HHIMS and implement the system in the hospital. HHIMS version 1.3 was release and this was one of the most successful implementations of HHIMS. With the success of Dompe HHIMS implementation, Ministry of Health also was favorable towards HHIMS and considered initiation of HHIMS Foundation to institutionalize HHIMS to state health sector need of electronic medical record.

District Health Information System 2

The District Health Information System version 2.0 (DHIS2) is a highly flexible, open-source health information management system developed by the Health Information Systems Programme (HISP) of the University of Oslo. The software development process is a global collaboration between students, researchers and developers in Norway, India, Vietnam and Africa (Staring, & Titlestad, 2006). DHIS 2 is a generic tool rather than a per-configured database application, which needs further customization to be used in specific health programme context. DHIS2 was first introduced to Sri Lanka as a public health information tool in the curriculum of Masters degree program in health informatics conducted by the Postgraduate Institute of Medicine (PGIM) in collaboration with the University of Oslo. Similarly, there were several hands on training sessions conducted to different staff categories of the ministry of health to make the Department of Health aware of the DHIS2 and its capabilities by HISP India; the Indian node of HISP project, in late 2009 and early 2010 and some of the central health authorities were offered field visits in India for familiarization with DHIS2 implementations. Initially the DHIS2 was customized as a student projects of the health informatics masters degree program of the PGIM to address the information need of the maternal and child health program of the Family Health Bureau (FHB); a state sector preventive health care organization responsible for maternal and child health, school health and family planning. The student project of customizing DHIS2 was carried out under the supervision of the senior administration of the FHB. Once a DHIS2 customization was ready for piloting, the system was demonstrated to the Family Health Bureau with the mediation of PGIM to obtain the permission to pilot the information system under the FHB. During the demonstration, ownership of the customized DHIS2 and data stored, customization motivations and development support were heavily questioned and FHB did not approved piloting of customized DHIS2 in Sri Lanka at that point.

After failing the top down approach, in 2011, Health Informatics Society of Sri Lanka (HISSL) tried to implement DHIS2 in a bottom-up manner in the North Western Province of Sri Lanka. To support the implementation, it was decided to sign a tripartite agreement between HISSL, PDHS of North Western Province and HISP India, even though this was not get materialized. However, PDHS of North Western Province invited HISSL to conduct a piloting under the supervision of FHB before implementing the DHIS2 system in the province. FHB also consented for the piloting of DHIS2 in the North Western Province and initially one Medical Officer of Health (MOH) area was selected and later it was expanded to 5 MOH areas. Initial training was provided to the staffs of MOH areas and data entry was commenced

in a central server provided by the PGIM. The financial support for the piloting was provided by the PGIM, HISSL and University of Oslo. Apart from the local training programs, selected staffs from Kurunegala RDHS office were offered an international training program collaboratively conducted by HISP India and University of Oslo. The MOH staffs were satisfied about the functionality of the DHIS2 customization and its flexibility to generate user defined data entry forms and reports. After the system was piloted for 2 quarters, a project evaluation report was handed over to the PDHS for scaling of the system. When the piloting was commenced for the 3rd quarter data entry, FHB asked PDHS to conclude the piloting mentioning that DHIS2 believed to void the supervisory role (accountability framework at MOH level) embedded in paper based reporting system as the main reason.

DISCUSSION

This study reveals empirical findings of two HIS implementations in Sri Lankan context based on inter-organizational trust lenses. It was argued that the trust process is influenced by the national culture and the norms and values of the organization (Doney, Cannon & Mullen, 1998). Sri Lanka is having a centralized healthcare system brokered by Ministry of Health. Also, the state health sector is equipped with a well-established and time tested paper based record system and owns better health indices compared to the other countries of the region. Hence in interpreting the findings, the lead-organization governance nature of the health sector (e.g. network organization was brokered by Ministry of Health) and its conservative approach towards HIS should also be noted. It was also observed that the health managers engaged in FOSS customizations/implementation decision making with the understanding of bespoke software development and with the little understanding of FOSS licensing.

In both the projects discussed above, participating organizational actors were legally independent of each others, even though they were mutually agreed and cooperating to realize long-term goal of successful implementation of HIS in each case. For example, in HHIMS project, ICTA was an independent body under the Ministry of Telecommunication and Information Technology, hence, beyond the control of the Ministry of Health. Similarly, PGIM is an independent academic institution and was beyond the jurisdiction of the FHB. Hence, these organizations form a network governance around each project without legal obligations based on their specializations in different disciplines and allocation of assets to the projects.

There were 2 level to health institutions; central and peripheral. The Ministry of Health and FHB were central healthcare institutions, whereas hospitals, MOH, PDHS and RDHS were peripheral institutions. The Ministry of Health, FHB and PDHS and RDHS mainly consisted of super users of the system. Medical Officers – In charge of hospitals and MOH were end users with administrative powers. Within the scope of this study, the organizational interactions among central and peripheral healthcare authorities and FOSS implementation mediator are considered the most significant inter-organizational trust relationships in shaping the network governance.

In evaluating these HIS initiatives for piloting and scaling by central healthcare authorities inter-organizational trust was central to the discussions. Whether FOSS developers and implementation mediators are trustworthy in organizational capacity in delivering the services related to implementations and maintaining the transparency of manipulating health information entrusted to their custody during HIS implementation were major concerns. Apart from these, financial and political transparency of donor agencies, trustworthiness of FOSS developers and implementation mediators on hidden costs of implementations and open source licensing, lack of trust on the ownership of customized software artifact and lack of trust of central health care authority in peripheral healthcare institutions were observed during the study. For the purpose of the study

the inter-organizational trust between health care managers and FOSS implementation mediators were interpreted under the broader perceptions of,

1. Whether HIS implementation mediator, as an organization has the thorough understanding of the HIS to be implemented and possess the technical skills to successfully implement the HIS and troubleshoot technical issues (competence).
2. Whether the implementation mediator maintained an adequate transparency up to the expectation of the healthcare managers, mainly in terms of confidentiality of medical data, open source license and ownership of the customized HIS (integrity).
3. Whether implementation mediator facilitate a positive change in the health care institution/organization with the HIS proposed, apart from implementation mediator's financial or otherwise egocentric motive (benevolence).
4. Whether implementation mediator is well recognized, has a good reputation and known to treat clients fairly (initial trust)
5. Whether implementation mediators makes beneficial decisions for customers, willing to provide assistance and caring and sincere during the project (ongoing trust)

Following in Table 2, Figure 1, Figure 2, Figure 3, and Figure 4 is a summary of salient feature of trust as a construct and process in HHIMS and DHIS2 implementation projects.

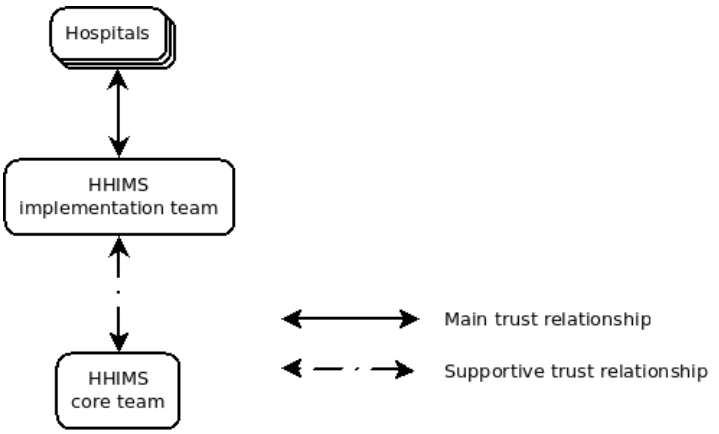
When considering the organizational network of HHIMS project, initially the network consisted of HHIMS core team and implementation mediators and the hospitals where HHIMS was implemented.

From the beginning, the inter-organizational trust was growing stronger between the hospitals those decided to implement HHIMS and HHIMS implementation mediators. So, the trust between HHIMS implementation team and the hospitals was lead to the implementation decision and expansion of the network

Table 2. Comparison of salient features of construction and maintenance of trust in HHIMS and DHIS2 implementations

Trust	HHIMS	DHIS2
perceived by health managers as a construct or variable	• Competence trust: maintained high throughout implementation • Integrity: low due to FOSS licensing issues, but improved later with publicly available source code • Benevolence trust: high due to improved reporting • Boundary spanners: present and played strong role	• Competence trust: low and not improved adequately • Integrity trust: average • Benevolence trust: low from central point of view but high from peripheral point of view • Boundary spanners: lacking
perceived by health managers as a process	• Initial trust: average (by engaging MDS project) • Ongoing trust: improved to high with repeated interactions • Trusting relationships: developing as ongoing activity • Consequence of trust: encouraging and rewarding to organizational actors • Feedback process: encouraging and improving	• Initial trust: low (perceived only as student projects) • Ongoing trust: remained low and not cultivated • Trusting relationships: developed with end users, but not with super-users (central health administrators) • Consequence of trust: discouraging to end user as restrictions and caveats from central health administrators) • Feedback process: encouraging by end users, discouraging at central level

Figure 1. Network organization around HHIMS project at the beginning



organization around the HIS implementation. Benevolence was perceived by the hospital authorities towards HHIMS core team as,

...HHIMS want to help day to day activities of hospital by improving the data capture and analysis, with its feature for individual patient records, pharmacy chits, day summaries and other administrative records...

HHIMS core team won the initial trust for its recognition as the force behind MDS. They were also identified as a responsible non-health entity by the hospitals, with high ongoing trust referring to their past performance, as follows.

... HHIMS team proves its capability in providing a good service to Batticaloe and Tricomalee hospitals in East. So, we [RDHS] are confident that they will continue same high standards here [Kegalle] as well.

Further they have the confidence over the product, HHIMS with the previous experience of MDS system. However, the Department of Health (DoH) was initially skeptic about the HHIMS core team and the FOSS artifact HHIMS. This was evident in discussions where it was spitted out as,

... Does HHIMS has an open source license and if so, what is the type of license? ...and what is the cost model of the HHIMS maintenance agreements...?

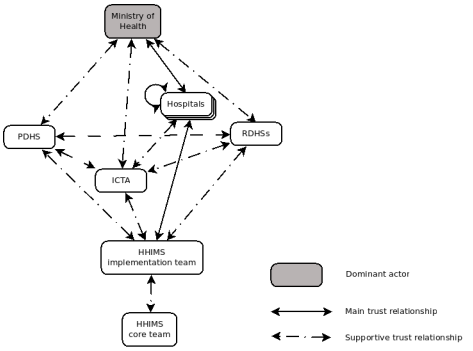
... Does HHIMS has license to use SNOMED within the HHIMS software?

...is the database used by HHIMS is free and open source or does hospitals have to pay an additional fee to use it with HHIMS?

As the super user of HIS, central health authorities did not pay much attention to the feature-richness of HHIMS. Likewise, ownership of the source code was not a concern in the trusting perception by the peripheral health care authority towards HIS implementors. Similarly, demonstrating the importance of ongoing trust, peripheral health managers were more concerned about the continuous and readily available technical support.

With the past successful projects, HHIMS core team and implementation mediators won the competence trust of RDHS, PDHS and hospitals. These past successful projects helped HHIMS implementation team to establish integrity trust with hospitals, so that hospitals to have faith in the HHIMS team that they will attend the specific requirements of individual

Figure 2. Network organization around HHIMS project at its peak



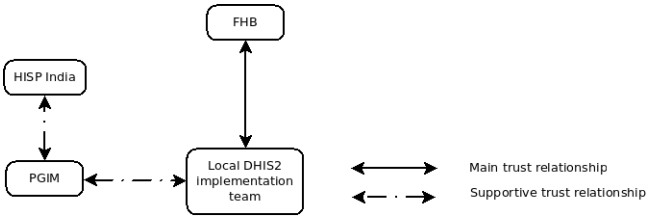
healthcare institution. Similarly, HHIMS implementors managed to maintain repeated contacts with each implementation ground even after the implantation process was completed. This repeated visits lead to consolidate the perception of integrity in hospital administrators towards implementation mediators.

The hospitals had the belief that an electronic health record system as a technology artifact will make the institution and the care process efficient and effective. This caused individual institutions to speak for HHIMS in product evaluations conducted by the Ministry of Health. Also, the role played by the ICTA was significant in formation of the network organization of HHIMS. ITCA being a well reputed government entity, having contributed to several successful national information technology inclusion projects won the trust of many participants of the HHIMS network. It functions as a boundary spanning agent cultivating ongoing trust in the network.

Similar inter-organizational relationship seemed to govern the organizational network in DHIS2 project and, trust between FHB, MOHs and implementation mediators were key factors leading to implementation decisions. Being started as a student project contributed to less initial trust towards DHIS2, making it difficult for FHB to place confidence on the customized application and expertise of the implementors. Hence, FHB demonstrated lack of competence trust on DHIS2 implementation mediators since the beginning of the project.

This was in long run seemed to be aggravated (not cultivating ongoing trust) by not organize as a readily deployable local implementation mediator team for DHIS2. However, this lead more actor to join the network organization, like HISP India and HISP global team. This further complicated the trust issue in central healthcare authorities as a perception of losing control over project. Also, there was no any identifiable boundary spanning agents to strengthen

Figure 3. Network organization around DHIS2 project at the beginning



the inter-organizational trust between health administrators and implementation mediators.

The core software artifact being developed outside Sri Lanka posed a disadvantage on perception of trust towards DHIS2 implementation by FHB in the form lack of integrity trust. This was understood as not having a local entity to look after specific needs compared to bespoke software development. Further, globally positioned developers' possible unauthorized access to stored health information in customized DHIS was a significant threat to inter-organizational trust. This was evident by the statements like,

...how can we [PDHS] assure those DHIS2 developers for not using health information stored in the database for commercial or any other purposes?

Unfortunately, FHB did not have technology trust on DHIS2, and the customized software artifact was not seen as a tool to improve public health reporting, hence not improved the ongoing trust. Following statements confirm it.

...We [FHB] are running the MCH data stream with paper based records for many years. Data completeness is satisfactory and reporting process is punctual. So, what more DHIS2 can offer us?

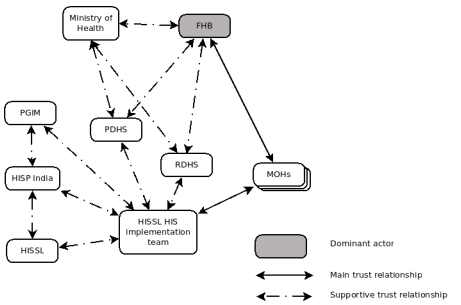
... PHMs fill paper forms and DHIS2 needs additional work of computerizing data. All the reports we are getting by PHMs on the paper forms.

We [FHB] have some specific requirements in the data stream, like role based user authentication, those are not available in DHIS2..... and the flexibility forms and reports of DHIS2 is not something we [FHB] want or will allow at MOH level....

Even though, the end user enjoyed the flexible data entry forms generation, central health administrators saw implementors promoting flexibility feature as encouraging periphery to bypass the embedded monitoring mechanisms of paper based records.

In general, it was noted that the trust was fluctuating during the trajectories of the both projects. Initially HHIMS has a weak trust due to the licensing issues and non-FOSS 3rd party software dependencies of MDS. However, with health managers improved understanding of HHIMS business model and code repository being migrated to state owned public code repository, trust towards HHIMS implementors were improving. Two exemplary implementation sites (Karawanella and Dompe hospitals) contributed in trust building process to a greater extent. After the success of implementation at Dompe hospital, even Ministry of Health was motivated to initiate a dialog on establishing HHIMS Foundation, a controlling body for design standardization and quality control. On the contrary, FHB's non acceptance of DHIS2 and rejection of data processed with DHIS2 was a negative consequence of trusting DHIS2 implementations by end users and peripheral super users. FHB was neutral to DHIS2 imple-

Figure 4. Network organization around DHIS2 for MCH project at its peak



mentation in the beginning and the development of trust was negative with time leading to a hostile response at the last days of DHIS2 implementations.

HHIMS was noted for its cultivation of trust with a better perception among involved organizational actors compared to DHIS2. Following were believed to improve the inter-organizational trust in HHIMS implementation process.

1. Initiating discussion with Ministry of Health to hand over the code base to ministry and suggestion of multi-stakeholder governing body (HHIMS Foundation) lead by health stakeholders.
2. Regular progress reporting on implementations and dissemination of 'HHIMS awareness' (cultivating ongoing trust).
3. Licensing the HHIMS under open source license, AGPL version 3.
4. Moving the HHIMS code base to a state owned public FOSS repository (GovForge).
5. Responsive support, maintenance and troubleshooting process of HHIMS implementation mediators.
6. Drawing reputed academic institutions to interact with the HHIMS development process (potential boundary spanners).
7. Try to consolidate the concept of 'HHIMS user community' as an umbrella organization, which leads to diffusion of inter-organizational trust.
8. Promoting 'centers of excellence' and encourage health sector organizational champions to lead implementation process (dissemination of personal trust to organization wide trust towards HHIMS)

CONCLUSION

This paper mainly focuses on the implementation environment domain (Chen, & Rossi, 1989) of the considered HIS programmes. Implementation environment domain attempt understand under what environment the treatment is implemented. In these case discussions, the treatment is the implementation of FOS HIS and the environmental conditions are the dynamic network organization around the HIS implementation. In the theory driven perspective, it is mentioned that how the programme implemented may affect programme process and consequences (Chen, 1989). In these particular cases, this is demonstrated by the dependency between the success of HIS implementation and the manner in which inter-organizational governance network formulated and expanded. In various instances during the lifespan of each project, inter-organizational trust was a factor to shape the path of the project. Also, it was evident that having a boundary spanning agent may strengthen the inter-organizational trust between participating organizations.

In answering the research question, "*How health managers' trust towards FOSS implementors changes and shapes HIS implantation trajectories?*" this study provide strong evidence that there is a noticeable difference between the perception of super users (mainly the central health administrators) towards IS artifact in two projects. At the central level and as super users, health managers are more concerned on broader issues like cost model of software agreements, open source licenses, ownership of software source code and possible unauthorized access to health information by developers or implementors. On the other hand, at peripheral level as end users, health managers are more concerned about the feature-richness and flexibility of the HIS. So, it is safe to assume that super user or central health managers/administrators have higher potential to alter the trajectory of FOSS HIS implementation trajectories, especially in centralized healthcare setup.

In the theory driven evaluation, it was always advised to perform a generalization evaluation to assess the generalizability of evaluation results to the circumstances of interest to stakeholders (Chen, 1989). In assessing generalizability, it is important to consider the centralized (brokered) nature of the Sri Lankan state health sector. In generalizing the above findings the individual country's context should be compared carefully with the context

described in this study, where there could have more flexibility at peripheral level or freedom for the action of HIS implementation mediators than in Sri Lanka. However, this analysis highlights few best practices FOSS implementors can follow, which may improve inter-organizational trust. These include, frequent interactions with system user to improve ongoing trust; maintaining the technical, financial and social transparency; organizing as a readily deployable and technically competent implementation team and encouraging the role of boundary spanning agent. When FOSS customization is considered as an IS outsourcing, there is always a place for psychological and social contract. Even if the initial trust is low, during repeated interactions with health managers, FOSS implementation team can cultivate ongoing trust to positively alter the implementation trajectory.

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II

NETWORK GOVERNANCE IN OPEN INNOVATION ADOPTION: CASE STUDY FROM HEALTH DOMAIN

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Abstract: Open Innovation is the use of purposive inflow and outflow of knowledge to accelerate internal innovation and to expand the markets for external use of innovation. Open innovation is often conflated with open source methodologies those empower local knowledge. Health information systems are becoming an integral part of health reform agendas throughout the world. Due to technological and financial limitations, free and open source software is increasingly being considered for health information systems development. Although open source health information system contributes to local innovation, its generic design may demand further customization as required by specific business needs of health programmes.

The customization and implementation of open source health information systems in developing country context demands the participation of various health sector and non-health sector stakeholders. In initial phases of implementations the governance of this organizational network is mostly informal and requires sensitive approach for it to evolve. This longitudinal case study was empirically positioned on three open source health information systems implementations in the Sri Lankan state health sector for four years duration. It tries to contribute to the open innovation discourse by analysing the network governance of the open source implementation networks in health information systems strengthening efforts.

Keywords: Open Innovation, Open Source Governance, Free and Open Source, Health Information Systems

1. INTRODUCTION

Open innovation is defined as a paradigm which assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms are advancing their technology (Chesbrough, 2003). It seeks to apply the use of the purposive inflow and outflow of knowledge to accelerate internal innovation. This process combines internal and external ideas into architectures and systems and is quite often conflated with open source methodologies for software development (Chesbrough, 2006). With current advancements in Information Technology, health information systems have become an integral part of health reform agendas of most developing countries, even though efforts are often constrained by technological and financial limitations. In this context, open source health information systems can play an enabling role in the global south through facilitating open innovation to occur by providing not only software solutions with no licensing costs, but also by contributing to local knowledge and technological advancement by ensuring free access to software source code (Câmara & Fonseca, 2007). Open source design and development (Staring & Titlestad, 2006) is seen as empowering strategy in developing country context for coordinating global and local design processes (Staring & Titlestad, 2008; Subramanyam & Xia, 2008; Twaakyondo & Lungo, 2008) by adopting ideas from external partners as open source software artefacts and methodologies.

Unlike in bespoke software, due to wider socio-political motivation of open source software, the design of the architecture is based on generalized and abstract end user requirement specifications and global standards (Braa, Monteiro & Sahay, 2004; Staring & Titlestad, 2007). Due to its generic nature, an open source health information system software may not always fit in to all the business requirements of a health programme during the current software release cycle. The generification approach (Pollock, Williams & D'Adderio, 2007) of open source health information system design and development may pose a significant challenge to healthcare organizations in introducing an *enterprise scale* open source health information system where considerable business process re-engineering is not possible without affecting the quality of care provision. The possible disagreements between user requirements and generified use cases pose a remarkable challenge that health managers and administrators have to face in the open innovation process when compared to the closed innovation (Almirall & Casadesus-Masanell, 2010) approach in custom software development. It was argued that the success of an information system implementation depends on the alignment of the functionality of the information system to the organizational work routines and business context (Heeks, 2006). Hence further customization of open source health information system represents an essential step in the implementation process.

Due to the technical and financial limitations typically existing in the health sector of developing countries, this customization process requires the participation of various health sector and non-health sector organizational actors in a networked manner (Puri, Sahay, & Lewis, 2009). These multi-sectoral actors are often independent from each other (Braa, & Hedberg, 2002) and in the early phases of implementation and operate outside formal contracts, and tend to work in implicit and on open-ended models referred to as a *network organization* by Jones, Hesterly and Borgatti (1997). However, such models typically pose significant challenges of governance as no one if formally responsible. Understanding some of these governance challenges is the focus of this paper, and is empirically examined in the context of three large scale open source health information system implementations from the Sri Lankan state health sector during the period from 2011 to 2014 involving multi-sectoral participation of individual level, locally and regionally operating organizational actors and university initiatives from both the profit and not-for-profit sectors.

2. THEORITICAL DEVELOPMENT

In open source projects, governance could happen at two levels. The first governance model refers to how the development project and developer community are managed (O'Mahony & Ferraro,

2007) while the second refers to the process of open source acquisition by the organization, including code re-use, cataloguing, auditing and monitoring (Kemp, 2010). Within the scope of this article, *governance* refers to the management of open source health information system project including acquisition by the health organization and stakeholder participation in the implementation network.

2.1 Open innovation and open source

Open innovation is defined as a paradigm that assumes that firms can and should use external as well as internal ideas, and internal and external paths to market, as they look to advance their technology (Chesbrough, 2003). Open innovation is both a technological and business model which allows organization not only to re-use external knowledge sources and to collaborate with external partners, but also to implement internal ideas otherwise unexplored. It applies the purposive inflow and outflow of knowledge to accelerate internal innovation, and a process which combines internal and external ideas into architectures and systems. However, it does not assume universal access to knowledge and the use of innovative intellectual property licensing structures to facilitate access, but more restrictively, to make organizations more amenable to inventions and innovations from outside the organization (Katz, 2013). In the open innovation practice, software projects can be launched from either internal or external technology sources, entering and exiting the development process at various stages (Chesbrough, 2006).

Open innovation is quite often conflated with open source methodologies for software development (Chesbrough, 2006). Open source represents an ideal external knowledge source, and challenges the mindset of the *Not Invented Here Syndrome* (Katz & Allen, 1985) promoting the adoption of external knowledge. Effective governance may help to overcome some of these opposing viewpoints, especially related to processes of acquisition, defining source reliability, tracking, roles and responsibilities and finally license compliance (Kemp, 2010). The governance would seek to align these processes with organizational strategy. Firms that fail to exploit such external knowledge opportunities may tend to place themselves at a severe competitive disadvantage (Rosenberg & Steinmueller, 1988), raising the need to effectively combine external inputs with in-house research and development. When firms can not (or don't wish to) develop sufficient absorptive capacity themselves in an open innovation process, networks and alliances are recommended choices to make enabling networks to build these combinations of knowledge (Gulati, 1998, Nooteboom, 1999).

2.2 Network organization and governance of software projects

A network organization is defined as a select, persistent, and structured set of autonomous firms engaged in creating products or services based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinate and safeguard exchanges (Jones, Hesterly, & Borgatti, 1997). The governance of a network organization is characterized by taking place in clusters of organizations with non-hierarchical collectives of legally separated units (Alter, & Hage, 1993), having long-term recurrent exchanges that create interdependencies (Larson, 1992) and demonstrable lateral and horizontal patterns of exchange(Powell, 1990). The centralization which is defined as the locus of authority to make decisions affecting network organizations (Pugh, Hickson, Hinings, & Turner, 1968) when present is referred to as a process of brokering (Provan & Kenis, 2007). The brokered networks are known as *lead organization-governed network,* coordinated by a dominant, single participant. The network organization is not uncommon to the health sector (Ansell & Gash 2007; Exworthy, Powell & Mohan, 1999) and have been prominent in public health initiatives (Alexander, Comfort & Weiner, 1998). Healthcare organization around open source health information system initiatives demonstrates numbers of features of a network organization for example; representing a cluster of organizations of legally separated units and having long-term recurrent exchanges between participant organizations resulting in inter-dependencies among the different actors.

The process of delegating open source customization to an implementation mediator can be considered as a software outsourcing approach involving several phases of initiation, growth, maturity and possible extension or amicable separation (Sahay, Nicholson & Krishna, 2003). Within the scope of this research, governance dynamics are limited to initiation and growth phases where processes of coordination and control are key (Hirschheim, Heinzl & Dibbern, 2007).

Coordination	Non coordination
	Formal, impersonal
	Formal, interpersonal
	Informal, interpersonal
Control	Self control
	Output control
	Behavioral control
	Clan control

Table 1. Governance Mechanisms (Hirschheim, Heinzl & Dibbern, 2007)

As shown in table 1, coordination modes range from non-coordination to formal and informal means. Four modes of control in play are control of self, clan , output and behaviour. Out of which self and clan control are considered as forms of informal control whereas output and behaviour control represent more formal, Clan control is more compatible with the network organisation in early phases with an informal governance structure whereas later it can be replaced by formal mechanisms with formal contracts containing detailed software requirement specifications. The governance mechanism can undergo changes and evolve from none to early and to late governance models.

3. RESEARCH METHODS

This comparative case study research explores underlying governance mechanisms in adopting open source health information systems in three cases in the Sri Lankan state health sector during the period2011 to 2014. The study seeks to analyse the trajectories of the network organizations involved and the supporting governance models answering the research question, "*what are the governance mechanisms that can be identified in successful open innovation adoption process in multi-sectoral networks implementing open source health information systems*". To understand these governance mechanisms, empirically three large scale open source health information system implementations from the Sri Lankan state health sector were studied during the period from 2011 to 2014. The examined projects were carried out with the participation of multi-sectoral stakeholders. The cases were carefully selected to represent participation of a range of categorise of implementation mediators, including individual level, local and regional health sector and non-health sector organizational actors and university sector initiatives.

One project concerned an electronic medical record system called Hospital Health Information Management System (HHIMS) for curative health care and it was characterized with formal contracts and profit-driven implementation mediators. The other two cases are customization attempts of the open source District Health Information System 2 (DHIS2) software for maternal health and tuberculosis and respiratory diseases. The implementation mediators in these two cases operated under not-for-profit (research and academic) mode with informal contracts. All three selected projects were large scale beyond the purview of a single actor and involved multiple stakeholders over time.

3.1. Data Collection

Data was collected focusing on governance decisions observing their control and coordination mechanisms through a multi-method approach (Mingers & Brocklesby, 1997). These included participant observation, semi-structured interviews with health managers and project implementers, focus group discussions, informal meetings and relevant document analysis, including project steering and evaluation meeting minutes and email communications. Non-coordinated self control observed during the study included internal reports and internal discussion groups whereas formal-impersonal coordination and output control included issue queries, client involvement plans, periodic reports, categorization of issues and project management plans. Status review meetings, conference calls, on-site coordination were formal interpersonal coordination and behavioural control mechanisms in the customization projects. Personal visits, meetings, email communications and phone calls and small group meetings were the informal interpersonal coordination attempts and clan control mechanisms observer during the longitudinal follow-up.

The data collected was analysed to understand the perception of health managers and implementation mediators. The role of the health managers ranged from institutional level managers (e.g. Medical Officers of Health, Medical Officers – In Charge) to administrators (e.g. Programme/Hospital Directors, Provincial/Regional Directors of Health Services). Some administrators interviewed (e.g. Provincial Directors of Health Services, Deputy/Programme Director Generals of Health Services) were mainly responsible for managerial and administrative decisions in the health information system project had minimal interaction with the customized health information systems as end users. They however were influential in implementation decisions and implementation trajectories. Decision making processes of health managers from both central and peripheral/provincial level were observed during the data collection process. Additionally, the implementation mediators were interviewed including individual consultants attached to a state health sector organization or other private sector players. Also, in several occasions the author represented the health information system implementation teams which helped to develop deep insights into the dynamics of interaction between the different players. The unit of observation of the study was the implementation network, and the views of top managers were assumed to represent the organizational perspective (Gaur, Mukherjee, Gaur, & Schmid, 2011).

3.2. Data Analysis

The study represents a comparative case study analysis (Yin, 1981; Yin 2003) involving the use of qualitative data (Miles, & Huberman, 1984). Within-case data was analysed and cross-case patterns (Eisenhardt, 1998) were identified to discern governance dynamics of the three network organizations. In both within the case and cross-case analysis, the main aim was to identify the governance decisions by health managers towards the health information system projects. The within-case analysis focused on variations of perceptions of the different actors towards the health information system project, whereas the cross-case analysis tried to identify variations of governance decisions based on the types of coordination and control mechanisms involved.

4. CASE DESCRIPTIONS

Sri Lanka has a well-established and time tested health service both in preventive and curative sectors with a comprehensive paper based reporting system. Health service is free for all and most of the annual health budget is reserved for drugs and medical services. Hence, budget for computerization is rather minimum. Furthermore, the Department of Health is not equipped with a software arm even though there is Information Technology carder in place at both the nation and provincial levels. Sri Lanka has the added advantage of having a training programme in-built to Ministry of Health for medical officers for health informatics. Further to this, Sri Lanka is

equipped with an eGovernment Policy[1] and a draft version of eHealth Policy and eHealth Standards and Guidelines. Department of Health Services dominates the health sector governance process. In this centralized governance there is little flexibility provided for external stakeholders such as funding agencies. There are many miniature scale health information systems being implemented in the local scope without proper plans for interoperability or integration. 'My Baby Syndrome' (Littlejohns, Wyatt, & Garvican, 2003) is a frequent observation resulting in neglected systems failing after the initiator has been subjected to mandatory periodic transfer to another health institution.

The electronic medical record system, HHIMS is the open source descendant of the electronic patient information system, Multi-Disease Surveillance project which was implemented in 27 state owned hospitals in the Eastern province of Sri Lanka (Pole, 2010) during 2006 – 2009 period. The system was developed to capture and process admission data and to generate health statistics and administrative reports. Based on the Multi-Disease Surveillance system's design, in 2011, HHIMS codes were officially released as HHIMS version 1. In 2012, HHIMS version 1.2 was released under the open source license *Affero General Public License*[2] and in 2013 a feature rich HHIMS version 2 was released under the same open source license.

The District Health Information System version 2.0 (DHIS 2) is a flexibly customizable, open-source health management information system developed by the Health Information Systems Program of the University of Oslo, Norway. The software development process is a global collaboration (Staring, & Titlestad, 2006). DHIS2 was first introduced to Sri Lanka as a public health information tool in the curriculum of master's degree program in Health Informatics conducted by the Postgraduate Institute of Medicine.

4.1. *Hospital Health Information Management System* implementation network

With the initial success of the Multi-Disease Surveillance system in the Eastern province of Sri Lanka, the project brought the system to the attention of Ministry of Health suggesting it to be expanded to the rest of the island. Ministry of Health reviewed the system and did not agree with the licensing of the Multi-Disease Surveillance system, which was free to be implemented only in the *2004 Asian tsunami* affected areas of the country (not free and open source). A request for the Multi-Disease Surveillance system to be implemented in another hospital in Sabaragamuwa Province was the turning point of the project. The Regional Director of Health Services invited Multi-Disease Surveillance team to develop an open source patient record software, and to implement it in 5 pilot sites in the province. With this request, it was decided to convert the Multi-Disease Surveillance system to an open source system and the local maintenance team was organized as the open source developer team. The new hospital information management system was developed under open source license and baptised as the Hospital Health Information Management System. Funding for the project was provided by the Information and Communication Technology Agency; the single apex body involved in Information and Communication Technology policy and direction for the nation. With the support of the Provincial Department of Health Services the system was successfully implemented in 5 hospitals within the district.

Then there were requests to the Information and Communication Technology Agency and HHIMS core-team to implement the system in 3 more districts. There was a review meeting for the HHIMS implementation, which was conducted by the Ministry of Health. The Information and Communication Technology Agency was authorized to proceed with the piloting of the system in the 5 hospitals. While being implemented in more than 10 hospitals in different districts, the application reached its next turning point of being implemented in the district hospital Dompe, which was contributing to various innovations in the system design and architecture. In the later

1 http://www.icta.lk/en/programmes/re-engineering-government/129-policy-documents/1344-e-government-policy.html

2 http://opensource.org/licenses/AGPL-3.0

part of 2013, the system was selected to be implemented in several hospitals in the Northern part of the island. Also, it was noted that the flagship implementation site, the district hospital Dompe was achieving extraordinary success (Kulathilaka, 2013), and as a result it was made the reference implementation reflecting the standards of the new version of HHIMS. Currently the discussion is going on for the suitable governance model for HHIMS foundation. The main issues to be settled in deciding the governance model includes the composition of the governing body (representation of health sector, IT-sector and other stakeholders), which stakeholder should own and manage the code repository (e.g. Information and Communication Technology Agency or Ministry of Health), the mechanism to regulate prospective HHIMS implementers and managing the feature and architecture under a national roadmap.

4.2. *District Health Information System 2* for Maternal and Child Health

Initially the DHIS2 was customized as a student project of the Postgraduate Institute of Medicine to address information need of the maternal and child health programs in the country under the supervision of a senior consultant of public health. After adequate customization, the system was demonstrated to the health managers and public health consultants of the health programme. Postgraduate Institute of Medicine also mediated to seek permission pilot the application in real life settings, but during the demonstration, trustworthiness of the customized DHIS2 application and data security was heavily questioned and approval was not granted to the proposed pilot project. After the initial failure, in 2011, Health Informatics Society, which is the professional association responsible for popularizing health informatics in Sri Lanka negotiated permission for this pilot in the North Western Province of Sri Lanka. For this purpose, the previously customized application instance was used. To support the implementation, it was decided to sign a tripartite agreement between Health Informatics Society, Provincial Department of Health Services of North Western Province and Health Information Systems Project - India who were to provide technical support. Unfortunately, the signing did not materialize. However, North Western Province permitted Health Informatics Society to conduct a pilot exercise under their supervision before taking a decision on the province wide implementation. The five Medical Officer of Health areas (equivalent to health districts defined by World Health Organization), were selected. Initial training was provided to the staff of the 5 Medical Officer of Health areas and data entry was commenced with a central server provided by the Postgraduate Institute of Medicine. The financial support for the piloting was provided by the Postgraduate Institute of Medicine, Health Informatics Society and University of Oslo. Apart from the local training programs, province staff were offered an international training program collaboratively conducted by Health Information Systems Project - India and University of Oslo. Data entry was done by Public Health Midwives under the supervision of Medical Officer of Health. After the system was piloted for 2 reporting quarters, a project evaluation report was handed over to the Department of Health, North Western province to scale the system to 5 more Medical Officer of Health areas. When the piloting was commenced for the 3rd quarter data entry, the central health programme abruptly halted the piloting process with the concern of the DHIS2 application would negatively interfere with the business process of the health programme.

After about a year's break it was suggested to pilot the maternal and child health customization of DHIS2 in the Southern Province. Postgraduate Institute of Medicine assisted the implementation and the project was entrusted to a Medical Officer trained in health informatics at the Southern Provincial health department. The mediation with central health programme was done through a Medical Officer-Maternal and Child Health attached to the provincial health director's office. Necessary basic hardware was also provided to the all Medical Officer of Health offices of the Galle district and the system was piloted in 17 Medical Officer of Health areas with slight modifications to the previous design. The system was well accepted by the staff and is awaiting scale up as a provincial data repository.

4.3. *District Health Information System 2* for TB and respiratory diseases

After initial rejection of DHIS2 as a candidate for maternal and child health management, it was considered to introduce DHIS2 to the respiratory diseases control domain customized for Tuberculosis and other chest disease registry management. National Tuberculosis Programme decided to use DHIS2 for Tuberculosis case management first. At the end of 2012, the customization process was started as an internal requirement of the National Tuberculosis Programme and commissioned by the top hierarchy of the programme management. The programme managers noted that the DHIS2 needed to be modified to a certain extent to accommodate all their requirements. Health Information Systems Project - India conducted an end user and implementer training in May 2013. At a later stage, National Tuberculosis Programme decided to use DHIS2 for Asthma case management as well. Since January 2014 Postgraduate Institute of Medicine provided support for the customization process. In July 2014 there was an evaluation of the customized solution to identify its suitability for island-wide scaling. Following the evaluation a new funding opportunity emerged through a global donor for the scale-up process.

5. CASE DISCUSSION

Open innovation and open source implementation appear to be possible for a health institution/programme to embark on since the software source code is freely available. Often initial steps towards implementation might be assisted by the open source community to a limited extent. Compared to the custom software development however, it appears that the health organization must own equal or more technical competency and resources to implement an enterprise-wide open source software solution if it is to be completed by the health stakeholder itself.

In HHIMS project the network organization consisted of Ministry of Health, regional and provincial health authorities, hospital authorities, Information and Communication Technology Agency and HHIMS core team and HHIMS implementation team. The HHIMS implementation team was an extension of HHIMS core team. Information and Communication Technology Agency was mainly plaid the role of project and fund management. The main funding agency, the World Bank didn't have any direct role in the project and channelled the financial aids through Information and Communication Technology Agency. Information and Communication Technology Agency and provincial and institutional health authorities had a good mutual understanding in implementations. Hence at this level the project coordination ranged from informal-interpersonal to formal-interpersonal. However the dominant actor, the Ministry of Health has more scrutinizing attitude towards the customizations and implementations. With implementations spread to several hospitals governance mechanism has grown to a formal-impersonal level. This peaked with the suggestion for the HHIMS foundation, where HHIMS source code, architecture and implementations suggested being managed by an independent body in the formal manner. In the initial phase of HHIMS the project demonstrated clan control features including personal visits, meetings and email and telephone conversations. The behavioural control mechanism, such as project status review meetings, conference calls and on-site coordination, appeared when the project grows to new implementation sites. Toward the maturity of the project where HHIMS version 2 was released, project demonstrated strong output control efforts such as change control mechanisms (mediated by health managers form the institutions where HHIMS implemented), problem queries (handled by HHIMS team), follow-ups and client involvement plans, periodic reviews and interim deliverables (included in formal contrast through the tender procedures).

From the initial phase of HHIMS implementations, it was noted that the Ministry of Health was attempting the governance of open source acquisition. Following are some of frequent debates quoted from project implementation meetings.

"Does Hospital Health Information Management System has an open source license and if so, what is the type of license ? "

"Does Hospital Health Information Management System have license to use SNOMED[3] [a medical nomenclature/terminology] within the Hospital Health Information Management System software?"

"Is the database management system used by Hospital Health Information Management System, free and open source? If it is only free for personal use, do hospitals have to pay an additional fee to use it with Hospital Health Information Management System?"

This open source governance, even though which is not comprehensive, has a remarkable effect on open innovation process so that HHIMS developers has to limit their innovation to open standards. Tender procedures also demonstrated a certain influence over the open innovation process. Initially the tender procedure was based on a high level (abstract) requirements where there is more room for innovative approaches. Towards the later part of the study, tendering was more comprehensive and consist of a detailed technical documents. Tender documents included minimum required functionalities expected from the customization with the comprehensive software requirement specification and use-cases. It was noted minor disagreements during the open innovation process between the health managers who contribute to the design and the implementation mediators who delivered the new software artefact. The conflicts were noted more on graphical interface design and modelling clinical care process in health information system functionalities. The health care organization looked at the issues in patient confidentiality and quality of care context whereas developers and implementers frequently had more technological perspective. HHIMS design and architecture was favourable for open innovation approach allowing external knowledge to be merged to software core and to transferring the innovation to new and existing implementations which can be seen as technology spin-offs (Chesbrough, 2006) for new markets.

In DHIS2 customization for maternal and child health, the network organization consisted of Ministry of Health, Family Health Bureau, regional and provincial health authorities of North-Western and Southern provinces, Health Informatics Society, Postgraduate Institute of Medicine and Health Information Systems Project - India. The Family Health Bureau was the dominant stakeholder during these implementations. Initial phases of the North-Western provincial pilot project ran with the informal-interpersonal coordination which was later became a formal-interpersonal coordination. During the Southern province implementation the formal-impersonal was the coordination mechanism of choice. At North-Western Province the project demonstrated clan control with minimal output control. However, in Southern province implementation the project utilized behavioural control mechanism, such as project status review meetings and on-site coordination in combination with output control mechanisms, such as client involvements in planning and periodic reviews. In the Southern Province, provincial health authorities played a major role in governing the implementation providing administrative leadership and liaise with the Family Health Bureau.

DHIS2 customization for Tuberculosis and other respiratory diseases management was carried out under the governance of National Tuberculosis Programme. Other members of the network organization were, Postgraduate Institute of Medicine, Health Information Systems Project - India, core DHIS2 developer team and Health Informatics Society. The coordination mechanism of the project was formal-impersonal and the control mechanism was noted to be formal with behavioural and output control measures, such as status review meetings, conference calls, on-site coordination, problem queries, change control, follow-ups, client involvement plans, interim deliverables and periodic reviews.

3 http://www.nlm.nih.gov/research/umls/Snomed/snomed_main.html

In DHIS2 implementations, externally developed and managed (requirement generification and version control) software core based on advanced technology was a barrier to open innovation adoption until recent. This disadvantage was more prominent under the frequent release cycles of DHIS2 adding new features to the code base with each release. This was remedied by the concept of DHIS2 Apps which itself is an adoption of open innovation by the core DHIS2 developer team by incorporating the Mozilla Open Web Apps[4] to DHIS2 architecture. This feature allowed country implementation mediators to extend DHIS2 functionalities by developing specific installable App (lightweight module) to address the necessary user requirements. Further more, it functions as an open innovation spin-off to the global DHIS2 community, if the newly developed functionality can be matched with the domain requirements of another health programme (new markets). With the decision to implement District Health Information System for respiratory disease control programme, open innovation adoption was prominent than the DHIS2 customization for maternal and child health. The programme managers of the National Tuberculosis Programme were more realistic about the gap between the capabilities of current District Health Information System releases and software features required by the National Tuberculosis Programme. Towards the later part of the customization, this understanding was very yielding so that the National Tuberculosis Programme understood that it can be benefited by developing a DHIS2 App for the Tuberculosis and other respiratory disease management.

Governance Feature	HHIMS project	DHIS2 projects
Coordination	Formal, impersonal	Formal, impersonal in successful open innovation process
Control	Initially clan control, later developed to strong behavioral and output control	Behavioral and output control in successful implementation projects
Open Source Governance issues (Kemp, 2010)	Licensing, hidden-cost, open standards	Licensing, unauthorized access to data by implementers/developers, control to data (e.g. cloud hosting), source reliability, tracking (hidden functions, information about other implementations and stakeholders), support (focal point for technical assistance), design-reality mismatch and capabilities (limitations) of the current release
Operational Model	Profit-oriented operational model	Research and academic focus with not-for-profit operational model

Table 2. Comparison of governance features of the considered health information system implementation projects

When considering the coordination mechanisms, formal control was observed from the beginning of the HHIMS project (e.g. project management plans). Informal and interpersonal coordination was observed in North Western province implementation of DHS2 (e.g. meetings) whereas more successful DHIS2 implementations (Southern province and Tuberculosis control programme) adhered to the formal and impersonal coordination mechanisms (e.g. periodic reports). Similar observations were made with regards to control mechanisms as well. The successful projects were embarked on behavioral and output control mechanisms, such as, confirmatory follow-ups, client involvement plans. The less successful approach of North Western province project demonstrated clan control with personal visits and communications such as email and phone calls to govern the project.

During the study it was evident that the open source governance is not a familiar concept among health managers and administrators. However, as summarised in Table 2, open source license,

4 https://developer.mozilla.org/en/Apps/Quickstart/Build/Intro_to_open_web_apps

hidden cost, ownership of source code, data security and hidden privileged system access by developers/implementers were some concerns unfavourable for the practices of open innovation (Paré, Wybo & Dellanoy, 2004). Following is an example of such concern noted during the study.

"...How can we trust whether District Health Information System implementers use data entrusted to them for other purposes..."

It was noted that most multi-sector stakeholders were legally independent of each other, even though they were in mutual agreements to cooperate in realizing long-term goal of successful health information system implementation. During the early phases of implementation attempts the mode of control commonly seen in the network organization is the clan control. Later this governance mechanism could consolidate to behavioural and output control. What brings the multi-sector organizations together to form an network organization was their specializations in different disciplines and allocation of technical and financial assets to health information system projects. The interactions seemed to initiate with interpersonal coordination which later formalized to impersonal coordination. Medico-legal concerns were also discouraging open innovation process (e.g. possible harm inflicted to patients due to the inadvertent use of the open source health information systems) unless proper legal clauses were not included in contracts.

6. CONCLUSION

Summarizing the above discussion it is possible to conclude that the multi-sectoral participation is to play an essential role in open source health information system implementations in Sri Lankan context. For an open innovation process to be successful, it is recommended to establish a formal and impersonal coordination mechanism at an early stage to facilitate the institutionalization of the health information system avoiding personal dependencies. This is evident since the early phase of the HHIMS project and in the more successful implementations of DHIS2, namely the Southern province maternal and child health system and Tuberculosis and respiratory diseases management system. Interpersonal as well as impersonal mechanisms of coordination were effective under the formal control compared to informal and interpersonal coordination mechanisms. Within the formal coordination mechanisms, impersonal coordination yielded more stable open innovation process compared to formal interpersonal coordination. This was evident by adopting HHIMS as an open innovation artefact by other healthcare institutions more readily, compared to DHIS2 customized to maternal and child health was considered to be scaled up to the national level.

Similar observation was made on behavioural and output control (e.g. on-site coordination, project management plans, periodic communication) leading to successful open innovation compared to self control or clan control mechanisms. Output control mechanisms, such as interim deliverables would be valuable in open innovation process which allows health stakeholders to evaluate the software artefacts incrementally. To promote open innovation among open source mediators, the open source information system architecture should provide a process to (generalize and) re-use spin-offs in new markets. Interestingly, open innovation process was appreciated and facilitated by lower level health administrators and managers, where are the implementation project governance decisions were made by the top level health administrators and managers mostly.

Due to the technical limitations and uniqueness of business process (clinical care pathway) open innovation appear to be less desirable in Sri Lankan state health sector. However, in combination with open source methodologies, the open innovation demonstrated competitive technological and financial advantages to the health programme. Technology spin-offs those are resulted from open innovation process could be valuable software artefacts to open source implementation mediator, even though these spin-offs may not be relevant (sometimes, could be discouraging) from a health programme management/administration point of view. Pre and post implementation support were identified as a major barrier to adopt open innovation in open source implementation projects in Sri Lankan state health sector. Similarly, hidden cost models and unauthorized access of health

information by external open source implementers and developers were considered seriously in arriving at implementation decisions by health managers and administrators.

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III

USING TRAINING AS A TOOL FOR CULTIVATING COMMUNITIES OF PRACTICE AROUND HEALTH INFORMATION SYSTEMS IN LOW AND MIDDLE INCOME COUNTRIES: A LONGITUDINAL MIXED METHOD STUDY

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ABSTRACT
Many attempts at implementing health information systems (HISs) in Low and Middle Income Countries (LMICs) have failed to mature or scale into desirable levels due to various reasons. Among these reasons, not identifying the design reality gap, inability to form support networks and non-availability of 'hybrids' who can link between health and information systems domains can be highlighted. In organizational contexts, such challenges can be overcome by cultivating communities of practice (CoPs). However, HIS projects in LMIC contexts may not have the opportunity to create an environment similar to an organization to facilitate cultivation of CoPs. This paper argues that HIS projects in LMICs can utilize formal, informal and workplace based online and face-to-face training methods along with the networking power of free and open source software (FOSS) communities as a means of cultivating CoPs. In substantiating this argument, the paper utilizes a mixed method longitudinal study design to follow-up a group of implementers trained in a FOSS HIS in Sri Lanka. The paper presents a practical training model usable in information system implementations in LMIC settings with the added benefit of being able to facilitate cultivation of CoPs. The paper also contributes theoretically by extending the conceptualization of 'cultivating CoPs' beyond organizational contexts.

KEYWORDS: Health Information Systems, online learning, workplace based learning, formal learning, informal learning, low and middle income countries, social network analysis, cultivating communities of practice, free and open source software,

1. INTRODUCTION

In Low and Middle Income Countries (LMICs), electronic health information systems (HISs) have been recognized as a key facilitator of better and equitable health care (Nolen et al., 2005; Warren et al., 2013). However, not many HIS implementations move beyond pilots in these countries due to different reasons even when infrastructure, technology and funding remain adequate. These reasons may include the inability to create support networks (Braa, 2004), failure to address the design-reality gap (Heeks, 2006), absence of 'hybrids' that can bridge between health and information system domains (Heeks, 2006) and the implementers insensitivity towards socio-political, socio-cultural and socio-technical factors within LMIC settings (Avgerou, 2008). When free and open source (FOSS) HIS solutions become much sought-after in LMIC settings, the need to address these issues become even more important as these systems need contextualization to facilitate local care pathways (Pollock et al., 2003).

Within organizations, when one wants to deal with imparting knowledge and skills, create support networks, effect innovation, bridge between various knowledge domains and cater to contextual elements, one approach is to make use of or create communities of practice (CoP) (Bate and Robert, 2002; Wenger et al., 2002). A community of practice (CoP) is a group of people who share a concern or passion for something they do, and learn how to

do it better as they interact regularly (Wenger, 1999). These groups are characterized by a shared domain of interest, a sense of community and a shared practice (Wenger, 1999). Generally, these three characteristics would benefit both the members of the CoP and the organization within which the CoP emerged.

In terms of HISs in LMIC contexts, it is known that no two settings would be the same when it comes to HIS implementation, scaling and maintenance (Braa et al., 2004; Nhampossa, 2005). Further, multiple vertical programs utilizing their own HISs would complicate the HIS landscape in LMICs and would hinder the dissemination of useful HIS related knowledge across different programs and institutions (Braa and Hedberg, 2002; Stansfield et al., 2008; Kossi et al., 2008). As health needs, economies and policies evolve over time, the authors experience is that HISs in LMICs need to adopt under fragile socio-political and socio-technical infrastructure. In a complex HIS landscape, such adaptations would require sharing of knowledge between different groups managing similar HISs, within countries, regions or even around the globe. Given that the idea of CoP is centred around sharing of knowledge related to a common interest and a shared practice, its existence or its creation for that matter, would make HIS instances in LMICs tolerate the many challenges thrown at it from time to time.

However, as the emergence of a CoP is usually a natural, spontaneous, and a self-directed process, attempts at forming CoPs artificially would often fail (Wenger, 1999). Nevertheless, Wenger et al. (2002) believe that CoPs could instead be cultivated and one of the keystones in this process is to facilitate and manage participation (Handley et al. 2006). From the point of view of HIS implementers in LMIC settings however, there aren't many opportunities or time available to impart participation and collaboration building amongst HIS staff, between HIS staff and other stakeholders, and between HIS staff and the global/regional expert community. In such a scenario, training may be one opportunity, which will provide the HIS implementers the chance to facilitate the desired participation amongst their target groups.

This paper argues that by facilitating participation and relationship building, HIS training can be used as a tool for the cultivation of CoPs among higher level HIS staff in LMIC settings. However, in creating a conducive environment for participation and relationship building, the paper sees the need to link formal and informal online, face-to-face and workplace based learning and embed FOSS communities within the training process. In substantiating its argument, the paper brings to the forefront empirical evidence from a multi-modal FOSS HIS training initiative aimed at a group of medical professionals in Sri Lanka. Based on its analysis, the paper contributes practically by enumerating a training model for HIS implementations in LMIC contexts, which could also be useful generally in IS implementations that are large scale, dispersed and are dependent on scarce resources. From a theoretical point of view, the paper contributes by extending the concept of cultivating CoPs beyond organizational boundaries using training as its facilitator.

This paper is also a follow-up to Siribaddana (2014) which demonstrated the usability of a combined Social Network Analysis (SNA) and a content analysis perspective in assessing participation and network building during online learning instances. Thus, this paper also expects to extend the usability of these tools in assessing the participation and collaboration building among learners taking part in a longitudinally arranged online, face-to-face and workplace based training program around HISs.

2. AIM

The aim of this paper is to 'link different learning strategies (formal, informal and workplace based learning) via a blended approach (online and face-to-face) in facilitating the cultivation of CoPs among higher level HIS staff in LMIC contexts'.

3. STRUCTURE OF THE PAPER

This paper will next present relevant research pertaining to HIS training in LMIC settings, use of distance online learning in HIS training, different aspects of learning (formal, informal and work-based learning), cultivating CoPs and community building around FOSS. Following presenting the relevant research, the paper will describe its methodology and the research design. This will then be followed by a phase wise description of the emerging themes and findings which will lead to a discussion about how the emerging themes narrate the story 'from online learning to communities of practice'. In the conclusion and recommendations section, the paper will propose a model that can be used by HIS implementers and trainers in cultivating CoPs around HISs and its theoretical contribution of extending cultivating CoP theory beyond organizational context.

4. RELEVANT RESEARCH

Following the free and open source movement, many organizations took the initiative to design, develop and distribute open source software pertaining to different technical domains. Health is one such domain where open source applications have made a mark (Weber, 2004; Delp et al., 2007; McDonald et al., 2003). This is more prominent in the developing contexts where financial and technical constraints impede the design, development, implementation and scaling of HISs (Mutale et al., 2013). However, with FOSS HISs, there need to be enough local capacity to meet the challenge of contextualizing the software, the training given and its utility, which can otherwise widen the design-reality gap as described by Heeks (2006). In order to minimize the said design reality gap, it is necessary to streamline the HIS functionalities with the business needs of health programmes (Hewapathirana and Rodrigo, 2013). One solution is to create 'hybrids' (Heeks, 2006) who are able to understand both the technical and the business ends of the FOSS HIS. However, creating hybrids per se would not allow harnessing the benefits afforded by FOSS, which is to harness the enormous amount of knowledge accumulated within FOSS communities, in terms of software development, customization and technology translation (Nhampossa, 2005).

4.1 HIS Training in LMICs

When it comes to HIS training in LMICs, different levels of users would require different types of training (Braa et al., 2007). For example, Braa et al. (2004) suggest those who are at district or provincial levels should be able to use HISs innovatively and thereby would benefit from a masters level training, preferably in health informatics. At the same time, Health Matrix Network (HMN) indicated that in addition to training, implementers of HISs should also look into remuneration and career development of the trained staff (Whittaker, Mares and Rodney, 2013). The issue of inadequate training pops up in most literature discussing HIS implementations in LMICs with some arguing that lack of skilled personnel have been a limiting factor in migrating from legacy systems to modern HISs (Mengiste, 2010).

While HIS training in LMIC settings haven't exactly focused its attention on initiating CoPs, health sector as a whole has seen such attempts centred around disseminating evidence based practices and promoting healthcare innovations (Li et al., 2009, Mold and Peterson, 2005). Experiences from these attempts have indicated that when it comes to gathering common purpose, healthcare professionals tend to rely on long training histories and institutional affiliations (Amin and Roberts, 2008). Interestingly enough, significant proportion of high-end HIS users and implementers in LMICs are also health care professionals (Heeks, 2006) who are assigned with the task of managing HISs.

4.2 Using Online Learning in HIS Training

The use of online learning for training HIS users and implementers is not common. However, Siribaddana (2014) suggests that online leaning is in-fact a plausible training tool in LMIC settings, particularly in conducting short-training programs aimed at generating participation and knowledge creation. However, online learning or e-learning on its own may not cater to the learning needs in such settings. Thus, as pointed out by Siribaddana et al. (2015), trainers of HISs may have to consider a blended approach, which is defined as a combination of online and face-to-face training. In fact, Garrison (2011) points out that most of the e-learning initiatives are in fact 'blended learning' initiatives, which fall within a continuum between fully online and face-to-face learning.

When it comes to applying online learning technologies in LMIC settings, it is understood that there can be many factors, which can limit its full implementation. For instance, LMIC settings may not have the necessary infrastructure (e.g. internet access, broadband access, computers for its users...etc) to facilitate online learning at a large scale and learners targeted for such training may not possess the necessary skills to use such a technology for learning. However, given that similar challenges are encountered and remedied when implementing electronic HISs in LMICs, implementing online learning technologies accessible to its target audience would not be an impossible task. Further, as argued through this paper, training of higher level users and implementers from LMIC settings would hardly give rise to an issue of lack of skills and accessibility as almost all of them would be having the desirable skills and resources to be trained and interact online.

4.3 Formal, Informal and Work-Based Learning

In modern day education, the importance of shifting away from the traditional classroom learning has been emphasized both at higher education and in work-based training (Leadbeater, 2000). The classroom based learning or the learning that depends on clearly defined curriculums, aims and objectives, timetables, teaching and examinations, is known as 'formal learning' (Colardyn & Bjornavold, 2004). In contrast, 'informal learning' or 'work-based learning' is perceived to be having haphazard, opportunistic and non-rigorous processes and structures of learning (Swanwick, 2011). However, in recent times, a middle path known as non-formal learning has been identified as a learning modality with its own pedagogy and process (Eraut, 2000; Werquin, 2007). For instance, in medical education, it has been recognized that medical students who undertake longer and more engaging clerkships in ward settings would gather a more holistic appreciation of ill health, patient centeredness and an enhanced professionalism when compared to students who are undertaking short clinical rotations (Holmboe et al., 2011). This however does not mean that traditional curriculum or classroom teaching can be replaced through full time informal or work-based training. The reason being that from an industrial relations perspective, work-based learning would not necessarily be under the control of the learner but instead it would be driven mainly by the needs of the workplace (Evans et al., 2010).

While informal learning is increasingly becoming an essential part of professional training in most fields of study, the task of integrating informal learning in formal learning programs remains a challenge (Svensson et al., 2004). In fact, opportunistic or reactive learning taking place in the workplace may usually remain tacit, disconnected with other knowledge and embedded to the context in which the learning took place (Rice and McKendree, 2014). This would mean that recalling such knowledge, sharing, and applying it in different contexts may become practically impossible. Application of learning technologies in the form of online learning to form online communities could potentially prevent such a scenario as it can allow learners the opportunity to reflect and share what they have learned, and thereby generalize the learning to build the necessary cognitive schema (Derry, 1996).

4.4 Cultivating Communities of Practice

While acknowledging the difficulty in designing a human institution such as a CoP, as pointed out earlier, Wenger et al. (2002) argue the possibility of organizations to cultivate CoPs by adhering to certain principles. One of these principles is to 'design for evolution', which indicates that CoPs will evolve when certain catalysts are in the right place at the right time. 'Open dialogue between inside and outside perspective' is another principle. Thus, as argued by Wenger et al. (2002), while insider perspective will guide members towards generating an understanding about the community and their own selves, the outsider perspective will enable the community to realize its full potential. Facilitating different levels of participation is another principle. In that, Wenger et al. (2002) recognize three main groups of participants, the active core group, the active auxiliary members, and the members who remain in the periphery. In addition, there also exists another group of participants who are not necessarily part of the CoP but is interested in the activities of the CoP. It is the dynamic interaction between these groups that facilitates the evolution of a community and its knowledge creation. In addition to these principles, cultivation of CoPs also entails paying attention to principles of public and private community spaces, a focus on value, combining familiarity and excitement as well as on creating rhythm for the community (Wenger et al., 2002).

4.5 Community Building and Learning around FOSS

The emergence of FOSS has radicalized learning in a way, which emphasizes the importance of participation even more. For instance, Whitehurst (2009, p.70) states that "*Open source amplifies a 'hands-on' approach to learning by connecting students to a community of users in an effort to solve problems*." According to Morelli et al. (2009), it [FOSS] promotes ethics of sharing and collaboration in the educational process. Thus, FOSS allows students to engage in real world tasks and in an active process of learning. In the eyes of Sowe and Stamelos (2007), this meant that FOSS functioned as a model for creating self-learning and self-organizing communities, which closely resembles CoPs.

When considering FOSS networks or electronic networks of practice (Wasko and Faraj, 2005) for that matter, contributions made by the members of its discussion forums have been recognized as the key reason for its success. The contributors to these networks do so not because of monetary gains, but because of the professional recognition that they receive, the experience that they have to share and because they are embedded within the given network (Wasko and Faraj, 2005). Even in relation to online learning, the current discourse is mainly focused on collaboration building and creating a more interactive learning environment (Palloff and Pratt, 2007), which allow students to self-reflect. Mezirow (1990) recognizes learning activities that facilitate interaction and collaboration building as 'transformative learning' and states that such learning enables the students to shed constraints of limited perspectives towards real world problems. However, Cranton (2006) emphasizes that unless the learning environment provides students with the necessary material and opportunities for dialogue, it would not be possible to achieve critical reflection on both the material and on one's own self.

5. METHODOLOGY

This study was part of an ongoing action research initiative around HIS training in LMIC settings and is a follow-up of a previous study on evaluating the participation, interaction and collaboration building in relation to short-term online training programs around HISs using SNA and content analysis. Thus, this research can be described as a longitudinal study as it analyzed several instances of online, face-to-face and workplace based training over a period of one year. The study can also be described as a mixed method study (Greene et al., 1989,

Creswell, 2013), given that it used SNA, which is predominantly a quantitative method, and structured content analysis, which is a qualitative method of analysis.

Apart from being motivated by their previous study, authors of this paper were also motivated in using SNA because it has been utilized in identifying and evaluating CoPs in various circumstances including in healthcare (Ranmuthugala et al., 2011), education (Cocciolo et al., 2007) and in business organizations (Cross et al., 2002). The selection is also augmented by the argument every CoP is a collection of one or more social networks (Schenkel et al., 2001). Further, when compared with other non-network methodologies, the SNA differs as it focuses on relational information rather than attributes of individuals within a given sample (Scott, 2000). Such relational information can be used to make inferences related to social networks and communities, particularly in relation to the evolutionary process of a CoP (Scott, 2012; Assimakopoulos and Yan, 2005; Wasserman, 1994). However, the study perceived that SNA alone cannot provide enough insights to the quality of the formed links within an emerging social network (Mayer, 2004). Therefore, the study also adopted a qualitative strategy when collecting and analyzing its data.

5.1 Empirical Setting

The empirical setting for the study was a HIS training program carried out by the health information systems program (HISP) network (a network of independent organizations formed around the development, implementation and research of the open source health information system, DHIS2). It was aimed at a group of medical professionals following a master's program in health informatics at the University of Colombo, Sri Lanka. These students were selected from amongst medical doctors working within the Ministry of Health in Sri Lanka and were expected to take up lead roles in HIS implementations and its management. As part of their training, these students had to undertake a health information project for their master's thesis. Therefore, during their second year, they were introduced to DHIS2[1] as a potential HIS that is usable for their masters project. The focus for this study was the online and face-to-face DHIS2 training provided to these students, subsequent uptake of their projects and work placements following completion of their training. The study was conducted in phases over a 12 – 14 month period and a batch of eleven students were followed-up from training to their work practices.

Phase I – Online and face-to-face training in DHIS2, conducted in collaboration with HISP, India (December 2013 and January, 2014).

In Phase I, the students were first exposed to a one-week online training program in DHIS2, which was designed as an introductory program before they are exposed to DHIS2 face-to-face training in India. The online training was the first instance where the students were exposed to DHIS2. During the online training, students were asked to participate in a discussion forum moderated by several DHIS2 experts from Sri Lanka and India. The discussion forum consisted of fixed discussion threads relevant to the online learning. The participants were not allowed to post their own threads but were asked to discuss their questions within the relevant thread. Following the week long online training, the students participated in a face-to-face training at HISP, India for another one week. While some of the topics covered in online learning were reiterated during the face-to-face workshop, the focus was to have hands-on training and for the students to obtain one to one support from experts

[1] The DHIS 2 is a tool for collection, validation, analysis, and presentation of aggregate statistical data, tailored to integrated health information management activities. DHIS 2 is developed by the Health Information Systems Programme (HISP).

from HISP, India. The students were also exposed to used cases from India where DHIS2 implementations have been on-going for several years.

Phase II – Online DHIS2 training conducted in-line with the East African DHIS2 academy conducted by the HISP, Oslo (May 2014)

In the second phase, the training was fully online and it coincided with the two-week online DHIS2 academy conducted for the East African region. The students were asked to follow the online content, which was designed for advance DHIS2 users. The students were also invited to participate in the online discussions along with their East African counterparts and the global team of moderators consisting of DHIS2 experts from Norway, East African region, and from Sri Lanka. The focus was for the Sri Lankan students to build networks with the global team and to learn from the experiences of their East African colleagues who already have experience in implementing DHIS2 in different countries. The second phase of training did not have a follow-up face-to-face session.

Phase III – DHIS2 projects and activity within DHIS2 mailing list (May – October 2014)

The third phase of training lasted for 4 to 6 months and there wasn't any formal training programs during this period. It consisted of students undertaking DHIS2 based projects in one of the health care institutions in Sri Lanka. The students had direct communication with local DHIS2 experts in relation to certain aspects of DHIS2 customizations. However, they were introduced to the DHIS2 mailing list (launchpad) and were encouraged to communicate via email with Oslo based DHIS2 experts who are also part of the ongoing Sri Lankan projects.

Phase IV – Evaluation of work practices (January/February 2015)

Following completion of their masters program, the students were assigned to various health care institutions by the Sri Lankan government and during the phase IV of the study, their work practices were evaluated in relation to continued networking with the local and global DHIS2 community and how the training impacted their work practices.

5.2 Data Collection

In phase I and II, one source of data for the study was the discussion forum within the online learning platform. The posts (n=160) made within the discussion forum each indicated a connection between two persons. Thus, each and every connection made was considered for the SNA. In all phases, email communications (n=44) were also used to assess the connections made by the students during the study period. Similarly, the posts made in the DHIS2 launchpad (n=32) were also utilized for SNA in phase III and IV. In certain instances, connections made by students were also uncovered during the interviews (n=10). These connections were also included in the SNA. The content of discussion forum postings, the emails and the posts made in the launchpad were used to assess its implication towards learning, networking and to assess evidence towards evolution of CoPs in all stages whenever these were available. All the students were interviewed after 1 month following their appointments to new work settings. The interviews were recorded and later transcribed in preparation for the analysis. In addition, field notes related to observed group dynamics among the students were also used as data for the analysis. These observations were made during face-to-face lab sessions and classroom sessions at different points in the training program.

5.3 Data Analysis

Using the discussion forum posts, email communications, interviews and email list posts it was possible to enumerate the connections formed between participants of each study phase. Using the enumerated connections, asymmetrical adjacency matrixes (Scott, 2012) were

created for phase I, II and III. These matrixes were then analyzed and visualized using the Open Source SNA tool SocNetV (Kalamaras, 2010). During the analysis, several measures were used to interpret the SNA findings.

Network Density: This refers to the number of connections made by the actors (students in this case) of a network out of all connections possible between the same actors (Scott, 2012). Network density is expressed as a proportion in this paper and therefore a network that achieves its maximum number of connections would gain a network density of '1'.

Degree Centrality (DC): DC measures the activity of an actor and in this case, it is based on the total number of messages sent by a particular actor (OutDegree). In general, actors with a high OutDegree are considered 'influential' actors within the network, which means that they are able to communicate with more actors and make other actors aware of their views. From the point of view of this study, an actor demonstrating a higher DC can be interpreted as 'more active' than others within the network. Similarly, InDegree refers to the total number of incoming connections to a particular node. It usually indicates the degree of 'prestige' of a given actor within the network and many actors would prefer to have connections with such important actors.

Clustering Coefficient (CO): CO is a measure of the degree to which nodes in the network tend to cluster together (Scott, 2012). In other words, CO of a particular actor in a network indicates how well its neighbouring actors are connected to each other. CO is also expressed as a proportion and therefore it will range from 0 to 1 with 1 indicating neighbours of one actor having achieved all possible connections among each other.

Furthermore, to graphically present these connections, Sociograms (Scott, 2012) were used, which were based on the DC of each actor. Authors believe that these diagrams would help readers understand the formation of networks and central role played by certain nodes within the network.

In analyzing the data qualitatively, the research adopted the eight step structured content analysis procedure as explained by Tesch (1990). Thus, the data were first looked at for its general meaning before being coded (Tesch, 1990). Coded data were then analyzed further in order to identify the overarching themes emerging at each phase of the study. The SNA findings and the qualitative analysis findings were triangulated in order to justify the emerging themes whenever possible. This enabled the study to establish qualitative validity (Golafshani, 2003) of the study findings. Two researchers were involved in coding and analysis of the data before comparing the identified themes for any deviations. Common themes were selected and agreed upon before proceeding with the analysis. Such an approach was expected to improve the qualitative reliability (Golafshani, 2003) of the study findings.

5.4 Limitations of the Study

The fact that the study was not designed to recognize the network building between study participants and those outside the study scope (e.g. IT experts outside DHIS2 community, past students of the masters program...etc.), hindered its ability to fully comprehend the scale of networking undertaken by the students. At the same time, the limited number of participants included in the SNA may have had some impact on its findings. However, the sample size is not a major determinant of SNA results (Krivitsky and Kolaczyk, 2015), especially when the inferences are made based on analytical findings of both SNA and qualitative content analysis.

Furthermore, the fact that the two researchers involved in this study also functioned as moderators of the online program and as supervisors of student projects meant that students might have not disclosed or have adjusted their statements to avoid any perceived conflicts although they were assured of anonymity of their data. However, such intrusions might have

been minimized as the students were interviewed following completing their training program. From an interpretation point of view, the fact that the two researchers being action researchers might have also influenced their interpretations of the study findings. However, through adoption of a mixed method, such influences may have been minimized.

6. FINDINGS AND EMERGING THEMES

6.1 Phase I

During phase I, there were 21 participants (including moderators and invited participants) attending the online training. According to the SNA, a network density of 0.75 was achieved among the online training participants. As demonstrated in Table 1, some students (nodes 8, 9, 10 and 12) have achieved a higher degree centrality (DC) than the two moderators, node 1 and 2. However, amongst the students (nodes 4 to 10, 20, 21), one was not active with a DC of 0 (node 4).

Table 1 : Degree centrality for each participant (Phase I)

Node	DC	DC'	%DC'
1	42	0.0707	7.07
2	43	0.0724	7.24
3	0	0	0
4	0	0	0
5	26	0.0438	4.38
6	22	0.037	3.7
7	20	0.0337	3.37
8	61	0.103	10.3
9	60	0.101	10.1
10	79	0.133	13.3
11	20	0.0337	3.37
12	62	0.104	10.4
13	46	0.0774	7.74
14	40	0.0673	6.73
15	22	0.037	3.7
16	2	0.00337	0.337
17	4	0.00673	0.673
18	0	0	0
19	5	0.00842	0.842
20	20	0.0337	3.37
21	20	0.0337	3.37

Furthermore, the network achieved an average clustering coefficient (CO) of 0.88 with almost all the students achieving a CO greater than the average CO. Based on the DC of each node, Figure 1 depicts the sociogram generated using SocNetV. In Figure 1, the triangles depict the students, circles depict the local moderators and experts, and the ellipses depict the experts from the region. The size of the symbols depicts the strength of the out-degree and as demonstrated, the students with the highest DC seem to play a central role within the formed network in terms of their connections.

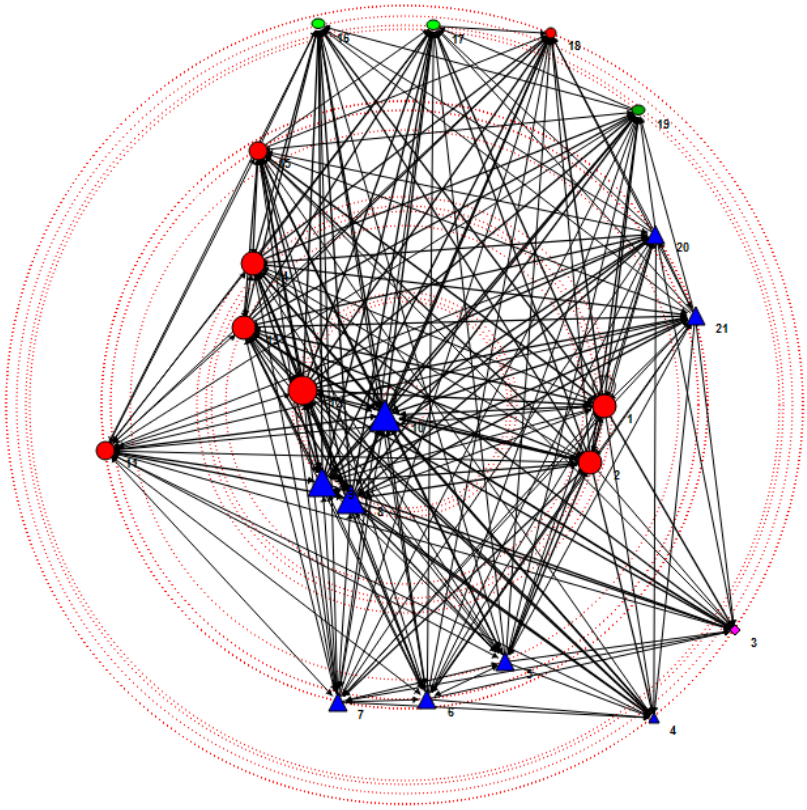

Figure 1 : Degree centrality of the online social network with node-size representing out-degree (Phase 1)

l to link students with owners of ongoing DHIS2 projects in Sri Lanka in a bid to introduce them to the local expert community. Statements such as, *"...when I talked with Dr <name>, I realized the problems that they had in terms of design and implementation..."* [one of the students] and, *"...no matter how much I studied, I didn't realize how DHIS2 would be helpful for me until I saw what Dr <name2> has designed for the program..."* [one of the students], indicate that to an extent this attempt had succeeded.

In fact, one of the project owners (node 13) accepted the invitation to moderate the online discussions and based on in and out-degrees (in-degree=32, out-degree=42), it was apparent that students interacted with him as much as they did with their colleagues and with the moderators. The discussion forum became a window of opportunity for the students to gain insights to ongoing projects, become aware about political nature of ongoing implementations, and to be informed of important stakeholders and actors within the local HIS circle. For instance, insights such as, *"...the ministry has implemented a process of integrating HISs under the control of <designation>....so you [student] will have to work with other HISs to get things inter-connected...."* [a project owner], "*you [student] need to obtain permission from <designation> in order to conduct an implementation in any health institution*" [local expert], and "*..if you can drop me an email I can send you all the details regarding the project so you will better understand what needs to be done*" [local expert], are some examples of the online forum being a window of opportunity. These statements indicate students gaining 'contextual awareness' in relation to their potential work environment, which was recognized as an emerging theme.

Another interesting observation during the online discussions was that students were trying to build on their existing knowledge regarding health care setting and information technology. However, they needed to make sure whether the learning is worthwhile for their

future. Statements such as, "*Will DHIS2 be able to cater to our setting?..*" and, "*Do we need expertise in DHIS2 as it seems like the job of an IT person?*", posed by students epitomized these concerns. In fact, they were searching for their 'identity' within the HIS community. However, having one of their own [doctors who have become HIS experts and project owners] explaining to them the usefulness of learning HISs made them align with the learning process as understood by statements such as, "*..I didn't understand the role we should play in HIS implementations until Dr <name> explained to us what he had been doing....*" [student] and, "*I was thinking whether I should take part in Moodle as it seem to be a waste of time but I realized its importance after having a chat with him [a project owner]"* [student]. Given the recurring emphasize towards identity formation, it was also recognized as an emerging theme.

Another emergent theme during phase I was the craving by the students to be part of the 'global community' or embrace 'globalness'. It was recognized that this craving was not necessarily emergent because of the global recognition of DHIS2, but it was because the students needed variance in their experience and global knowledge regarding HISs. For instance, students mentioned that, "*We don't have enough expertise here if we try to implement DHIS2 and if we need a small change done to the software*" and "*Sri Lanka don't use much HISs and we can't learn on implementation issues unless we ask someone from Africa, or India for that matter*." The fact that regional experts shared their experiences, rather than expertise, it seems to have made an impact on the students' perception of HISs. This can be realized from student statements such as, "K*nowing that there would be help available, as DHIS2 is a FOSS, it is less riskier for me to use it..*" and, "*..the more I hear from people outside Sri Lanka about using DHIS2 for HISs, the more comfortable I get..".*

6.2 Phase II

During phase II of the study, the number of participants in the online forum were 46. These included 11 students (nodes 4 to 12, 14 and 15), three moderators (nodes 1,2 and 3) and 31 representatives from the East African region. The overall network density was 0.85, which was higher than the network density achieved in phase I. It was interesting to note that according to Table 2, one of the students (node 9), achieved the highest %DC of 8.54 in phase II while around five students were not active in the network. However, three students (nodes 5,6 and 7) who were comparatively 'less' active during phase I online interactions were seen more active during the phase II (%DC's of 3.97, 2.01 and 5.89 respectively). The student who achieved the highest %DC in phase I (node 10), achieved a %DC of 3.97 in phase II, which is above the mean (2.17) of %DC.

The average CO for the phase II was 0.941, which is also greater than the CO of phase I. In other words, it could be argued that nodes in phase II were strongly connected to each other's neighbours than in phase I. Figure 2, demonstrates the Sociogram generated based on the DC data for phase II.

Table 2 : Degree centrality for each participant (Phase II)

Node	DC	DC'	%DC'
1	92	0.0393	3.93
2	14	0.00598	0.598
3	4	0.00171	0.171
4	0	0	0
5	93	0.0397	3.97
6	47	0.0201	2.01
7	138	0.0589	5.89
8	0	0	0
9	200	0.0854	8.54
10	93	0.0397	3.97
11 – 14	0	0	0
15 – 20	46	0.0196	1.96
21	95	0.0406	4.06
22	46	0.0196	1.96
23	92	0.0393	3.93
24	92	0.0393	3.93
25	46	0.0196	1.96
26	48	0.0205	2.05
27 – 32	46	0.0196	1.96
33	92	0.0393	3.93
34 – 46	46	0.0196	1.96

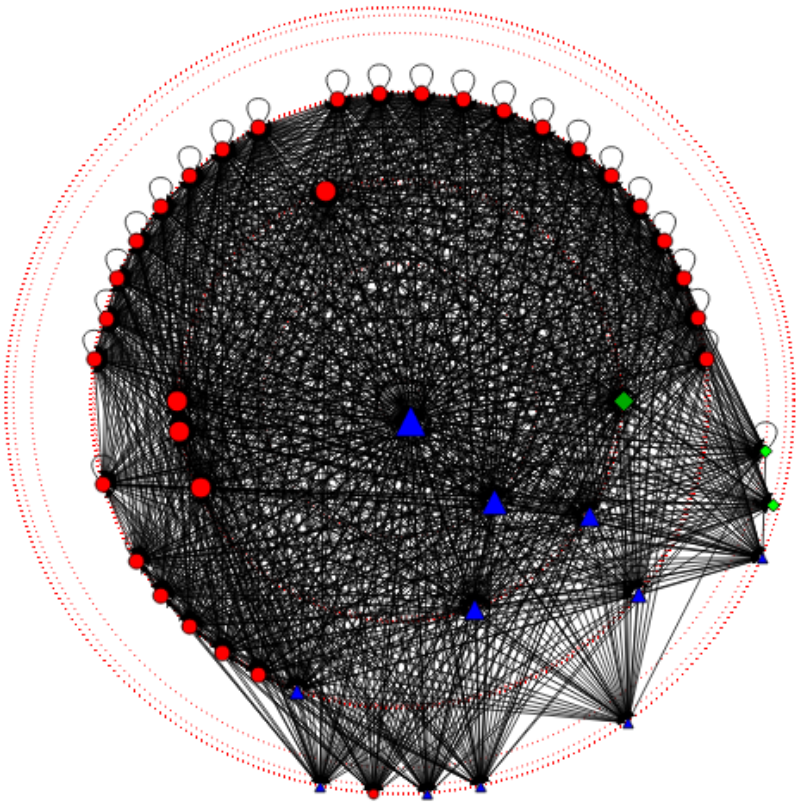

Figure 2 : Degree Centrality of Social Network with Node-Size Representing Out-Degree (Phase II)

The Sociogram depicts the role played by the students during the discussions and it is evident that those who contributed to the discussion forum seem to have played a central role or are better connected when compared to other participants of the online learning.

During the interaction, it was also evident that common grounds emerged in relation to answering an assignment question, managing complex databases, integrating different database instances and around potential 'bugs'. The importance of these topics was that they were not planned discussions but were discussions evolved based on a problem and continued until they [the participants] found common grounds. For example, one of the students asked the question, "*Is there a way in DHIS2 to re-assign one person from one facility to another?...*" to which one of the participants from Africa replied "*..I have also tried to do this but it seems like a 'bug' in the system do not allow such transfers in the current version.*" The two participants were then seen engaging in a discussion about their experiences with regard to the tracker module (The tracker module enables DHIS2 to create individual records and track a person over time throughout his or her care pathway) of DHIS2 from which the initial question emerged. The discussion attracted several more 'tracker enthusiast' and ended up discussing the future direction of tracker, as illustrated by statements such as, "*..is tracker aiming to be an EMR in the future?*"[one of the students], "*it would have been great to see the tracker helping out in the decision making process...may be with some skip-logics*" [participant from Africa] and "*the curative service provisions are not in the tracker roadmap*" [one of the developers]. Statements such as these indicate the passion shared by these participants with regard to their common interest, the DHIS2 tracker and therefore the theme, 'common interests' emerged.

At the same time, the discussions within the online platform generated 'new links' that would have expanded the students' network. For instance, one of the students posted a query, "*Is there anyone familiar with linking DHIS2 and OpenMRS?*", to which a participant from the African region replied by saying, "*I will send you a link to a person who does that but he is not in the e-learning program*". He followed it up with a link to the person mentioned earlier, who was an expert in DHIS2 in another country. In another instance, to a similar request from a student, one of the participants replied by saying, "*I have read an interesting article related to your issue and I think it contains what you are looking for <link>*". Thus, linking human and non-human resources outside the social network within the e-learning platform was apparent from the discussion forum and we acknowledged this under the theme 'connectivist features'.

During the interviews, it was also apparent that students developed their own strategy in engaging with the online discussion forums, which continued throughout the study. The strategy was to discuss issues in a small group and agree on posting the question to the online discussion forum. This was apparent from the statement, "*before we made a post, we used to discuss it among ourselves and if we thought that it need further inputs, we posted it to the discussion forum.*" [one of the students]. While this was not expected by design, it meant that a 'clique' has been formed within the student group, which now tries to fulfil their information needs by reaching out to external parties. We classified such behaviours under the theme, 'cliquing'.

Generally, these cliques were rather small with 2 or 3 members. However, once a post was made, other students, who could have also participated in the discussion face-to-face, would also contribute online. We recognized this phenomenon under the theme, 'expression style' and was corroborated through statements of students such as, "*I knew my friends were discussing certain problems in the lab but I didn't take interest to participate.....but when I saw the question that they were discussing in the online platform I couldn't resist to say what I felt.*"

6.3 Phase III

As explained earlier, phase III consisted of the project work and the interactions that took place within the DHIS2 mailing list and via emails. For analysis, a social network formed by

27 nodes were utilized. Among these 27 nodes, eight represented the students (shown as a triangle in Figure 3), 15 represented 'global experts' (shown as squares in Figure 3) and four represented local experts (represented as circles in Figure 3). The social network formed by these 27 nodes only achieved a density of 0.14 as against 0.75 and 0.85 in phase I and II respectively. However, this can be explained by the nature of the emailing list as against discussion forums used in phase I and II.

Table 3 : Degree Centrality for Each Participant (Phase III)

Node	DC	DC'	%DC'
1	3	0.00929	0.929
2	80	0.248	24.8
3	4	0.0124	1.24
4	13	0.0402	4.02
5	0	0	0
6	23	0.0712	7.12
7	42	0.13	13
8	16	0.0495	4.95
9	58	0.18	18
10 - 11	0	0	0
12	31	0.096	9.6
13	2	0.00619	0.619
14	3	0.00929	0.929
15	1	0.0031	0.31
16	4	0.0124	1.24
17	2	0.00619	0.619
18	7	0.0217	2.17
19 -20	1	0.0031	0.31
21	3	0.00929	0.929
22 - 26	1	0.0031	0.31
27	25	0.0774	7.74

When considering the DC of the students, node 9 achieved the highest %DC of 18 while node 7 achieved a DC% of 13. Node 6 also achieved a %DC of 7.12. Three students however did not gain a DC as they recorded a 0 out-degree. It should be noted that node 9 was considerably active in all three networks with high DC (phase I, II, and III) although node 6 and 7 became more active during phase II and III.

The CO for phase III network was 0.367, which was lower than both phase I and phase II. This indicated that the neighbours of each node in phase III network were less connected to each other than in phase I and phase II. This could be explained by the fact that in email lists, anyone in the list could have responded directly to the posts made by the students rather than a selected group of experts communicating to all the students. At the same time, because students first discussed their issues among themselves in small cliques before posting, it was only one student who made the post on behalf of several students. Figure 3 shows the Sociogram generated for phase III. In that, it is possible to note that the students have build up connections with both the global and local experts.

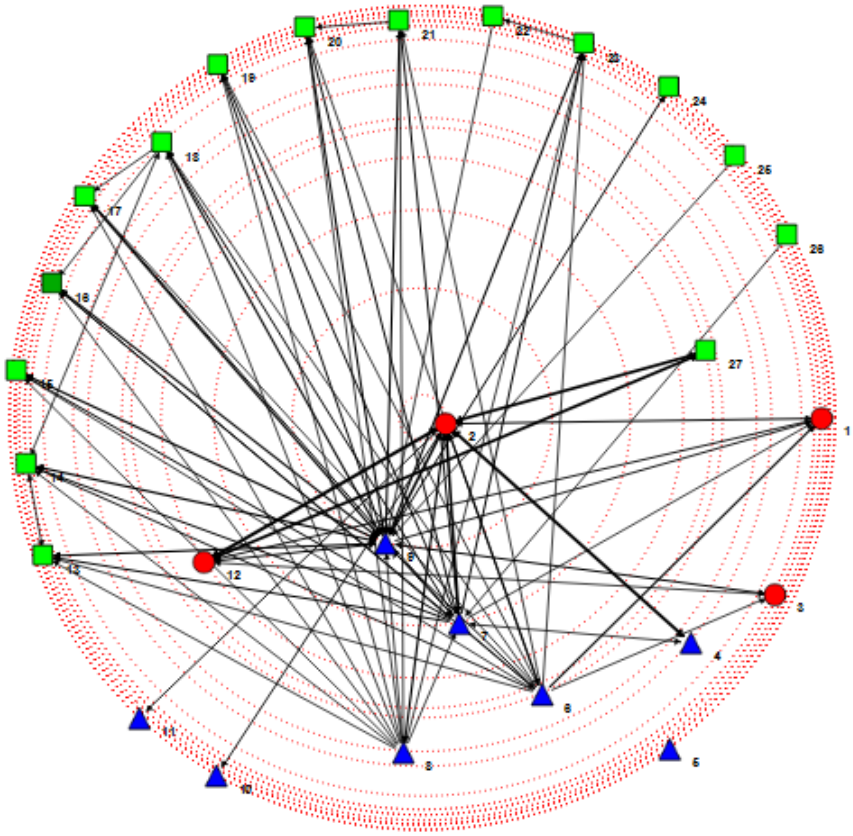

Figure 3 : Degree Centrality of Social Network with Node-Size Representing Out-Degree (Phase IV)

As expected, the posts made within the emailing list were mostly related to technical aspects of DHIS2. However, it was noteworthy that 'cliquing' continued to emerge as the preferred strategy for the students to interact with the global community. One student pointed out that, *"...because we discussed the question among ourselves before we made a post, we were able to gain a useful and a more specific response from the global team....otherwise we would have been asking the same question over and over again at different points in time."*, Another indicated that, *"..although we were doing different projects there were many common issues and most of it were resolved by ourselves and for the rest we needed the developers."*

At the same time, a student who wasn't much active in the mailing list made the remark, "*I managed my project from what I already knew....and if I had an issue, I first asked from one of my colleagues, then from Dr <name>, then from one of my friends from a previous batch....by that time, I usually resolved my issue.*" Similar remarks highlighted the learning style adopted by the student, and some of the other students for that matter, to manage resources in a pre-defined manner. The approach was based on closeness or accessibility of these resources to the person in question. Even in relation to self-learning, one student pointed out that, "*I usually look at the Moodle and try to search in the web if I have specific issues. If it is still not clear, I would ask from a colleague or from Dr <name>. The mailing list is usually the last resort.*" Given this general notion of making use of familiar and easily accessible resources, we recognized similar expressions under the theme 'comfort zones'.

6.4 Phase IV

This phase focused on the students experience in work settings soon after their training period. Therefore, the data collection relied upon the interview data. During this period, it was apparent that students have continued their practice of 'cliquing', this time with almost all the members of the group. As stated by one of the students, "*when we received placements I suddenly realized that I no longer have anyone close-by to ask questions....but I was confident as I have enough people to go to via email and mailing list*."

Another student mentioned that, "*we decided to call ourselves <name> team, as among ourselves, we have the answers to most of our technical issues*". The students, now professionals in health informatics, also mentioned that they maintain their own mailing list, which is open only to themselves and to some of the local DHIS2 experts with whom they interacted closely during their training period.

However, they were also keen on maintaining the relationships that they developed with the regional and global community. This was clear from statements such as, "*I keep in touch with <global expert> and <regional expert> through email whenever I need clarifications regarding customization or implementation*"<one of the students>, "*<global expert> told me to talk with <another global expert> for my <issue>*", and "*from time to time I look at the email list and contribute to threads which I find interesting...I think its useful to be part of the community in terms of my work*" <student>. In general, these remarks can be classified under the theme 'sense of community'.

7. DISCUSSION

During different phases of this study, we tried to create opportunities for the students to maximize their participation with different groups of people including DHIS2 experts and DHIS2 users. Findings from the SNA suggest that the students did take these opportunities and some of the students seem to have played a central role in the online interactions.

Table 4 : Comparison between DC and CO of the Students in Phase I (PI), Phase II (PII) and Phase III (PIII)

Node	%DC' (P1)	CO (PI)	%DC' (PII)	CO (PII)	%DC'	CO(PIII)
4	0	1	0	0.979	4.02	0.667
5	4.38	0.893	3.97	0.932	0	0
6	3.7	0.893	2.01	0.932	7.12	0.346
7	3.37	0.893	5.89	0.921	13	0.326
8	10.3	0.893	0	0.979	4.95	0.484
9	10.1	0.866	8.54	0.921	18	0.16
10	13.3	0.875	3.97	0.932	0	0
11	3.37	0.893	0	0.979	0	0
12	10.4	0.893	0	0.979	9.6	0
21	3.37	0.893	4.06	0.931	0.929	0

When it comes to the CO of different stages, the strength of clustering became more when the students interacted for the second time in phase II following gaining exposure to the community through phase I (CO of 0.88 in phase II against a CO of 0.75 in phase I). The lowering of the CO in phase III can be attributed to the changing nature of the mode of interaction, which was the mailing list. Based on phase IV findings however, it became evident that the cohesion or the grouping amongst the students as observed through CO of phase I and phase II continued beyond phase III. This may have further strengthened during the work placements as they strived to form a group identity rather than an individual identity. However, it would be false to assume that CO per se is indicative of stronger or

weaker 'grouping' and networking amongst students. Nevertheless, an improved CO from phase I to phase II along with qualitative findings of identity formation, common interest, cliquing and sense of community over all four phases strengthened the argument that the interactions observed do indicate the formation of a community. Given the fact that these findings seem to extend beyond the training endeavour and that trained students continued to work on HISs as part of their work practices, it was possible to assume that the community formed was more likely to be a community of practice than anything else.

When considering the background of these students, it is also possible to argue that they emerged from several CoPs, which had health as its knowledge domain. The community that they have been interacting consisted of doctors, nurses, and other health staff. However, during the training, they had a new 'common interest', which was to find methods and utilize DHIS2 for their projects. They also had a new domain of knowledge, which was HIS. These manifestations were shaped at the beginning through formal learning arrangements in online and face-to-face environments. The reason for suggesting formal learning to be responsible for these manifestations was that the said themes were emergent during the early phases of the study, which were dominated by formal learning arrangements. However, these manifestations did not necessarily warrant the group to be called a CoP, but perhaps a 'learning community' (Speck and Stollenwerk, 1999). Thus, one of the earliest signs of forming of a CoP was students' enthusiasm towards finding their own identity within their new found domain and interest. During the early phases of the study, it was evident that moderators had to facilitate linking between students and other actors within the DHIS2 community. High DC and high CO of the moderators during phase I and II strengthened this argument. However, in formal learning arrangements, this was expected and was desirable from the point of view of the trainers (Salmon, 2003).

Furthermore, two factors that emerged from the study that may have lead students to find their 'identity' were, gaining of 'contextual awareness' and the perception of 'globalness'. By being aware about their context, students would have been able to shape their own activities, which is a recognized need in the formation of CoPs *(*Dourish & Bellotti, 1992; Gillet, Helou, Rekik and Salzmann, 2007). While contextual awareness might have shaped student activities to a certain extent, the perceived 'globalness' meant that they became aware about the context outside their practice as well. In a way, as pointed out by Gareiss (2001), globalness also enables people to conceptualize relevance of their learning to their own setting. In the eyes of the students, this meant that they have the power and confidence to form and be part of a community of themselves, as external network seems to remain stable, strong and supportive.

At the same time, students formed cliques among themselves in order to deal with the issues arising out of their common interest. By forming small cliques, students have shown that they value sharing their ideas and discussing problems among themselves before seeking external support. During phase III, one reason for the lower CO was the formation of cliques, which made students to interact in the mailing list as a group rather than as an individual. Interestingly enough, the students were networking not only among themselves, but also with the local and global DHIS2 experts. This indicated that students were not intending to work as a closed group but as a group wanting to expand their knowledge by being responsive to the ongoing developments. To an extent, this illustrated students' perception that they are novices in DHIS2 and mailing list is a way of establishing their identity within the global DHIS2 community. However, by phase IV, they seem to have distinguished between themselves and the global community, as they decided to formally recognize their group as a named community. The said community was linked with the global community through the boundary spanning members of the group.

While the formation of the CoP evolved over time, there were also evidence indicating the linkage between formal and informal learning. Connectivist features emanating through the study were indicative of this linkage. As pointed out by Siemens (2006), "learning, defined as knowledge patterns on which we can act, can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets." This is the fundamental assumption in the connectivist learning theory. During the training, students became aware about where the knowledge resides. For instance, they had access to the formal learning setting in the form of e-learning platform, which was available for them for referencing. They also had access to a community of regional and global DHIS2 learners to interact with who had practical expertise in LMIC settings. At the same time, students also recognized that expert knowledge is available within the mailing list and among themselves to different proportions. In other words, students generated a set of links connecting the formal learning with different informal learning options.

It was also evident that students preferred to follow 'formal' structures of learning (e.g. e-learning content, moderators), the so-called 'comfort zones', before tapping into the informal learning opportunities (e.g. external resources of learning, regional and global experts). This can also be considered as an approach adopted by students themselves to link formal and informal learning. However, as the learning progressed into phase III, the usefulness of formal learning structures gradually diminished and informal learning modalities became the key learning tools for most students.

Another aspect that needs highlighting was the fact that some students preferred informal settings (e.g. online discussion forum) as against formal learning settings (e.g. laboratory) to express themselves. Recognized by us as the 'expression style', we considered this to be an important aspect as it allowed students other than those directly involved in 'cliques' to take part in the discussions using online tools. In a way, facilitating learning through both online and face-to-face did gave students a choice, allowing greater participation and greater expression.

8. CONCLUSION AND RECOMMENDATIONS

While acknowledging the fact that the group investigated in this study does not resemble a usual group of HIS implementers being trained in most LMICs, the study does indicate that a training program incorporating formal and informal online, face-to-face and workplace based training modalities would be able to initiate the formation of a community of practices. Given the commonness in most IS implementations, which are large scale, dispersed and are dependent on scarce resources in LMIC contexts, the training strategy recommended in this paper could also be generalized for such projects. However, there are three main goals and associated areas that one should focus when designing and implementing such training programs. The three goals include linking of formal and informal learning, promoting participation and building a sense of community. Table 5 depicts these three goals and the focus areas along with some implementation choices.

In relation to linking formal and informal learning, three focus areas were recognized. One is the need to facilitate 'comfort zones' in learning by giving the students enough options to move between formal and informal learning. Second is to design a culture of connectivist learning by emphasizing more on reliable and accessible knowledge residing within regional and global communities. This not only stimulates students to network but also build confidence in them to take up the challenge of HIS design and implementations, knowing that support is available at short notice. Thirdly, it is necessary to understand the preference among students in expressing themselves either face-to-face or online, and provide them with the blended option of interaction.

Table 5 : Implementer Training Model for LMIC Settings.

Goal	Focus areas	Implementation choices
Linking formal and informal learning	Comfort zones	Online curriculum linked with discussion forums
		Online and face-to-face moderators who are responsive and accessible
		Supplementing curriculum with used cases from similar contexts
	Connectivist approach	Introducing external knowledge bases including user manuals, used cases, videos...etc.
		Actively promote link building between students and experts within discussion forums and in face-to-face learning.
		Introduce students to local and regional project owners.
		Using moderators who themselves are well connected and networked.
	Expression style	Facilitate both online and face-to-face discussions in relation to same learning objectives.
Enhancing Participation	Contextual awareness	Using project owners as moderators in online and face-to-face training
		Designing discussion topics to reflect contextual issues
		Field visits
		Promoting past-students to contribute as moderators
	Globalness	Include used cases from similar contexts elsewhere in the region or globe.
		Facilitate the participation of members from the global community.
Building sense of community	Common interest	Include activities, which generate issues of similar nature for all the students.
		Arrange group sessions discussing various issues
		Design themed discussions based on general issues.
	Identity formation	Create networking opportunities with project owners
		Facilitate participation in live projects
		Utilize moderators with similar background to the students as role models.
	Cliquing	Recognize cliques and facilitate its functioning
		Enable formed cliques to express themselves to others

With regard to promoting participation, it is necessary for the students to become aware about their working context through insights from people who they can relate to. They should also feel that they belong to a society beyond their work practices as feeling of 'globalness' encourages students to be proactive in network building and learn from experiences emanating from similar contexts. It should also be pointed out that facilitating different expression styles would also promote participation as it provides freedom for the learners to express themselves.

Last but not least, it is necessary to provide scaffolding for generating a sense of community among the learners. In that, the learning should facilitate generating a common interest and in this regard, assignments, case studies, student projects, themed discussions and even informal chats were recognized as having the potential to ignite the commonness among the students. Secondly, it is necessary to support students in term of discovering their identity within the context of HISs. However, this has shown to be a gradual process, which may not necessarily resemble the 'legitimate peripheral participation' as described in situated learning (Lave and Wenger, 1991), at all times. Thirdly, students would form cliques and these cliques have the potential to ultimately evolve into CoPs when students make sense of their learning and work practices. Naturally, such evolution takes time and therefore, it is vital that training programs are designed in such a way that students are constantly provided with the necessary scaffolding to form and maintain such cliques as long as possible.

From a theoretical point of view, the study feeds to the discourse around cultivation of communities of practice by presenting a training lead approach. While traditional IS implementations would restrict themselves to short training programs which are largely aimed at transferring knowledge and skills, a training program aimed at cultivating CoPs would also aim at building networks, enabling participation, collaboration, imparting a sense of community and supporting to develop one's identity. However, such facilitation would only be possible if trainers gain full and unrestricted access into an organization. Given the limited access afforded to IS implementers in LMIC contexts, striving to facilitate CoPs around ISs such as HISs would be nearly impossible and costly. Nevertheless, using a blended approach consisting of online, face-to-face and workplace based training, and with the participation of the regional and global FOSS communities, this study demonstrates the potential of training in cultivating CoPs, even at a distance.

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IV

OPEN SOURCE ADOPTION IN HEALTH SECTOR: UNDERSTANDING THE STAKEHOLDER RELATIONSHIPS IN A RESOURCE CONSTRAINED SETTING

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ABSTRACT
Free and Open Source Software (FOSS) is increasingly being the choice to strengthen health information systems (HIS) in Low and Middle Income Country (LMIC) contexts. FOSS is becoming a commercially viable option in today's software industry. In LMIC context, bridging the gap between generic open source design and specific local contexts calls for the participation of multi-sector stakeholders to realise FOSS implementations. This multi-sector stakeholder network, together with the FOSS platform can be theorised to form a software ecosystem (SE) around FOSS implementations in a resource constrained setting.

In this new paradigm, governing the open source acquisition and implementation process becomes a central challenge, which is distinct from the governance of open source developer communities. This paper attempts to identify the essential stakeholder categories involved in FOSS HIS implementations in a LMIC context and; to understand the stakeholder interactions in this SE at different stages. The analysis is based on a longitudinal case study of two open source HIS implementations and an attempt to establish a FOSS governance body in the State health sector of Sri Lanka during the period 2011-2014. The paper contributes by suggesting a model to understand the essential stakeholder categories and their interactions in FOSS implementation SE in resource constrained settings.

KEYWORDS
Software Ecosystem, Free and Open Source, Open Source Governance, Health Information Systems, Low and Middle Income Country

1. INTRODUCTION

With current advancements in Information Technology (IT), HIS has become an integral part of health reform agendas of most LMICs. However, HIS implementation efforts are often constrained by technological and financial limitations in LMICs. In this context, open source could play an enabling role by providing not only software solutions with no licensing costs, but also free access to the software source code, contributing to local knowledge and technological advancement (Câmara & Fonseca, 2007).

Open Source Software (OSS) refers to any computer software whose source code is publicly available under open source licensing (Gwebu & Wang, 2011). Open source design and development is seen as an empowering strategy in LMIC contexts channelling the global software development to support local business processes (Staring & Titlestad, 2006; Staring & Titlestad, 2009; Subramanyam & Xia, 2008; Twaakyondo & Lungo, 2008). The open source software has increasingly started to appear in enterprise scale HIS implementation projects effectively competing with proprietary solutions, especially in the public sector of LMICs (Chamili et al., 2012). The open source software phenomena has also undergone a significant transformation from its free origins to a more mainstream, commercially viable form which is referred to as *Open Source 2.0* (Marsan et al., 2012). Higher quality (security, reliability, flexibility), low total cost of ownership, and no vendor lock-ins are among the main advantages of open source software to an organization (Gwebu & Wang, 2011). However, generic design, limited documentation, lack of training opportunities,

overwhelming version proliferations and constraints imposed by various FOSS license are the known challenges in implementing open source solutions (Spinellis & Giannikas, 2012).

Mitigating the possible adverse effects of these disadvantages and leveraging on the advantages of FOSS adoption is a remarkable challenge that health managers and administrators face in implementing open source in health sector. Due to the technical and financial limitations in LMICs, the open source adoption process calls for the participation of various health and non-health sector organizational actors (Puri et al., 2009). These entities often operate informally, independent from each other in the early phases of FOSS implementation and operate outside formal contracts in the form of a network organization (Jones et al., 1997). This stakeholder network, together with the FOSS framework it is built upon, can be theorised as a SE. A SE "consists of a software platform, a set of internal and external developers and community of domain experts in service to a community of users that compose relevant solution elements to satisfy their needs" (Bosch & Bosch-Sijtsema, 2010; 68). The large scale information system (IS) analysis is moving from software product line and isolated software projects to SE (Bosch, 2009; Dittrich, 2014). This also influenced us to choose SE as the theoretical lens of this research to align our work with a growing body of knowledge.

Organising the stakeholder network to realize the FOSS customization and implementation is a critical to the success of the OSS acquisition. For enterprise FOSS acquisition efforts, organizations may have to rely on in-house IT specialists as well as third party OSS specialists (Marsan et al., 2012) which is fraught with governance challenges. However, the benefits of OSS are fully realized only when its use is accompanied by a proper open source governance process (Black Duck, 2013), which includes processes of FOSS acquisition, approval, cataloguing, auditing and monitoring. Poor open source governance can expose the organization to operational, legal and security risks leading to the failure of the implementation initiatives. Governing the multi-sector interactions require sensitive approach for the implementation to evolve from its initial fragile state to a stable institutionalized state. Hence, understanding the stakeholder categories and their interaction in HIS implementation SE has become an important aspect for the success of enterprise-wide OSS implementations in health sector.

This paper empirically draws upon two large scale open source HIS implementation projects and, an attempt to establish a FOSS governing body in the State health sector of Sri Lanka during the period 2011 to 2014. The study especially focused on understanding the key stakeholder interactions in FOSS implementation ecosystem, including those of central and regional health administration, various local and foreign development partners, ICT/health IT regulatory bodies, university sector, FOSS developers and HIS implementers.

The aim of this study was,

1. To identify the essential stakeholder categories involved in open source FOSS HIS implementations in a LMIC context.
2. To understand the stakeholder interactions in the FOSS implementation SE at different stages.

The rest of the paper is structured as follows. In the next section, key concepts around FOSS implementation governance and multi-stakeholder network organization are discussed. Followed by which, the research methodology is elaborated, including a description of the empirical settings. The analysis includes a description of the governance issues in FOSS implementation SE. The paper concludes by proposing a model to understand the stakeholder interactions with respect to FOSS implementation governance.

2. OPEN SOURCE GOVERNANCE IN FOSS IMPLEMENTATION SE

In relation to an open source ecosystems, two tiers of governance can be identified. The first refers to how the OSS developer community is managed (O'Mahony & Ferraro, 2007) while the second refers to the OS acquisition process by the client organization. Within the scope of this article, *open source governance* refers to the governance of the FOSS implementation (adoption) process which includes OS acquisition and governing the stakeholder participation in OSS implementation process. Spinellis and Giannikas (2012) further divided this process in to primary and secondary adoption of FOSS. Primary adoption is where management decides that a particular HIS is required to support a perceived need (top-down implementation), whereas, secondary adoption is concerns the operational level processes to achieve this integration.

2.1 Software Ecosystem Surrounding FOSS Implementation

In a LMIC context, health departments are often poorly equipped with technical resources. In such situations where a firm cannot develop sufficient absorptive capacity by its own, networks and alliances help build combinations of knowledge (Gulati, 1998, Nooteboom, 1999). Similar phenomena can be observed in the health sector of LMIC context as well, where it welcomes multi-sector stakeholders to form a support network in OSS HIS implementations (Braa et al., 2007).

SE is an emerging trend within software industry, implying a shift from closed organizations towards open networked structure. The concept of SE has been described by Bosch and Bosch-Sijtsema (2010; 68) as to “consists of a software platform, a set of internal and external developers and community of domain experts in service to a community of users that compose relevant solution elements to satisfy their needs”. In this context, the FOSS HIS implementation network and the FOSS framework it is based up on fits the definition of SE. Further, the SE is theorized as a way to construct large software system on top of a software platform by composing components developed by actors both internal and external to the network (Manikas & Hansen, 2013). Hence, the SE is a networked community of organizations, which bases their relations to each other on a common interest in a central software technology (Hanssen, 2012). A SE is a means to construct large software system on top of a software platform by composing components developed by actors both internal and external. Bosch and Bosch-Sijtsema (2010) further mentioned that the scope of SEs are inter-organizational, including external stakeholders and the software extensions provided by external contributors.

FOSS provides a viable platform for growing SE from the angles of implementation technology, development methodology, business model and governance (Kilamo et al., 2012). According to Dittrich (2014) software framework and 3rd party applications developers are both important in end-user configurable software development in a SE. This can be adopted to FOSS as well, where FOSS firm plays the role of framework developers and 3rd party developers and FOSS implementers plays the role of application developers in extending generic FOSS functionalities aligning it with the implementation domain need. Converting core open source products to organizational IS provides the basis for the revenue model for implementers. However, this is different from the traditional sales funnel since the product can be used by the prospective customer before the actual 'buying' happens (Riehle, 2012). Third party implementers (also known as, implementation mediators) provide essential support to the end users by assisting to select which OSS aligns best with the business needs, including selecting the right version and estimating the customization needs.

Manikas and Hanssen (2013) has identified orchestrator (platform owner), niche players (influencers), external actors (e.g. developer teams), vendor (or reseller) and customer (end user) as the main actors involved in SE. Client organizations may outsource the customization to external FOSS vendor firm to aligning the generic OSS capabilities with the

organizational business process model (Nagy et al., 2010; Riehle, 2009). This could be financially supported by donor agencies. The governance of such network organization is characterized by a non-hierarchical collective of legally separated organizations (Alter & Hage, 1993). This cluster of organizations aims for long-term recurrent exchanges that create interdependencies (Larson, 1992). The FOSS implementation stakeholder networks also differ from the concept of the network defined in current Enterprise Architecture frameworks (Zachman, 1997). Unlike in the network described in the conventional Enterprise Architecture concept, in FOSS HIS implementations, the interacting stakeholders may not be directly involved in the health care delivery business process. Hence, the conventional enterprise architecture principles are not adequate to understand the stakeholder dynamics in FOSS implementation. With the increased use of OSS in enterprise-wide applications, independent OSS suppliers have emerged as being important contributing to generate the critical mass of experts around an OSS projects (Ven & Mannaert, 2008). These experts help to mitigate undesirable effects, for example by establishing version authentication, training/certification, documentation and education to end users. Inside champions (Riehle, 2009) function as boundary spanning agents (Perrone et al., 2003) improving organizational trust towards the OSS and external implementer teams.

2.2 OSS Governance

The success of an IS implementation depends on the alignment of the system's functionalities to the organizational work routines and business processes (Heeks, 2006). Effective open source governance needs to facilitate aligning the organizational business processes and strategies to open source acquisition by cataloguing functional and non-functional requirements, auditing source code and source reliability, defining roles and responsibilities and monitoring license compliance (Kemp, 2010).

IS implementation governance mechanisms can broadly be categorized in to coordination and control activities (Hirschheim et al., 2006). The coordination, which is defined as, “integrating or linking together different parts of organization to accomplish a collective set of tasks” (Van de Ven et al., 1976, p. 322), range from non-coordination to formal and informal coordination. The control is defined as “… the organization’s attempt to increase the probability that employees will behave in ways that lead to the attainment of organizational goals ” (Henderson & Lee, 1992, p. 757). The four modes of control in play are self control (monitoring the self), clan control (monitoring the team by the members of the team), output control (monitor and evaluate output by a manager) and behaviour control (monitor and evaluate team members’ behaviour by a manager). Out of which self and clan control are considered as forms of informal control mechanisms, whereas output and behaviour control represent more formal mechanisms. Clan control is more compatible with the network organisation which is seen in the initial phase of implementation with an informal governance structure. Later it can be replaced by more formal governance mechanisms with legal contracts containing detailed software requirement specifications.

Governance is an important process as argued in the Open Source 2.0 model (Fitzgerald, 2006). The governance in Open Source 2.0 paradigm is characterized by the vendor driven commercial mechanism (Riehle, 2012), as contrasted to the conventional FOSS developer community model. Within this, a substantial part of the software source code and resources are provided by the FOSS firm, and third party entities generate revenues from complementary services, such as training and end-user customization, to support a client organization's business practices. In the open source 2.0 paradigm, enterprise-wide open source implementations increasingly resemble custom (bespoke) software development with post-release customization and implementation supported by third party support firms. Several models has been proposed to describe this FOSS implementation governance such as

Single Vendor Commercial Open Source Model and Service/Support Open Source Model by Dixon (2009) and the Third Party Service Provider Model by Krishnamurthy (2003) to describe the interactions in FOSS implementation ecosystems. These models are centred on a firm external to the client organization supporting and managing the OSS development and providing post-release customization support to the client organization. The Single Vendor Commercial Open Source Model and Service/Support Open Source Model (Dixon, 2009) have been used as the catalyst for the proposed model (Figure 4) discussing their limitations.

The Single Vendor Commercial Open Source model (Dixon, 2009) describes the interaction between the software developers, sales, product management and support teams, and the customer. In this model (Figure 1), the developers have continual, direct communication with the broader development community. The support and services department is market-focused and involved in creating the required product. Usually, there is a community liaison role whose job it is to focus on community growth and satisfaction, and also to assist with incoming contributions.

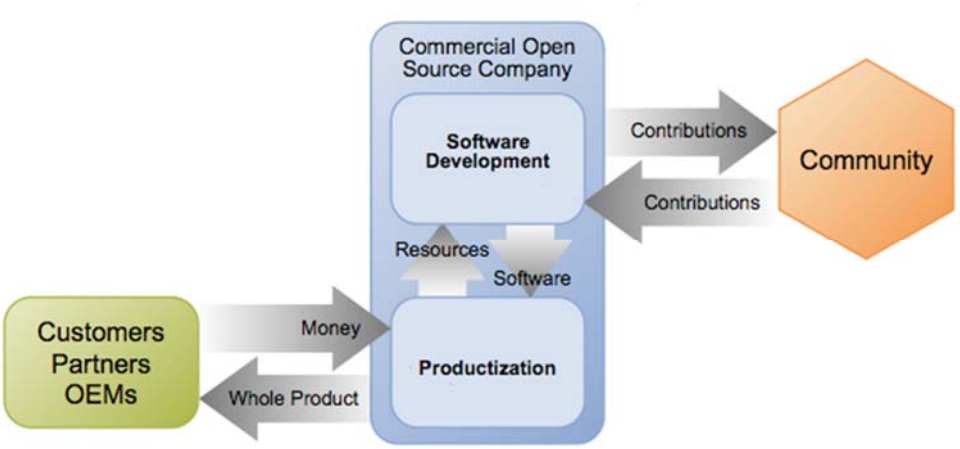

Figure 1: Single Vendor Open Source Business Model – Simplified from Original (Dixon, 2009)

In the Service/Support Commercial Open Source model a strong role of a service provider emerges as a supportive entity separating the open source firm from the customer. In this scenario, the open source implementation service provider maintains the communication with the costumer providing post-release customization support. The service provider will perform the customization and component development activities providing a whole product to the open source client. This role is either played by a third party software firm or by an extension of the open source developer firm. The main role of the open source developer firm is to manage the software release cycle and ensure the sustainability of the volunteer developer community around the open source product.

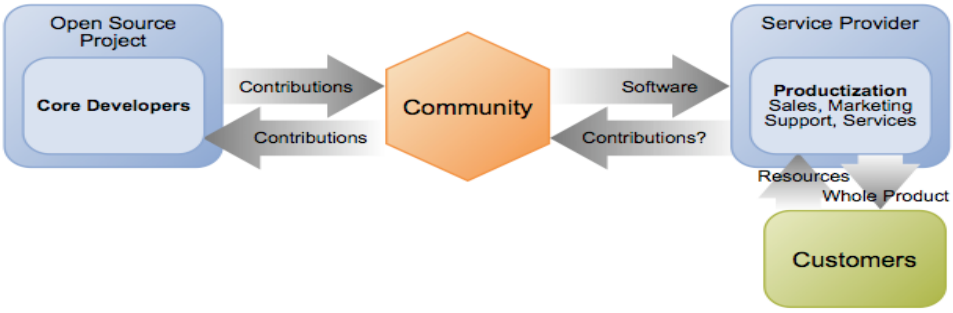

Figure 2: Service/Support Commercial Open Source Model – Simplified from Original (Dixon, 2009)

Compared to the single vendor commercial open source model, in the service/support commercial open source model, resources are provided to the OSS developers and support entities are different. However, this model provides relatively low overhead to maintain a support mechanism without the need of an 'Enterprise Edition' of the software which enables recovering investments made by the open source firm. In this approach, many potential customers do not perceive enough value in the whole product features alone to convince them to become customers. This model is limited as the company does not have direct control over the direction of, and development of the open source software.

3. Research Approach

This study was based on qualitative methods to explore the stakeholder interactions in two HIS implementation ecosystems and an attempt to establish an open source governance body within the State health sector of Sri Lanka over a four year period from 2011 to 2014. Using an interpretive approach, the study seeks to understand the stakeholder interactions in the form of governance decisions in FOSS implementation SEs. The researchers selected the two large scale FOSS HIS implementations from the State health sector of Sri Lanka to make sure to include possible stakeholder categories (Manikas & Hansen, 2013) and interactions (Dixon, 2009; Krishnamurthy, 2003) discussed in the contemporary literature. They were included, implementation mediators, central and regional health administrators, non-health sector organizational actors and university sector initiatives, regulatory bodies and funding agencies.

The two HIS implementation cases represented customization attempts of the open source District Health Information System 2 (DHIS2) software for Maternal and Child Health (MCH) programme and the National Programme for Tuberculosis Control and Chest Diseases (hereafter referred to as the TB programme) in Sri Lanka. These two cases provided us the opportunity to observe the longitudinal stakeholder interactions in FOSS implementation SE. The implementation mediators in these two cases operated under a not-for-profit (research and academic) mode with informal contracts going beyond the purview of a single actor and involving multiple stakeholders over an extended period. The cases covered the MCH system in two administrative districts of Kurunegala in North Western province and Galle in Southern province; and a vertical health programme with its peripheral chest clinics and sputum investigation centres for the TB programme, respectively. The third case selected was an attempt to establish the National Foundation for Open Source Health Software (NFOSHS) which sought to regulate the network of FOSS actors in Sri Lanka. This provided us the opportunity to observe the underlying governance decisions in stakeholder selection in FOSS implementation SEs. It provided a rich insight in to the client

organization's decision-making process of governing the participation of FOSS developer firms and FOSS implementers.

Figure 3 below illustrates the time line of each project relative to their span during the period of this study.

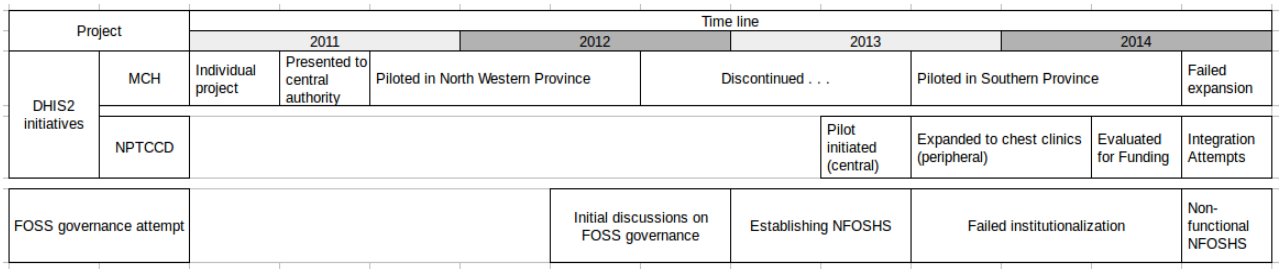

Figure 3: Time Line of the Case Studies with Major Milestones

The data collection was started in 2011 and continued till the end of 2014 with the first author continuously engaging in FOSS implementation activities representing a stakeholder entity. The data gathering was focused on understanding stakeholder categories and their interactions in the multi-sector network organization using a multi-method approach (Mingers & Brocklesby, 1997) involving participant observation, semi-structured interviews, focus group discussions and document analysis. Emphasis was given to understand the views of the health managers and administrators and HIS implementation mediators, who represented the key stakeholder interactions. The unit of analysis was the SE, and the respondents were so selected to represent the organizational perspective (Gaur et al., 2011). One of the authors of this paper took part in the participant observation (Flick, 2014) sessions in DHIS2 implementations and activities in establishing the NFOSHS. The participant observation was combined with document analysis, which included project steering and evaluation meetings minutes and other email and online forum communications. The project steering committee and evaluation meeting minutes were from the two HIS implementations. These meetings were attended by central and peripheral health managers and administrators, medical officers of health, consultant community physicians and field health care staff along with the implementation team. The documents from NFOSHS included meetings minutes and online forum excerpts.

Health managers and administrators and FOSS implementation mediators were the informants in the semi-structured interviews, which helped to understand the insights of key decision makers and also the project governance and implementation trajectories. eight interviews for the MCH programme (one with central programme manager, three with provincial administrators and four with implementation mediators) and 10 interviews for the Tb programme (three with central programme administrators, two with IT officers and two with Medical Officer – Health Informatics and three with external FOSS implementers) were conducted. These interviews assisted to clarify the stakeholder behaviours and governance decisions observed during the participant observation sessions. Similarly, during this study, implementation mediators, Medical Officers of Health (MOH), Medical Officer - Health Informatics, Public Health Nursing Sisters and Supervisory Public Health Midwives were the participants in the focus group discussions. In the MCH project, five focus group discussions were conducted and the number of participants were ranged from five to eight. One each were conducted with central MCH programme and Southern province stakeholders. Three focus group discussions were conducted in North Western province implementation where, one was with provincial stakeholders and the other two were with MOH office staff. During the Tb programme project, three focus group discussions were conducted with the Tb programme administrators and IT staff. The first author participated three focus group

discussions in NFOSHS and the participants were ranged from 12-17. The group became a tool to reconstruct individual opinions (Flick, 2014) towards the institutional/organizational understanding of the situation studied. The table 1 below summarizes the key informants who were subjected to the participant observations and interviews.

Project	Key Informants/attendees
MCH	Programme director, Director – Information Systems, Consultant Community Physicians representing MCH programme, Medical Officer – Maternal and Child Health (Kurunegala and Galle), Medical Officer – Health Informatics (North Western Province and Southern Province), MOH (Kurunegala, Pannala, Galle), Public Health Nursing Sisters and Supervisory Public Health Midwives of respective MOH areas, Provincial Director of Health services (North Western and Southern provinces), Regional Director of Health Services (Kurunegala and Galle), Chief Public Health Inspector – Galle MOH Representatives form Post Graduate Institute of Medicine (PGIM) and representatives from Health Informatics Society of Sri Lanka (HISSL) as implementation mediators
TB Programme	Programme Director, Medical Officer – Health Informatics, Consultant Community Physicians, Consultant Chest Physician, Medical Officers in Chest Clinics, IT staff of the TB programme Funding agency: Head and members of Country Coordination Mechanism, Members of CCM, Representatives from international funding agency Integration with HIV programme: Director -HIV programme, Consultant Community Physicians Representatives form PGIM and representatives from HISSL as implementation mediators
NFOSHS	Director – Health Information, President – HISSL, Medical Officer - Health Informatics representing key ministry officials and vertical health programmes, Representative from ICT Agency of Sri Lanka and PGIM, directors of vertical health programmes, representative from Sahana FOSS Foundation, representatives from technical universities.

Table 1: Key informants and attendees in the focus group discussions, the interviews and the participant observation sessions

The role of the health managers and administrators observed ranged from institutional level managers (e.g. Medical Officers of Health) to administrators (e.g. Programme Directors, Provincial/Regional Directors of Health Services). Hence, decision making processes of health managers representing both central and peripheral/provincial level were studied. The implementation mediators who were observed included internal staff (TB programme and the Southern Province) as well as volunteers external to the health programme, such as from the Post Graduate Institute of Medicine (PGIM) and Health Informatics Society of Sri Lanka (HISSL). The first author of this paper engaged in the NFOSHS activities as an attendee to the stakeholder meetings and the electronic communications (forum posts and email communications). In July 2014, both the authors participated in a situation assessment and a

requirement gathering meeting on behalf of an international funding agency, where different stakeholder perspectives, including of the funding agency, engaged in HIS implementations were studied.

Data analysis followed the interpretive tradition (Walsham, 2006) with a case study approach (Yin, 1981; Yin 2003). Within-case data was analysed and cross-case patterns (Eisenhardt, 1989) were identified to discern the governance trajectories of network organizations. In both forms of analysis, the main aim was to identify the essential stakeholder categories and their interactions in the FOSS HIS implementation ecosystem. The within-case analysis focused on identifying the stakeholder categories and longitudinal variations of their interactions. The cross-case analysis tried to identify differences between stakeholder interactions among two FOSS HIS implementation ecosystems.

4. CASE DESCRIPTION

Sri Lanka has a well-established and time tested health service both in preventive and curative sectors with a comprehensive paper based reporting system. Health service is free for all and most of the annual health budget is reserved for provisioning drugs and medical services. Hence, budget for IT is rather minimum. Furthermore, the Department of Health is not equipped with a software arm even though there is ICT cadre is in place at both the national and provincial levels. Sri Lanka has the added advantage of having a training programme in-built to the Department of Health for medical officers as a Masters programme in Health Informatics. Further to this, Sri Lanka is equipped with an eGovernment Policy[1] and a draft version of eHealth Policy and eHealth Standards and Guidelines. National eGovernment policy of Sri Lanka through its eGovernance initiative recommends the usage of FOSS as a cost-effective alternative to government sector institutions. Department of Health Services dominates the health sector governance process.

The District Health Information System version 2.0 (DHIS 2), upon which these SEs were built, is a flexible customizable, open-source health management information system developed by the Health Information Systems Program (HISP) of the University of Oslo, Norway through a global collaboration (Staring & Titlestad, 2006). DHIS2 was first introduced in Sri Lanka in 2008 as a public health information tool in the curriculum of master's degree program in Health Informatics conducted by the PGIM, University of Colombo in collaboration with the University of Oslo.

4.1 District Health Information System for Maternal and Child Health

Parallel to the Masters programme in Health Informatics started in 2010, several DHIS2 training sessions were conducted for public medical doctors starting from 2011 to showcase its capabilities as a customizable public health information system. The ministry of health officials were the audience for these workshops and the technical assistance was provided by the HISP India.

The first DHIS2 instance was customised as a student project of the PGIM for the MCH programme in the country under the supervision of a senior consultant of public health from the programme in January 2011. After adequate customization, the system was demonstrated to the health managers and consultants of the health programme. PGIM also mediated to seek permission to pilot the application in real life settings, but during the demonstration, trustworthiness of the customized DHIS2 application and data security was heavily questioned and approval was not granted to the proposed pilot project. After the initial failure, in April 2011, HISSL, which is the professional association responsible for

[1] http://www.icta.lk/en/programmes/re-engineering-government/129-policy-documents/1344-e-government-policy.html

popularizing health informatics in Sri Lanka negotiated permission for this pilot in the North Western Province of Sri Lanka. For this purpose, the previously customized application instance was used to set up an application server. To support the implementation, it was decided to sign a tripartite agreement between HISSL, Provincial Department of Health Services of North Western Province and HISP India who were to provide technical support. Unfortunately, the signing of the agreement did not materialize. However, the North Western Province permitted HISSL to conduct a pilot exercise under their supervision in the third quarter of 2011 before taking a decision on the province wide implementation. Five MOH areas[2], were selected for this pilot and initial training was provided to the staff of these areas. The data entry was commenced with the central application server provided by the PGIM, financially supported by the University of Oslo. The provincial health ICT staff was offered an international training program collaboratively conducted by HISP India and University of Oslo in January 2012. During the pilot phase the data entry was continued by Public Health Midwives under the supervision of MOHs in the first and second quarters of 2012. After the system was piloted for the two reporting quarters, a project evaluation report was handed over to the Provincial Department of Health to seek the permission to scale the system to 5 more MOH areas. However, the central MCH programme influenced the decision of the provincial health authorities and the piloting was abruptly discontinued. The reasons cited by the MCH programme were the concern that the DHIS2 application would negatively interfere with the ongoing processes, such as supervisory mechanisms, of the health programme.

After about a year's dormancy, in December 2013, another province expressed its willingness to use the DHIS2 customized for MCH reporting in a provincial scope. Hence, it was agreed to pilot the maternal and child health customization of DHIS2 in the Southern Province by the provincial health authorities and HISSL. PGIM assisted the implementation and the project was entrusted to a Medical Officer trained in health informatics. The mediation with central health programme was done through a Medical Officer-MCH attached to the Provincial Director of Health Services office. Necessary basic hardware was also provided to the all MOH offices of the Galle district and the system was piloted in 17 MOH areas with slight modifications to the previous design. The system was well accepted by the staff of the piloted district and is awaiting scale up to the provincial level. A series of interviews were conducted with the provincial health authorities after the system was piloted for about a year in July 2014, and the staff expressed deep satisfaction, especially in the ability of the DHIS2 to analyse data in different dimensions and present them as local dashboards. Medical Officer – Maternal and Child Health was guiding the implementation and liaise between provincial health authorities and Family Health Bureau. However, the key person coordinating the project was transferred to a different institution, and with this the project was halted even though pockets of data entry continue till today. Plans to get central approval and scale up the system province wide were halted with the transfer.

4.2 DHIS for Tuberculosis control programme

After the initial rejection of DHIS2 for MCH programme, its introduction was explored for the respiratory diseases control programme including Tuberculosis and other chest disease registry management (Figure 3). By this time there was a custom-made IS that had been implemented with limited functions. Inadequate support from the developers impeded the customization process leading to the TB programme deciding to discontinue this system. Further, the TB programme decided to use DHIS2 for Tuberculosis case management first. At the end of 2012, the customization process was started as an internal requirement of the TB programme and commissioned by the top hierarchy of the programme management. The

[2] MOH area is equivalent to Health Districts defined by World Health Organization

programme managers noted that the DHIS2 needed to be modified to a certain extent to accommodate all their requirements. HISP India conducted an end user and implementer training in May 2013. By this time, one state technical university had signed an agreement with the ministry to provide technical support for HIS implementations, including DHIS2. This agreement helped to boost the trust of the TB programme administrators towards DHIS2. There were several project management meetings conducted followed by the workshop involving the TB programme staff and from universities and HISSL. University of Oslo temporarily provided a server space for the pilot.

PGIM allocated 2 postgraduate trainees for the project and HISP India provided the necessary training. With these resources, the TB programme decided to expand DHIS2 beyond the Tuberculosis registry to Asthma and other chronic respiratory diseases case management as well. Since January 2014, PGIM has provided support for the customization process by providing a high-end server, located at the TB programme. The Tuberculosis IS was tested with the data from chest clinics and microscopy centres island-wide, whereas the Asthma component was tested using the data from Colombo chest clinic. The TB programme wanted to expand the Asthma component to a peripheral hospital based chest clinic also to test the robustness of the solution. In July 2014 there was an evaluation of the customized solution to identify its suitability for island-wide scaling. The meetings were directed to explore the possibility of integration of TB and HIV data to monitor co-infections under WHO guideline for the Three Interlinked Patient Monitoring System for HIV, MCH and TB (WHO, 2013). The TB programme administration also expressed their willingness in identifying co-infections with HIV and agreed to share the high level indicators with the HIV programme under integrated information architecture. University of Oslo experts reviewed the DHIS2 customization's design and advised on effective reuse of data elements, indicators and organization units. NTPCCD was satisfied on how the DHIS2 now comprehensively captured Tuberculosis data providing the ability to analyse multiple data dimensions in a flexible manner. Following the evaluation, a new funding opportunity emerged through a global donor for the scale-up process. However, there were no consensus between the donor and the TB programme on how to apply for this funding, and balancing needs of HIS with funding needs for supplies (drugs, laboratory equipments) management. So, the funding applied was lesser than estimated for the full scale programme-wide HIS implementation. In a follow-up meeting in December 2014, the consultant community physician in-charge of Asthma control expressed his approval to use the Asthma and COPD component of the DHIS2 customization in a programme-wide manner. He further requested to expand DHIS2 beyond the TB programme and to private sector chest diseases management as well.

Due to the budget limitations, there was a dilemma on how to proceed with the customization. HISSL volunteered to perform the essential customization required and to convince the TB programme administration about the sustainability of the open source approach. Parallel to this, the funding agency arranged two representatives, a Medical Officer - Health Informatics and a system administrator to be trained in Advanced DHIS2 training in Vietnam in early 2015. It was also proposed to integrate Tuberculosis and Asthma and COPD components of the DHIS2 customization to a single integrated solution. Similarly, there appeared the need for updating the new changes to the data collection forms in Tuberculosis and Asthma programme and to include Lung Cancer registry also to the integrated system. It was also planned to create a dashboard so that the funding agency can directly monitor the health programme's activities and aggregate reports.

4.3 National Foundation for Open Source Health Software (NFOSHS)

The initial discussion towards a national FOSS regulatory body for health sector came up in late 2012. A stakeholder group was formed and by February 2013 the initial version of the

constitution was drafted for the National Foundation for Open Source Health Software (NFOSHS). This group was inspired and guided by another FOSS regulatory body called Sahana Foundation[3] which was initiated as a Sri Lankan FOSS disaster management project and later scaled up to a leading global FOSS disaster management IS initiative. The discussion for the constitution went on for months with ongoing debates on the composition of the stakeholders and the authority to be vested to the foundation. Initially, the stakeholders selected included medical officers with health informatics qualifications representing various directorates in the Ministry of Health, the ICT Agency of Sri Lanka (ICTA), Health Information Unit of the Ministry of Health, several state sector and private sector universities and few non-health informatics health administrators/managers. Later the composition was altered to include all health informatics qualified medical officers, ICTA, Health Informatics Society of Sri Lanka, Sri Lanka Medical Association, some universities and few non-health informatics health administrators/managers. From the beginning, there was a representation from Sahana Foundation in an advisory position.

The objectives of the NFOSHS were to maintain an up-to-date list of applicable open source software solutions and to evaluate candidate FOSS software and to perform quality assurance of implemented software. The mechanism for achieving these goals was to establish committees including a Project Management Committee for key software recognized to be managed under the NFOSHS. To evaluate these FOSS applications, an ad hoc committee structure was proposed. These temporary committees would automatically get dissolved upon completion of the task. The project management committees were standing committees which had some authority vested under NFOSHS. These committees would act as a software incubator, to nurture the open source software and ensure it aligns with national health information needs. The voluntary community representation in this committee was decided in consultation with the NFOSHS. Within this framework, a Project Management Committee was suggested for DHIS2 as well. The National Foundation for Open Source Health Software was initiated on October 2013 followed by a series of discussions among prospective stakeholders involved with FOSS and software development monitoring/regulating. Unfortunately the expected results were not achieved and after these initial meetings, the foundation became non-functional.

5. Analysis and Discussion

To meet the growing demand of development partners' measurement and accountability requirements and challenges posed by the population dynamics and changing disease landscape, country health programmes are increasingly moving towards programme-wide HIS implementations. With the limitations of resources in LMIC contexts, enterprise FOSS is becoming increasingly popular based on multi-sector stakeholder participation including health sector, FOSS implementers, development partners and other governing bodies. The theoretical lens of this analysis is the SE. The stakeholder network and the FOSS framework are considered to form the SE surrounding HIS implementation in the empirical setting.

5.1 Revisiting Stakeholder Categories

Enterprise scale FOSS frameworks such as DHI2 require their generic functions to be extended. This is possible in FOSS due to the absence of licensing/subscription costs, which is not possible with proprietary software. This is contrasted with the potential advantages of custom software, such as, on-demand support and training, reliability of the roadmap and availability of professional services to support implementations. This process of further customization of an open source artefact under the Single Vendor and Service/support

[3] http://sahanafoundation.org/

Commercial Open Source Model is referred to as *productisation. (*Dixon, 2009).

When considering the early FOSS models (prior to the Open Source 2.0 concept) they mainly focused on open source projects and the volunteer developer communities (Krishnamurthy, 2003). Commercial firm's developers have an extended role in Single Vendor Commercial Open Source model beyond releasing the software to participate in the support, services and product management. This is particularly important in the generic open source software model where the features of the software have to be continuously aligned with the business needs of the organization. However such customization related services can be provided not only by the FOSS firm, but also by the implementation mediator, who can be either internal or external to the client organization. Apart from the developer community, the open source firm and customers are supported by several other entities, and thus cannot be explained using the Single Vendor Commercial Open Source Model. To fill this gap, the Service Support Open Source Model has evolved. In this model, the development is assigned to a third party service entity. However, in some cases, the FOSS developer firm also provides the customization and implementation support to the client organizations. However, this model fails to explain the role of other supportive entities, like funding agencies and standards enforcing bodies.

Single vendor commercial open source model has three key participant groups, namely; core developers (referred to as the commercial OS company), OS volunteers (referred to as community) and the end users or clients (e.g. Ministry/Department of health or individual health programmes). The model represents the productisation of the FOSS artefact as a process carried out by the vendor OS development company. However according to our observations, implementing an HIS using DHIS2 (making a 'whole product') needs a substantial health/medical input and unique approach due to the heterogeneity of country/programme specificities of health systems. The MCH programme administrators once mentioned, "We [MCH programme] need to see the data entry forms as per the exact design of the paper form, so as it won't confuse users. We also need all existing data elements and indicators in the electronic solution". Hence, carrying out such implementation is beyond the capacity of a globally placed developer team. Open Source companies may have a sales and marketing team who manages the productisation process (and user support and community management). However, this model is not sensitive enough to accommodate the role of third party implementers who play an important role in aligning the OS product with the health programme's business needs. Hence, the Service/Support Commercial Open Source model is proposed where the service provider replaces the productisation role performed by the developer team of the Single Vendor Open Source Model.

However, according to the empirical experience, several aspects of current FOSS stakeholder modelling are required to improve in order to understand the stakeholder interactions while focusing the governance dynamics within the SE. Empirical evidence suggested that the better coordination between key stakeholder groups was a significant effect on FOSS implementation trajectory. This was highlighted in project implementation meetings as well by implementer team as "In North Western Province, we [HISSL/PGIM implementation team] failed to maintain a good coordination with central authorities. So, we should maintain a good conversation with the central authorities in Southern Province implementation". As per the first research objective, following stakeholder groups were identified as the essential categories. They include the core development team (e.g. HISP global team), implementation mediators (e.g. individual implementation mediators, implementation service firms) and FOSS client organizations (e.g. health programme managers/administrators on representing organizations) and the FOSS community (volunteer implementers and developers). Apart from these actors who are directly involved with the FOSS product, it is possible to identify two major auxiliary stakeholder categories (internal

and external) that influence the FOSS implementation trajectory. Auxiliary internal stakeholders consist of local health administrators and policy-makers such as ministry of health. Global standards enforcing bodies and international development partners (funding agencies) are auxiliary external stakeholders. We observed that the funding partner was guiding Tb programme to use DHIS2 when they were considering several options, demonstrating the ability of an Auxiliary External stakeholder to influence the FOSS acquisition governance decisions.

Hence, drawn from the theoretical background presented in the section 2, we would like to propose an alternate model (Figure 4) to understand the stakeholder interactions in OSS HIS implementation ecosystem. In our theorization of FOSS implementation ecosystem, the Auxiliary External Stakeholders possess the ability to influence client firm, implementers as well as developer form, whereas Auxiliary Internal Stakeholders' scope of influence is limited to the client firm and implementers. The main interaction between the client firm and implementers are implementers supplying 'whole product' (customized FOSS solution) to client firm in exchange of payments for the service of implementers. The main interaction between FOSS developer firm and implementers are, making available of the FOSS framework to implementers by FOSS firm in exchange of various services (such as, OSS bug reporting, channelling user requirements shaping future developments, promoting FOSS framework among prospective clients) rendered by the implementers. We would like to highlight the knowledge exchange (two-way arrows in figure4) between developer firm and the developer community and; between implementers and implementer community.

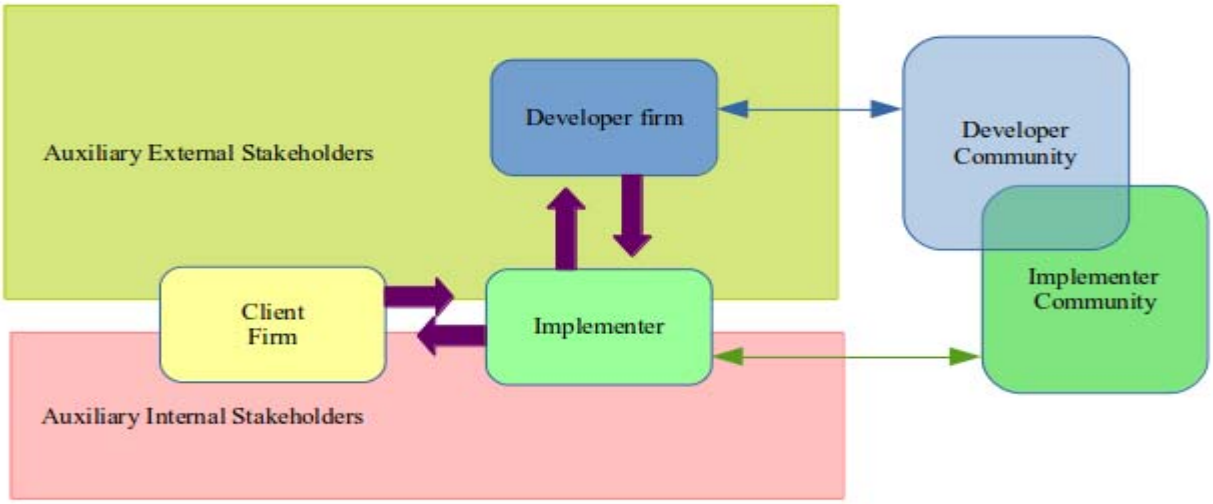

Figure 4. FOSS 2.0 Implementation in Health Sector: Deciding Organizational Actors

The community member is an individual voluntarily contributing to the open source project by providing use cases and peer reviews as well as assisting in testing, translations and bug fixes. The community members can function either at the implementer or developer levels depending on their health and information technology expertise. They could have boundary spanning behaviour (Perrone, Zaheer, & McEvily, 2003) conveying FOSS expertise to the health domain. This model represents an overlap between developer and implementer communities. The reason for this overlap is, in some occasions we noted that expert implementers has the ability to interact with the developer community to solve complex issues they faced during the implementation (usually such issues need code or database level modifications). So, there is a possibility for a functional overlap within an experienced implementer between the roles of a developer and an implementer. This was noted during

observations sessions as some implementers registering in DHIS2 developer forum in addition to implementer forum to look for solutions for some complex implementation issues. Hence, an experienced implementer, who can play a developer role may register in a developer forum and interact with the FOSS developers to seek answers to implementation issue. This boundary spanning behaviour is represented as the overlap for the simplicity of the proposed model. According to our empirical findings, when a FOSS community member is employed by a customer firm, the boundary spanner role they play strengthening the 'sales' contract between the customer organization and the open source 'vendor' (FOSS firm). When a community member is working for a customer (e.g. Medical Officer - Health Informatics who are also a DHIS2 community member), the community member's experience leads him/her to significantly influence the governance decisions as a boundary spanning agent. We can quote such instance where an implementer in Tb programme once mentioned as “I [the internal implementer] talked to … [core DHIS2 developer] in the forum and got a good answer. So, I explain director that this [a functional requirement of the Tb programme] is possible with DHIS2”.

The Auxiliary Internal stakeholders could be national standards enforcement bodies, health administrators and policy-makers. They have a certain influence to decide the implementation trajectory in the initial phases of implementation. The Auxiliary External stakeholders, namely, the globally operational (international and regional) funding agencies and global standardizing bodies, have more control over the core open source developer team through their financial contributions and health and information technology standards. They also exert certain control over implementers as well as clients through similar means. Especially, the funding agencies can exert control over HIS client organizations through their reporting requirements and financial allocations. The Auxiliary Internal stakeholders whose scope is national and local have little or no control over globally positioned open source projects. However, local authorities exert their influence over implementation mediators as well as clients through their guidelines, standards and local health policies.

5.2 The Stakeholder Interactions in FOSS HIS Ecosystem

Establishing key stakeholder group and evolution of the control mechanism (formulating the strategy/policy, re-mediation and communication) are major components in the open source governance process (Kemp, 2010). The selected cases, which were studied during this study indicated the necessity of the interactions of various stakeholders to realise an HIS implementation. The composition of this multi-sector stakeholder network varied depending on the scenario and during various stages of the course of implementation. However, FOSS developers and the implementation mediators were essential support to the client health institution in each SE. The implementation mediators (customization agents) ranged from external or internal and individual or firm. For the TB programme, internal (individual) implementation mediators played an important role, and towards the later part of the project HISSL took over the implementer’s role delivering necessary technical customizations. In the MCH project, the implementation mediators were mostly external (HISSL & PGIM). A strong inter-organizational coordination was noted through a boundary spanning role in Southern province during the initial phases of implementation. During this phase, few organizational champions exercised a clan control mechanism for the project governance. When analysing the governance of external technical stakeholders’ in this SE, the local health administrators had little influence over the global (core) development team and its decisions. However, the implementation mediators were able to facilitate this governance process. For example, in a Tb programme’s stakeholder meeting, an administrator mentioned, “… Ok, we [administrators] are not sure about these IT stuffs. They [pointing at implementer team] are the IT experts. So, let’s go by their [implementers’] decision”. On the other hand, funding

agencies had closer contacts both with the global team and local health administration, and facilitated both the strategic and operational approaches to influence the HIS implementation decisions of the SE.

Our empirical exposure revealed that FOSS customization tasks (extending code base to accommodate new feature requests, deploying server and implementation) could also be delivered by a supportive team emerging from the core FOSS developers. However, more importantly around enterprise scale HIS projects, third party supportive entities emerge as customization and implementer firms. This implementer group would customize FOSS solutions and extend the capabilities of the FOSS framework (creating the 'whole product' from open source framework) to align it with the organizational business needs (user requirements of the client organization). This group has an important role in open source governance also, namely, to select the appropriate OSS version (open source discovery) to implement the organizational IS; requirement aligning and further customization; minimizing business risks by open source licence management and ensuring open source product compliance with organizational policies.

Outsourcing the implementation to external implementation mediators proved to be a quicker way to achieve a good quality product as proposed by Nagy, Yassin and Bhattacherjee (2010). However, in the long run, this inhibited the development of local capacity. For example, during the later phase of the MCH and the TB programme projects, the lack of internal capacity impeded the growth of the projects. When the internal implementation mediators had a better understanding of the technical aspects of DHIS2, they played a relatively strong role as a boundary spanner to gain the confidence and trust of the health managers and administrators. Tb programme showed us another example to highlight how important the FOSS expertise of internal implementers when the play the boundary spanning role. Initially the TB programme administration was not convinced about DHIS2's ability to manage Asthma cases. By that time, Asthma case management system was using an older version of DHIS2 tracker with limited functionalities. During several meetings in October 2014, this issue was discussed in detail and the new features of DHIS2 were explained and its adequacy to support the TB programme's business needs. The reason for this misunderstanding was mainly due to lack of experience of the internal implementer on DHIS2 release process and hot to synchronize the customization with the frequent release cycles of DHIS2. Hence, a wrong message was conveyed to the central health administrators and HISSL had to take an additional effort to rectify the situation and reassure the decision makers.

In the SE surrounding the DHIS2 customization for MCH, the stakeholder network consisted of Ministry of Health, MCH programme of the Family Health Bureau, provincial health authorities of North-Western and Southern provinces, HISSL, PGIM and HISP India with the MCH programme being the dominant stakeholder. Initial phases of the North-Western provincial pilot project ran with the informal-interpersonal coordination, which occurred mostly through personal contacts. This later became a formal-interpersonal coordination, which is still an inter-personal communication, but under official supervision of provincial health authorities. During the Southern province implementation the formal-impersonal was the coordination mechanism of choice, where all decisions were taken by an official body and conveyed to all stakeholders though official channels. At the North-Western Province the project demonstrated clan control where decisions were taken by a group of individuals. The output control was minimal where little attention was paid to the timely delivery expected outcomes. However, in the Southern province, the project utilized some behavioural control mechanisms (overseeing the stakeholder actions in SE), such as project status review meetings and on-site coordination and control with client organization’s strong involvement in planning and periodic reviews.

Compared to the North Western Province approach, in Southern Province, provincial health authorities played a major role in governing the implementation providing administrative leadership and supporting liaison with the central MCH programme. DHIS2 customization for Tuberculosis and other respiratory diseases management was also carried out under the governance of the TB programme. Other members of this ecosystem were, PGIM, HISP India, core DHIS2 developer team and HISSL, and adhered to the governance of the health programmes leading to better outcomes. Where successful interactions were seen in SEs, the coordination mechanism was largely formal-impersonal and the control mechanism being formal. In such situations the SEs demonstrated behavioural and output control measures, such as status review meetings, conference calls, on-site coordination, problem queries, change control, follow-up visits, and monitoring of interim deliverables.

Ordinary FOSS users are neither FOSS developers nor FOSS community members. In the health sector, they consist of end users employed by the client organisation as well as the administrative layer of the client organization, who are usually not familiar with FOSS concepts. In enterprise-wide HIS implementation, this group may consist of external collaborators or supportive stakeholders of a large scale HIS implementation, such as funding agencies or standards enforcing authorities. The functions they expect from software tend to be routine and standard and they lack level of technical sophistication which is necessary to initiate a FOSS acquisition process. This is an important barrier in institutionalizing a FOSS IS in an HIS ecosystem. Similarly, during the study it was revealed that the open source governance is not a familiar concept among health managers and administrators. However, open source license, hidden cost of software maintenance, ownership of source code, data security and hidden privileged system access retained by developers/implementers were some concerns among the health programme administers (Paré et al., 2009). The quote “...How can we trust whether DHIS2 implementers use data for their own agendas which is entrusted to them for testing purposes...” by a central level health programme manager is an example of such concern observed during the study. It was noted that most multi-sector stakeholders were legally independent of each other, even though they were in mutual agreements to cooperate. During the early phases of implementation, the mode of control is of clan control and the decision making is done by a group of members in the team. Later this governance mechanism evolves to include behavioural and output control. What brings the different organizations in the network come together to form a network is their respective specializations and resources they can bring in to realize the FOSS implementation. The interactions in this SE are initiated with interpersonal coordination which with time get increasingly formalized.

The services' domain experts are providing is an important aspect in a SE. In HIS implementation ecosystem, this amounts to clinical care provision and interruption of which will be a serious matter. Hence, medico-legal concerns also inhibits the FOSS adoption process (e.g. possible service interruptions or harm inflicted to patients due to the inadvertent use of open source) and requires adequate legal protections and technical sophistications in the contracts. For example, in a one NFOSHS meeting a health informatician tabled an issue, “What happen if some thing happened to a patient due to the coding issue of an electronic health record? Not showing an alert when prescribing a drug for which patient is allergic could be lethal. In open source, the system is free, but who take the responsibility of this kind of technical issue?”. The total cost of ownership is also a major concern we noted in empirical setting. This was conflated with the notion of ‘free’ in FOSS definition. The DHIS2 proved expensive in relation to custom software development in the TB programme project, and this was repeatedly questioned by the administrators and escalated to a state of impending breach of trust towards DHIS2. “You [implementer] said in a previous meeting that this is a free software. So, how could it be this ” The uncertainty that surrounds OSS

included risks related to the OSS supply chain (e.g. a FOSS release being postponed) and project and product related risks, which adversely influence trust relations between the health administrators and implementation mediators. Due to these reasons, at each level professional support was expected by client organization since OSS was seen as an unprecedented implementation challenges (Marsan et al., 2012).

Not having a formal OSS policy has been identified as a barrier to open source adoption (Marsan et al., 2012) and Sri Lanka was not an exception. The National Foundation for Open Source Health Software was a remedial measure suggested, to serve as a software incubator; to nurture open source heath software with the participation of community based code committers. NFOSHS was based on open source developer community governance models such as the Wild Hive model (Dixon, 2009). In establishing NFOSHS, Ministry of Health failed to consider emerging commercial open source model where third party implementers/suppliers play a prominent role in supporting the acquisition process.

6. CONCLUSION

The aim of this study was to identify the essential stakeholder categories involved in open source FOSS HIS implementations in LMIC context, and; to understand the stakeholder interactions in these SEs at different stages. As we argued in this paper, the three key stakeholder groups who are critical to the FOSS implementation ecosystem are client organization, FOSS developers and the implementers. Around this relationship, there were supportive stakeholders who participate as internal or external stakeholders to the client firm's business process. Hence, in this paper, we contributed in expanding our understanding of the role of different key stakeholders involved in the early phase of implementation. We also contend that the success of the early phases of implementation depends on the trust relationship between these key organizational actors. Even if the model proposed in figure 4 theorised in relation to the FOSS implementation in health domain, this may be applied to analyse OSS ecosystems in other domains as well. Further, this model can be a source to understand the governance trajectory of non-OSS projects as well since the client organization, software supplier and auxiliary stakeholders identified in the proposed model are common to custom software development and software procurements. Hence, it is possible to generalize this model to a range of software acquisition scenarios.

The mutual exchanges and influences in FOSS implementation ecosystem among different stakeholder groups can be explained using the proposed model in figure 4. Implementation mediators and developers may provide the whole product to the clients whereas implementation mediators in addition, will provide end user training and on-site consulting services. The implementers could be an extension of the FOSS firm, 3rd party implementation team or an internal implementer who was employed by the client firm. A client form employed internal implementer can be seen as a boundary spanning agent conveying domain concept to the FOSS development realm and drawing FOSS technical expertise to the application domain. Hence, the internal implementers have a significant influence over the FOSS acquisition process.

Open source is seen as a risk to be managed by client organizations, especially in aligning the business needs and FOSS supply chain, over which client organizations have no direct control unlike in custom software development. This risk can be mitigated by exploiting the boundary spanning role implementers play. The client organization can use FOSS implementers to convey their business requirements to the FOSS firm through implementers. Similarly, implementers can assist the client firm to align OSS versioning and software releases with the OSS implementation plan. Similarly, the potential role of the Auxiliary External Stakeholder category suggested in the figure 4 should not be undermined during the implementation process.

Coordination is prominent and essential between implementation mediators and client firm and in some cases between core open source developers (FOSS firm) and implementers. For an open source implementation to be successful, it is recommended to establish formal and impersonal coordination mechanisms at an early stage to facilitate institutionalization independent of personal interests. Output control mechanisms, such as interim deliverables are valuable in facilitating SE governance by evaluating the software artefact development trajectory incrementally.

Clients are not interested in FOSS per se, instead they demand the 'whole product' to support their business process. FOSS sometimes conveys the message of' free software' and when implementation requires substantial financial commitments (cost to hire implementation agents and further coding on FOSS code repository). Hence, client organizations need to develop their internal expertise in long run after moving to an open source SE. This implementation cost of an open source software is highly contradicting against the fact that the software itself being offered free of charge. Hence, in a such situation, justifying the implementation costs of open source software needs to present the benefits of implementation services and to contrast the mediated implementation with non-mediated implementation to highlight the whole product resulted by open source customization process.

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V

Open Source Software Ecosystems in Health Sector: A Case Study from Sri Lanka

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Abstract. A software ecosystem consists of a software platform, a set of internal and external developers and domain experts in service to a community of users that compose relevant solution elements to satisfy their needs. Open source is well-known for its potential to frame software ecosystems with its networking tendency and provision for further customization with access to software source code. Open source is increasingly becoming the choice for health information system implementations in low resource settings.

This longitudinal case study was designed to study the research question, how a software ecosystem is being built around an open source health information system implementation. Empirically the study was positioned in a multi-sector initiative identifying and support nutritionally at-risk households to eliminating malnutrition. The discussion reveals how new dependencies between health and non-health sector actors were created with the emerging software ecosystem based on an open source framework and supplementary custom-built web and mobile components.

Keywords: Software ecosystem · Free and open source software · Health information system

1 Introduction

Compared to the traditional software project perspective, software ecosystem (SE) is an emerging trend within the software industry [1]. A SE typically consists of a software framework, internal and external developers, domain experts and a community of users that compose the relevant solution elements [2]. The SE is the choice to construct large software system on top of a software framework by composing components developed by actors both internal and external [3]. Hence, Free and Open Source Software (FOSS) provides a viable framework for growing a SE from the angles of implementation technology, development methodology and governance [4]. Being a relatively new concept, SE has not been discussed adequately in the IS discourse [5]. Hence, SE literature needs more empirical studies from various domains, such as open source and health [6].

Sri Lanka possesses a well-established health care delivery model, with most of the health indicators are at a comparable level to those of the developed world. However,

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the nutritional indicators were lagging behind compared to other health indicators. Malnutrition has a multi factor contribution including both health and non-health denominators. Thus, the revised National Nutrition Policy (NNP) of Sri Lanka [7] suggested inviting non-health sector stakeholders to the nutrition management tasks giving them active roles in eliminating malnutrition. This demanded an integrated information system to monitor nutritional status and to track health and non-health intervention to coordination across different sectors. An open source HIS with supplementary custom developed web and mobile components was introduced to overcome the challenge of integrated information need across different sectors. This FOSS HIS implementation around multi-sector participation was an ideal empirical setting to study a domain specific SE. Hence, a longitudinal case study was aimed at understanding how a SE is being built around an open source HIS implementation, expecting to contribute to the growing body of knowledge on SE.

The organization of the rest of the paper is as follows. The second section reviews the current literature on the theoretical underpinning of the study while the third section elaborates the research approach and methodology. The next section reveals the findings of this longitudinal case study. Followed by which, the fifth section presents the analysis and the discussion leading to the conclusion of the study which is presented in the section six.

2 Theoretical Background

2.1 Software Ecosystems

A SE is a means to construct a large software system on top of a software framework by composing components developed by actors both internal and external. For the purpose of this study the SE was defined as to "*consists of a software platform, a set of internal and external developers and community of domain experts in service to a community of users that compose relevant solution elements to satisfy their needs*" [2]. This perspective differs from traditional software project approach in several important aspects. In a SE, the initiating actors (the client organisation) don't necessarily own the software produced by the contributing actors and may not hire the contributing actors [3]. In comparing traditional software projects to SE, it was shown that the scope of a traditional software project typically is intra-organizational. Whereas the scope of a SE is much broader and is including external developers and the further extensions that they provide as well as contributions from other parties [8]. SE are mainly categorised in three broad categories as being operating system-centric, application-centric and end-user programming centric SEs [9]. The application-centric software ecosystems, such as the empirical setting of this research, is organised around a domain specific application.

The general composition of a SE is the software firm (framework developer), (3rd party) software suppliers, client firm, intermediaries and client firm's customers. According to Dittrich [1] framework developers and 3rd party application developers are both important in a SE. This is particularly the case in the FOSS domain, where the core FOSS firm plays the role of framework developers. In this context 3rd party

developers and FOSS implementers play the role of application developers working on extending the generic functionalities of the open source framework by aligning it with the needs of the implementation domain.

2.2 Open Source

FOSS is a well-established practice to manage both software development and distribution. It permits access to the software source code, together with the permission to modify the source code as well as to redistribute the derived works[1]. Given this kind of end-to-end control, FOSS is generally a good a framework for building SEs [4]. Open source software provides the capability to develop complex systems on freely available source code and enables constructing a SE without large initial investment [10]. FOSS reduces system implementation costs by eliminating vendor monopoly. Furthermore, it promotes indigenous technology development by allowing access to the source code which facilitates the global to local transfer of knowledge [11]. Additional benefits of FOSS include vendor neutral technology through free access to the source code and reduced total cost of ownership with no licence fee [12].

The open source phenomenon has undergone a significant transformation from its free software origin to a more mainstream, commercially viable form which is referred to as *Open Source 2.0* [13]. Clients are willing to pay for customizing Open Source Software for organizational business needs because customization related services are critical factors influencing the OSS adoption in many organizations [14]. Hence, FOSS firm also look to 3rd party software service providers to add specific functionalities to the core framework, which is beyond the capacity of FOSS firm alone. Several FOSS governance models are suggested to describe this 3rd party contribution in open source adoption, such as the Third Party Service Provider model proposed by Krishnamurthy [15]. This FOSS business models can be regarded as a stakeholder participation model in SE around open source adoption.

3 Research Approach and Methodology

This longitudinal interpretive case study was conducted in the State health sector of Sri Lanka over a period of two years from 2014 to 2016. It was empirically situated within a large scale FOSS HIS implementation effort, which is aimed at establishing a multi-sector stakeholder network consisting of health and non-health sectors around the implementation of a nutrition information system. We positioned ourselves within the qualitative research practice [16] with a case study approach [17]. The empirical work was guided by the research question, how a SE is being built around an open source HIS implementation. The reflection of the findings followed the interpretive tradition.

[1] Open Source definition, https://opensource.org/osd.

3.1 Data Collection

The data collection was done focusing on stakeholder behaviour of the SE around the open source HIS implementation for the Nutrition Monitoring and Intervention Tracking project. The empirical setting included the State health sector institutions in three districts, two public administrative settings and a central coordinating unit. The multi-method approach included participant observation, interviews, focus group discussions and document analysis [18].

Participant observation was a main approach of gathering data providing an overview of the stakeholder behaviour and the evolution of the SE. The observation were done during the project steering meetings, HIS and non-health IS design and implementation meetings and web and mobile application training sessions. The settings for the participant observation sessions included the central coordination unit, three regional and 17 peripheral health units and two peripheral administrative units. In-situ interviews were conducted during the participant observations to clarify the decisions taken on the SE trajectory and the stakeholder participation.

When interviewing the multi-sector organizational actors, semi-structured interviews and focus group discussions were used. Health managers and non-heath sector administrators were the key informants in the semi-structured interviews. They provided rich insights to the process of decision-making during the HIS implementation. This study used data from eight interviews with health managers, 11 interviews with the administrative sector managers, five interviews with the representatives of the funding agency and 12 interviews with FOSS implementers and 3rd party developers. Medical Officer of Health (MOH), Medical Officer – Maternal and Child Health and Public Health Midwives (PHM) were the participants in focus group discussions on mobile app and FOSS HIS back-end at peripheral level. The health sector group discussions included 17 MOH areas. Five group discussions were conducted with participation from the health and public administrative sector actors, funding agency and FOSS implementers. Participant observation and interviews were supplemented by the document reviews for a deeper understanding. The documents analysed comprised of email communications, project steering meeting and evaluation meeting minutes, official letters and policy documents related to the HIS ecosystem.

3.2 Data Analysis

During this study the raw data was recorded as manual field notes at the time of interviews and participant observation sessions, which were later transcribed into complete manuscripts. Interview data was compared and triangulated with other evidence such as participant observations and document analysis. The data analysis follows the interpretive tradition [19]. A basically inductive approach [20] was followed when interpreting field notes to understand the FOSS HIS ecosystem trajectory.

4 Research Findings

In Sri Lanka a nutrition policy was first introduced in 1986. However, the nutritional status of children were not satisfactory although a wide range of programmes from growth monitoring to nutrient supplements had been ongoing for many years.

4.1 Multi-sector Stakeholder Network

Hence, in August 2008, Department of Health appointed a task force to revise the NNP [7]. The committee apprehended the fact that the nutritional well-being of a population is influenced by determinants that cut across the areas of responsibilities of different sectors which extends beyond the scope of the Department of Health. The revised NNP was expected to provide a framework for inter-sectoral coordination in order to accelerate efforts to achieve optimum nutritional status. However, Department of Health alone could not achieve the multi-sector coordination. In this regard, the conventional paper based reporting system was not sufficient to facilitate the required multi-sector coordination to achieve the objectives laid down by the NNP.

In 2013, NNP was revised again and the National Nutrition Secretariat of Sri Lanka (NNS) was established to achieve a better coordination of multi-sector activities prescribed by NNP. The NNS was positioned directly under the Presidential Secretariat of Sri Lanka giving it the capability of inter-departmental coordination. A major task of the NNS was to develop the Nutrition Action Plan targeting the priority areas for action. NNS was entrusted to monitor and evaluate the progress of activities under the Nutrition Action Plan at National, Provincial, District and Divisional levels. Three districts, where malnutrition was prevalent, were selected to launch the pilot project. Under this project, MOH and Divisional Secretariat were the main coordination points for the health and non-health sectors respectively at the lowest administrative level. Field level multi-sector coordination was assigned to the Village Committees, which has the PHM as the focal person to identify nutritionally at-risk households. 'Grama Niladhari' (government officer to the village), 'Samurdhi Niyamaka' (government appointed social service officer), Agricultural Extension Worker and Development Assistant helped PHM to identify root causes for malnutrition during Village Committee meetings.

4.2 Implementation of the IS

NNS facilitated the implementation of an information system to realize the multi-sector coordination. Initial meetings were coordinated by the NNS and attended by health and non-health sector stakeholders, funding partners and HIS implementers. The open source public health information system framework, District Health Information System[2] (DHIS2) was used as the HIS back-end. Selection of FOSS was due to several reasons including the encouragement from funding agency for its potential sustainability with

[2] https://www.dhis2.org.

global contribution, satisfying the guidelines of national eHealth policy on software source code ownership and not having a recurrent licensing cost. DHIS2 was customized as per the requirements of the Nutrition Action Plan under the supervision of the NNS and the Department of Health. A significant customization was needed to adapt DHIS2 to cater the specific requirements laid down by Nutrition Action Plan. Sub-components of the IS were shaped by the functionalities prescribed by the Nutrition Action Plan.

Initially the system architecture was designed as a single component. However, there were some concerns among health sector stakeholders, such as, "Health information is too sensitive to be seen by 'Grama Niladhari' or 'Samurdhi' officer. So, the two systems cannot be a single integrated solution". Hence, later it was decided to keep the health and non-health components of the information systems separated due to the sensitive nature of health information and the information system was then designed as two separate sub-systems within a single SE. The selected information of the families with malnourished children supposed to be entered to the system by PHMs, who were appointed as the field level data collection operatives. It was agreed to share the data gathered to the HIS component with the non-health sector component only after removing the socially sensitive information. To assure the privacy and confidentiality of health data, only the minimum essential data set required for nutrition interventions were shared with the Village Committee and other non-health sector stakeholders.

The proposed HIS design demanded PHMs to enter data during home visits. This required a portable solution for PHMs instead of the standard web interface of DHIS2. Hence, NNS suggested PHMs to be given a mobile device for field level data collection. However, due to several unique requirements Nutrition Action Plan laid down, the native DHIS2 mobile app was not adequate for this purpose. Further, the DHIS2 mobile app was not fully developed to the potential of its web counterpart at the time of implementing this multi-sector nutrition IS. After several rounds of discussions, it was decided to develop a custom smart phone based mobile app as the field level data collection tool. The mobile app development was an iterative process where prototypes were created and feedback was received for the interfaces from NNS, Department of Health and the funding agency. The DHIS2 web Application Programming Interface (API) was used to communicate between the mobile app and the central server. The mobile app design was shaped by the inputs from the PHMs as well. The coding of the mobile app was outsourced to a third party software development firm by the HIS implementers. 600 smart phones and 70 laptops were provided by United Nations Children's Fund to pilot the system in the three selected districts. In-service, on-site training programme was conducted in each MOH area for MOHs and PHMs on mobile application and the DHIS2 based data analysis back-end. The pilot was supervised by NNS and the Department of Health. The development of the non-health components was negotiated in parallel to the piloting of HIS component. The non-health sector system was designed to track interventions done by the multi-sector stakeholders. A custom web app for the DHIS2 back end was developed to facilitate easy visualization of the intervention taken by the Village Committee and Divisional Secretariat level coordinators.

We observed that the implementers used to express their concerns about the weak technical documentation during custom component development. "We need support on integrating the custom modules/apps through web API. If support is available, we can

speed up the development. Otherwise, it is a very time-consuming to study the API calls, especially when the API changes rapidly with frequent release cycles [of DHIS2]" was a such concern. We noted that client organization and the funding partners were also questioning about the support implementers get from the FOSS firm. "What would be the support you [implementers] are getting from DHIS2 community? If their support is readily available, we believe that this implementation would be more sustainable" was such a quote made by the funding partner.

5 Analysis and Discussion

In this section we discuss how a SE is being built around an open source HIS implementation. In this study the software framework is the DHIS2 open source HIS framework and the solution element it built was the nutrition monitoring and intervention tracking system. The internal developers are the HIS implementers employed by the NNS and the external developers included core DHIS2 team and the 3rd party software firm who developed the mobile and web components. Domain experts were the MOH and Divisional Secretariats who supervised the nutrition assessment and interventions. The community of users mainly included PHM from health sector and Village Committee members representing non-health sectors.

5.1 Emergence of the SE and Its Composition

Software implementation exercises need to consider the end user requirements as well as the needs of client organization commissioning the software customization [1]. In this study, the most important requirements leading to the inception of the SE were the need for the field level nutrition surveillance and the tracking of the multi-sector nutrition interventions enabling a collaboration across domains. This stakeholder integration in the SE emerged on top of the IS. Otherwise, these actors would have operated with fragmented information flows. According to Hanssen [5], SE emerges through the use of a technology focus, which in this case study was the open source framework, DHIS2. The selection of FOSS as the candidate technology was decided not only by the ability to align with the business requirements, but also the ability to comply with the policy and financial considerations. The scope of the SE is much broader than a single IS project, through the software extensions (e.g. web and mobile apps) provided by the external contributors [2]. The integration of 3rd party components with the core software framework makes the SE to expand beyond the conventional organizational boundaries. In the empirical setting this was evident from the use of custom components, which were integrating multi-sector stakeholders to a single SE.

In application-centric SEs, the aligning of software architecture to the organizational structure also plays a crucial role [2]. This was the case for DHIS2 and the multi-sector nutrition intervention tracking effort as well. FOSS doesn't incorporate special features that are catering only for minor sub-sets of users. Instead, FOSS framework such as DHIS2 aims at generic solution that can be accessed through APIs, on which custom component development may be used to develop special features by

customising and extending generic functionalities. In this context, it was important to simplify the contribution of 3rd party developers. Not having a sufficiently detailed API documentation was a major drawback which delayed FOSS implementers developing 3rd party components.

In additions to its particular technical characteristics, the evolvement and behaviour of the stakeholder network is also a unique feature of the SE [5]. In general, a FOSS SE would comprise core FOSS developers providing a framework for 3rd party developers together with several layers of actors customizing and configuring the software product [5]. Similar features have been demonstrated in this paper, where behaviour and perspectives representing multiple organisations have been interacting and forming the SE. In a SE there will, at any time, typically be a leading or central organizational actor, which is referred to as the central referent organization [5]. The NNS emerged as the central referent organization in this case study. However, towards the later phase of the study, the HIS implementer played this role.

The network organization in this case comprised health sector and non-health sector organizational actors as domain experts and end users. The global DHIS2 implementer community and 3rd party mobile/software developer teams were indirectly involved in the implementation effort through the HIS implementers. As Bosch and Bosch-Sijtsema [2] mentioned, software ecosystems build new dependencies between components and their associated organizations that did not exist earlier. In this case study, the health and the non-health components of the system formed new links and dependencies between health and non-health actors, which were not there before. The overall objective of the project is to deliver coordinated nutritional services. For this objective to be achieved, the 'new' interdependent cooperation between different sectors that have evolved within the SE will need to be further strengthened and sustained.

FOSS implementers and 3rd party solution developers are important players in the FOSS SE [5]. The 3rd party developers are key actors as they are aligning and adapting the generic FOSS solutions to the specific domain needs by developing custom components. However, encouraging the 3rd party developers to contribute back to the FOSS code base is also important. The HISSL implementation team have contributed back to the code base by providing feedback and new requirements, which is as important as 'code' in a literal sense. DHIS2 core developers and developer community have supported 3rd party developers in Sri Lanka to understand the API, which is a key technology enabling integration of 3rd party contribution to the FOSS framework. However, active support is needed from the FOSS firm towards 3rd party developers and implementers in this regard. Evidence of the FOSS firm providing active support to the implementers improved the client organization's trust on the FOSS product as well as on FOSS implementers.

IS projects are in constant negotiation of boundaries within a SE [21]. In a software project, the technical negotiation happens on the boundary between local and global software development networks. For the domain specific negotiations in this case, the inside is the health domain and the outside is the non-health domain. Domain specific negotiations take place at the boundary between health and non-health through the PHM in this case. Over time, the stakeholders experienced the SE and its components were influenced by such negotiations. As a result, new spaces for negotiation, such as the Village Committees, emerge as the organizational structure of the SE is stabilizing.

PHM functions as a domain specific boundary spanning agent [22] in the nutrition intervention domain, freely moving between the health sector and the non-health sector. In the technical space of the SE, another boundary spanning role was noted for the role played by the local DHIS2 implementers. They bridge the gap between FOSS developer community and the 3rd party component developers to whom they outsourced custom component development.

In the long run, uncertainty about whether the 3rd party components will be integrated with the FOSS code repository will also be an important factor in motivating external developers. Third party components with sufficiently generic use cases are potential candidate components to be merged with the FOSS code repository.

6 Conclusion

SE is a new business model which needs the contribution from new empirical domains to be further developed to include domain specific behaviours. Hence, we expect the lessons presented in this paper to help FOSS firms, implementers and clients to better understand the ecosystem building processes and how a sustainable ecosystem in the FOSS HIS domain may be developed. Some findings may be applied to custom software development ecosystems in the health domain and others may be applied to FOSS ecosystem development in general.

In LMIC context, multi-sector SE can be developed to enhance local technical capacity, which would otherwise be impossible to maintain in the State sector. Application-centric FOSS SEs contributes to this aim by providing access to the code repository and developer community. However, the presence of FOSS implementers and 3rd party component developers are essential for a viable FOSS ecosystem to emerge in LMIC contexts. The FOSS firm and domain experts (client organization) alone are not sufficient.

A SE has internal and external stakeholder networks which could be either domain specific or technical. In particular an open source SE need to have a central FOSS framework and custom components developed that are extending generic open source software functions. It is important to apprehend the role of the FOSS implementers, which a client firm can employ to customize an open source software. Whether internal or external to the client organization, the FOSS implementer has a boundary spanning role bridging the FOSS firm and the 3rd party component developers. Identifying the 'central referent organization' [5], who manage the participation of different stakeholders, was an important step in governing the stakeholder interactions in the SE in our case. However, the role of the central referent organization may be played by different organizations during SE evolution.

The role of 3rd party developers is also noteworthy for a viable SE around an open source implementation. The FOSS SE should maintain a good support for 3rd party developers. These include rich API documentations and a clear path for 3rd party components in the FOSS road map. Similarly, the FOSS firm needs to expose 3rd party FOSS development and implementation channels to prospective FOSS customers.

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