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Different Approaches to Complementing Software Platforms: A Case Study of Digital Innovation across 10 Developing Countries

Collinson, N. ^{1,2}[0000-0002-6907-4054], Mahundi, M. ³[000-0002-0138-0928] and Nielsen, P. ¹[0000-0003-3723-6976]

¹ University of Oslo, Ole-Johan Dahls Hus, Gaustadalléen 23 B, 0373, Oslo, Norway

² University Eduardo Mondlane, Av. Julius Nyerere, nr. 3453, Maputo City, Mozambique

³ University of Dar es Salaam, Dar es Salaam, Tanzania

pnielsen@ifi.uio.no

Abstract. Software platforms offer a foundation for digital innovation and have the potential to take advantage of and leverage the knowledge and skills of distributed and diverse software organizations as ‘complementors’. Due to their location far away from platform owners, scarce resources, and limited capacity to hire and retain skilled human resources, organizations in developing countries typically face barriers for participating in digital innovation. This paper aims to improve our understanding of how these organizations can take part in digital innovation. The basis for our research is a case study of software organizations located in different developing countries and their role as complementors related to the DHIS2 software platform, a platform made for the public health sector in developing countries. We contribute by exploring and showing how these organizations differ along multiple dimensions, for instance, the maturity of their software development team, their relation to the platform owners, and their access to resources. Further, we identify and develop a taxonomy consisting of six different forms of digital innovation unfolding in the fringes of a software platform ecosystem and identify contextual factors influencing these different forms.

Keywords: Complementors, Software Platform, Fringes, Innovation.

1 Introduction

As software platforms permit and require innovations on top of them for their prosperity, to release their economies of scope and scale, the platform owners must ensure that other organizations engage in innovations on top of their platforms. This effort is enabled by the underlying architecture of platforms which is characterised as an ‘extensible codebase’ [29]. While the objectives and governance of software platforms might be different from one platform to another, they are all defined by their architecture comprising of two parts; one with low variety and high reusability and another with high variety and low reusability [4, 15]. The first part forming the core of the platform while the second forming the periphery, or the fringes [25]. Innovations

related to software platforms thus unfold on two levels: at the core platform to improve its generic features, and on the fringes to serve specific local needs [25]. Being, in the last case undertaken by individuals or organisations, other than the platform owners, commonly referred to as complementors [6, 15, 20, 28], because they develop 'complements' both to the core of the software platform [15, 20] and to the fringes.

Participating in innovations on a software platform requires a considerable amount of resources. Despite that, organizations in developing countries that are not well-positioned, being far from the platform owners, with scarce resources and limited capacity in terms of skills, also participate in digital innovation. We attempted to understand this phenomenon and answer the research question; in what ways do individuals and organisations in developing countries complement software platforms? We respond to this question by engaging in a qualitative case-study method in which we follow ten organisations working and complementing a software platform known as District Health Information System version 2 (DHIS2).

DHIS2 is a software platform meant for managing public health data in different formats. It is currently used in more than 100 developing countries [2], with 15 of them using it as a national standard for health data management. Several other organisations including the US President's Emergency Plan for AIDS Relief (PEPFAR) are also using the platform. DHIS2 is developed and managed by the University of Oslo through an action research network known as Health Information Systems Program, HISP. Founded in the early 2000s [2, 7], HISP built a network of universities, local HISP groups, and individuals actively taking part in the development of health information systems. It, therefore, consists of the platform owner who in this case is the University of Oslo and more than twelve organisations, the HISP groups, serving as complementors to the platform. This study investigates the ways ten of these HISP groups take part in developing innovations related to the platform, as well as the social and technical factors influencing their efforts.

2 Related literature

Research on software platforms is steadily increasing [3, 21], which is indicative of their role in society. Different studies have addressed several issues related to software platforms. Some have endeavoured to understand what software platforms are [4, 16, 30], others have investigated their architectures [4, 29] and many others have had concerns on how these platforms are managed [17, 28, 29]. Despite this increase in studies, though, studies on approaches and impact of platforms in developing countries are still minimal [21]. Having this in mind, we attempted through the current study, to contribute to this.

2.1 Innovations on Software Platforms

One of the ways to identify the types of innovation is in relation to what other items are connected to the Software Platforms. Hilbolling et al [20] identify three types on this basis; complements dedicatedly connected to the core only, complements connecting platform and other products, and connecting between platforms or one plat-

form with larger ones. In turn, Gizaw et al [18] look at innovations in terms of how the global and local contexts are reconciled. As such they introduce the terms *embedding*, referring to how the global context fits into the local, and *disembedding*, referring to the local context influencing the global. In this sense, one form of embedding is what they refer to as appropriation [18], where local developers address their local needs by configuring the platform through the capabilities that the platform owner intentionally built. An advanced form of embedding includes the development of applications on the platform to address needs that the platform owner did not anticipate. Eaton [13], on the other hand, identifies two types of compliments to a software platform; *applications* or apps and *enablers*. While investigating the mobile devices software platform, the last author refers to application type of complements as small software applications that address the immediate needs of the users and, as enablers those software applications which support the development and use of other applications on the software platform.

Several scholars have attempted to investigate the contributing factors of innovations on software platforms, suggesting that these come from both, the platform owners development and working modality (endogenous), and the environment in which the platform works (exogenous) [29]. The recurring endogenous determinant of innovation on a software platform relates to governance. Although the evolution of digital platforms is unpredictable and without control [1, 9, 19] scholars agree that governance of the social and technical components of a software platform can influence the trajectories of its innovation. Ghazawneh and Henfridsson [17] look at governance in light of controlling resources for enabling or constraining third parties in developing innovations on the platform. They, therefore, introduce two contrasting concepts, resourcing and securing. In rudimentary terms, resourcing refers to less control by the platform owners to allow for more innovations while securing refers to more control by the platform owner. Control can also change over time, for example related to what is most strategically sound for the platform owners [26]. Similar to resourcing, Koutsikouri et al [22] present three triggers to innovations namely adding service value, creating design attractors, and lowering infrastructure barriers. The last two are a direct match to the concept of securing. Rocha and Pollock [27], however, argue that the purpose of the platform is much more determining than its control.

Other studies investigated these factors in a combination of endogenous and exogenous. Mahundi et al [24], for example, describe three sets of factors influencing innovations; structural support, which is about organisations, technical support that are provided through endogenous support by the platform owner, and process support related to organisations for the sustainability of the introduced innovation.

3 Method

In this study, we attempted to understand reality through the perceptions of actors in their field [12]. We, therefore, employed a qualitative inquiry, which involved practitioners in the selected settings. Since we wanted a detailed understanding of 'how' complementors engage with the platforms and why some ways are more common

than others we employed case study approaches [5, 11]. We built the empirical setting around the DHIS2 software platform and the different ways in which individuals and organisations complement it.

3.1 A Data collection

In qualitative studies, a researcher has a significant impact [12]. Researchers in this study have influenced the collected data following their positions. One of the authors, being a co-coordinator of the development and implementation of DHIS2 at the University of Oslo, has vast experiences in how this platform is managed in different parts of the world. Another author has been working with HISP Tanzania for the last fourteen (14) years in different capacities related to DHIS2, including development, capacity building, and technical support. The third author, working at University Eduardo Mondlane in Mozambique, is currently engaged in research and technical support to the DHIS2 local implementations through the HISP Mozambique. Besides their experiences, researchers also conducted ten semi-structured interviews with practitioners in the field.

We selected HISP groups, to engage in the study and then selected individuals based on the time they have spent in their organisation and the roles they have taken in their teams. From Africa, the study included HISPs Tanzania, Mozambique, Malawi, Rwanda, Uganda, Nigeria, and the HISP Western and Central Africa, whereas from Asia the study benefitted from experiences of HISPs India, Bangladesh, and Vietnam. Most of the interviews were audio-recorded and transcribed verbatim into different text files, except for three, which experienced some technical constraints. We gathered information related to the organization, financing, and extension of their operations.

3.2 Data Analysis

We employed a theoretical thematic analysis [8, 10, 23] as a guide to the data analysis process in which we strictly observed the six phases of analysis that Braun and Clarke [8] suggest. In phase one, we familiarised ourselves with the data by listening to the audio files and later transcribing them, verbatim. This gave us an idea of the contents in the interview as well as interesting findings. We could also clearly establish the different characteristics features of the HISP nodes which were a part of our study. We understood how they are organized, how they interact with DHIS both in the field and in their development sites and other innate features. Following, in the second phase, we picked two issues of interest for our research question; *ways/forms of engagement* and *influencing factors*. We then listed the codes related to the issues and identified others as potential issues to explore further. These codes included; *configuration, hacking, customisation, scaling, extending, integration, interoperability, application to the core, local application*, and many others. During phase three and four we embarked on an iterative process of suggesting themes and discussing them among ourselves, in a process which helped us to refine our understanding of the process of innovation. It was through these iterations that we were also able to establish relationships between codes and their patterns and eventually started charting

relevant themes. In stage five we defined the resulting themes that we had finally agreed upon and, in phase six we documented them as present in the findings section.

4 Case Description: The HISP Groups

The organizations we focus on in this paper are all HISP groups that have a history of support from the University of Oslo (UiO) from their inception. These, either based in local universities or as independent organizations, typically with a close relationship with the Ministry of Health (MoH) through research and development projects. Many of the lead local experts in these organizations are graduates with a Ph.D. from UiO. Table 1 lists the HISP Groups involved in the study,

Table 1. The main target of support from the HISP Groups selected for the study.

<i>HISP Group (team size)</i>	<i>Country/Region supported</i>
<i>Western and Central Africa (23)</i>	16 countries in the region and 5 countries in other African regions
<i>Tanzania (19), Uganda (16) and Rwanda (5)</i>	East Africa / Consortium
<i>Mozambique (15)</i>	Lusophony countries in Africa
<i>Vietnam (10)</i>	4 countries in South East Asia
<i>Malawi (5), Nigeria (8), India (45) and Bangladesh (6)</i>	<i>Own country</i>

While some of these organizations are non-profit, by nature, all share similar support mechanisms based on projects and contracts with MoH, Universities, or donors. Due to limited funding, most of them experience human capacity constraints, and with the need for continuous development of local competence, the teams rely on support from UiO employees.

The HISP groups are actively involved in capacity building and training locally and abroad, involving team members, health practitioners, and students from the Universities related to the local projects. In a collaboration between them, HISP groups organise international academies, sometimes with the support and involvement of the core development team at UiO. These training activities are conducted in different languages, for instance in French, Portuguese, and English by HISP Western and Central Africa, HISP Mozambique, and HISP Tanzania, respectively, and according to the actual needs and maturity of the local users.

Besides academies, HISP groups also closely collaborate through cross-country projects. The language here plays a significant role, for instance, the Eastern Consortium that connects the HISPs Tanzania, Uganda, Rwanda, Malawi, and others are English speaking. HISP Mozambique, on the other hand, supports implementations in three Portuguese speaking countries within the region covered by the HISP Western and Central Africa. Sometimes collaborations are intercontinental where HISP groups in Asia have had several collaborations with HISP West Africa.

Each HISP group maintains its profile. For example, some only work with NGOs that support the government, like HISP India, while others do not limit their relations

and work with private and other non-governmental organizations as well, like HISPs Uganda and Nigeria.

The organizations selected for this study are in different stages of maturity, with HISPs India, Bangladesh, Western and Central Africa, Tanzania, Uganda, Rwanda, and Mozambique being the more mature. HISP Vietnam, Nigeria, and Malawi are still in a phase of capacity building. The different HISP groups typically have a staff of technical DHIS2 experts, public health experts, implementers and project managers. Some of the HISP groups have a stronger technical capacity and is thus more involved in software development.

5 Ways local organisations complement DHIS2

We have seen before that individuals or organizations can be considered ‘complementors’ if they develop ‘complements’ to a software platform. In our case study, the activities related to this complementing have continuously transformed the DHIS2 platform in many different ways. We define complementing as engaging in activities to improve the working or usefulness of a platform by developers other than the platform owner. We identify, through analysis of our empirical data, six ways through which organisations from developing countries take part in the innovation of a software platform. We classify these ways into three, *hacks and customisation*, *requirements translation* and *development*. Subsequent sections describe these ways in detail.

5.1 Hacks and Customisation

Complementors in this category attempt to customise and hack the software platform to fit the contextual requirements. The first way in this category is *customisation*. Through customisation complementors with a fair understanding of how the platform works incorporates the local requirements into the platform. In Tanzania, for example, the first official use of the DHIS2 involved three data collection tools related to HIV in 2009. The HISP team kept defining more tools as needs were arising and this is a common exercise in the organisation since then. The national rollout of the system with the DHIS2 platform was done in 2014 with fifteen (15) data collection tools defined in the platform.

Complementors also engage the software platform by *extending the use-domain*. In this, complementors use the same platform to address the system requirements in the domain other than the intended. Compared to customisation, this engagement required more support from the platform owners as it involved both, hacks by the complementors and generalisation of some features by the platform owner. In table 2 we list a few examples of where to different HISP teams have been extending the use-domain of DHIS2.

The third way of complementing is through *integration*. Software platforms often meet other systems in local contexts. Some of these existing systems are deeply institutionalised and therefore not easy to change. A way to work with them is by integrating them into the new platform or communicating data between them and the platform. HISP Mozambique presents a good example of this. They worked to connect a

system from COVIDA, with the dashboards in DHIS2. So while stakeholders were managing data in their system, reports and visualisations were managed through DHIS2. They further developed mechanisms to connect DHIS2 with the data from an ODK server.

Table 2. Examples of other domains the DHIS2 platform had been implemented.

New Domains	Countries
Education	Gambia, Malawi, Guinea Bissau and Mozambique (in discussions)
Agriculture (with Forestry and Veterinary)	Rwanda, Mozambique, and Tanzania
Environmental Health	Uganda
Water points management	Tanzania and Mozambique
Road safety	Tanzania

5.2 Requirements Translation

In this way, complementors do not develop the innovation but, instead, structure the requirements and serve as clients to the platform owner who then develops the innovation. A member from HISP West and Central Africa stated, generically, that;

“At the same time, we have also been pushing for some features coming from the field and those features have been another part of DHIS2 core, although we cannot claim that it is only from our side but we also express this demand” HISP West and Central Africa, June 2019

This also happened in Bangladesh;

“... so [in 2011] we build dashboard into DHIS2 with the framework and that idea was quite good, and I think that triggered the need for the dashboard and introduced it to the DHIS2, so that’s actually our idea...” HISP Bangladesh, February 2020

5.3 Development

Through this, complementors develop software solutions on software platforms. First complementors can engage in *local application development*. This happens when users of a platform face a challenge that the existing platform cannot address and it is not in the priority of the platform owner. As exemplified in table 3, complementors then resort to developing applications on the platform as a solution to the challenge. Stressing on this necessity, a HISP Vietnam team member explains that;

“It depends on the requirements, one of the things is... if everything can be solved in DHIS2, we just ... use the DHIS2, writing any new code or any new app, maintenance and all the different things is a long time commitment, so that is the one thing which we want to avoid most of the time” HISP Vietnam, November 2019

Table 3. Examples of local application development.

HISP Group	Example Local Applications
HISP West and Central Africa	Predictor functionality in DHIS2 to support eLMIS
HISP Tanzania	USSD Manager: An app that enables the configuration of USSD forms in DHIS2 by non-programmers.

Complementors can also engage in *cross-setting development*. This resembles local application development but differs in that the resulting application becomes useful in other settings. It requires not only programming skills but an accurate understanding of the platform core. Once in every year, the UiO organises week-long conferences attended by DHIS2 stakeholders from all over the world to promote this kind of engagement, among other things. Table 4 lists some examples of applications that later formed part of the core,

Table 4. Some of the contribution of the HISP Groups to the software platform

<i>HISP Group</i>	<i>Application</i>
HISP West and Central Africa	Minimize data collection tools to reduce overlap data Extend the predictor functionality to create specific Indicators
HISP Tanzania	i. Bottleneck analysis (BNA) application. HISP Tanzania had the development roles while systems analysis was managed by HISP Uganda ii. Function maintenance: an application meant to help with all the computations which the DHIS2, by default, is not supporting iii. Interactive Dashboard: A dashboard that presents data from the DHIS2 database but allows dynamic changes in the options of presentation

6 Discussion

Literature shows a variety of forms and types of innovations on a software platform [13, 18, 23]. This study focused on understanding how individuals and organisations in developing countries take part in contributing to the innovations of a software platform. Our empirical data reveals six ways through which these third party organisations contribute to the progress of software innovation. These include *customisation*, *extending use-domain*, and *integration*. Others are *requirements translation*, *local application development*, and *cross-setting development*. We, further, grouped these ways into three classes; customisation and hacks, requirements translation, and development.

This study is significant for two main reasons, among others. First, it systematically identifies the different ways of engaging in the innovation process. Several other studies have listed a few ways of engaging with the software platform in a manner we found not comprehensive. Eaton [13], for example, lists apps development to mean small apps and enablers' development to mean bigger apps that support others. This partly coincides with one category of ways in which we identified development. We found out that development can be in two forms, either developing applications for local use or developing applications that can also be used in other contexts. Gizaw et

al [18] to the former as embedding where developers attempt to fit the global artefact into a local context, and the former as disembedding which means local contexts abstracted for use in the global. The effort, we found, is not on the size but the context of use. Second, our analysis highlights the need to consider what exists already. One of the ways of engagement, we found, was *integration*. Software platforms are not installed in vacuum. They often meet existing systems in the different settings they arrive at. One of the innovations on these platforms is that of connecting them to the existing, well-rooted electronic systems, either for permanent or temporary use.

This study also found different factors influencing these innovations. Some related to the architecture of the platform, others related to the platform owners conduct, while others related to the capacity of the complementor. The strength of the community of complementors is also another factor.

The architecture of the platform itself determines how much the platform supports innovation. While the generic architecture of platforms is by default to allow innovations, some allow more than others. This is congruent with what Ghazawneh and Henfridsson [17] describes in terms of control over a software platform. They cite two forms affecting how much a platform can allow innovations. Resourcing and securing, where the former means giving more control, technically, to complementors and the later means less control to complementors. A member of HISP Mozambique declares that;

“What enablers, to individuals [who are] developing... first is what the DHIS2 provides, when they start to open up a friendly API so that people can do local development, I think this is the one that enables individuals to start thinking on how to develop... and the second one [enabler] is the possibility of having these academies where you teach individuals how to use the API... so now we know that I can use the API to develop my local applications” HISP Mozambique, November 2019

One particularity of the open software platforms, such as DHIS2, is the possibility to attract independent complementors. While it allows for extension through scaling or chartings and does not pressure the platform owner with dependencies of the complementors. The platform owner, also, has so much influence over how innovations on platform progress. The UiO as platform owners devised several mechanisms to promote innovations on DHIS2. They, for example, organise annual meetings to show-case innovations, they train complementors on the platform through technical systems as well as postgraduate educations. Many individuals in the complementor organisations are graduates from the UiO. The UiO also plays an intermediary role where international institutions channel their requirements for development to them and the UiO connects the different nodes for development. Importantly, the UiO modality of working with stable institutions was one of the driving forces. HISP West and Central Africa started as a UiO initiative to support Sierra Leon 2008, with locals from Togo who had an affiliation with the UiO. Later, in 2012, the locals with support from the UiO formed the HISP West and Central Africa. HISP Tanzania, on the other hand, started as a project within the UDSM, but later registered HISP Tanzania as an incorporated company that now works in complementarity with the UDSM.

Several factors are related to the complementor organisation. Such factors include their setup which is not antagonistic with the existing government structures. Irrespective of the size and maturity of the team, the endorsement of DHIS2 by the government has positively influenced innovations on the platform. One HISP manager declares their strength to be;

“... that we have a good relationship with the government and we are working with the government so this is a very big strength because we do not need to convince the ministry to do work with us, they are relying on us and this trust and understanding is our major strength” HISP Manager, Bangladesh, February 2020

7 Conclusion and recommendations

There is a considerable body of literature on the architecture of software platforms and how that architecture influences innovations. It is, further, clear that for an increase in the economies of scale and scope, third party developers have to contribute to the progress of a software platform through innovations. Not much is known, though, on the ways through which these third parties situated in Developing Countries take part in the innovation processes. In this study we attempted to respond to the research question: in what ways do individuals and organisations in developing countries complement software platforms? We engaged this question by examining how ten (10) members of the HISP network complements the DHIS2 software platform through innovations. We were motivated by the fact that these organisations work from the developing countries and, therefore, not well-positioned in terms of funding, skills, and other resources.

We identified six ways through which these organisations complement to the DHIS2 software platform. Such ways include customisation to fit the contextual requirements, extending features to address, developing local applications, developing functionalities for the core platform, integration with the existing software systems, and rationalising requirements. We, further, identified the social and technical factors influencing third party actors into complementing the software platform. These factors include those related to how the platform owner motivates innovation. In our case study, the platform owner has been very active in supporting third parties in development. These have been through organising training academies and annual meetings. We also found that some of these factors are related to the software platform itself, how its interfacing features like API support innovation. Other factors included the organisation of the third party institutions, and how the community of practice around the platform promoted complementing by these complementors. Clarity on the ways of engaging in innovation by third parties, and the different factors influencing that is beneficial to platform owners and third parties in furthering the use of software platforms.

Further research could focus on if and how these factors are also relevant related to other software platforms and in other contexts, establishing quantitatively how each of these factors influences the process of innovation and through which of the six ways we have identified.

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