The DHIS2 Open Source Software Platform: Evolution Over Time and Space

Chapter · April 2017

CITATIONS
0

READS
2,941

2 authors:

Jørn Braa
University of Oslo
74 PUBLICATIONS **1,893** CITATIONS
SEE PROFILE

Sundeep Sahay
University of Oslo
173 PUBLICATIONS **6,342** CITATIONS
SEE PROFILE

Chapter 42: The DHIS2 Open Source Software Platform: Evolution Over Time and Space

Jørn Braa, Sundeep Sahay

Take-home messages:

- DHIS is an Open Source Software application platform for health that has developed over two decades by adapting to changes in technology and supporting the changing needs of health systems.
- The driver of the DHIS' success is the DHIS and HISP community and network, which is built up around projects and activities carried out by university groups, NGOs, health authorities, and other actors; "networks of action."
- The combination of research and development has been the key to the endurance and success of the DHIS and HISP community building; PhD and masters research directly linked to implementation projects carried out as action research is a key part of the methodology.

Introduction

This chapter describes the evolution of the District Health Information System (DHIS2) over a 15-year time period starting from the mid-nineties to date. The system has undergone significant technological transitions, starting from a standalone application based on Microsoft Office to an open source web-based platform on which national and global systems are running. While these transitions reflect changes in technologies, they are also both a product of and a contributor to changes in countries' health systems. This DHIS2 is, on the one hand, a free and open source software platform for the collection, management, analysis, and use of health data. On the other hand, it represents a community of developers, implementers, users, and researchers who constitute the Health Information Systems Programme (HISP) research and development network. As the technical aspects of the DHIS2 are relatively well described at www.DHIS2.org, in this chapter we instead give an overview of the DHIS and HISP community, design principles, and development approaches, as well as their background, challenges, and future prospects. Furthermore, we provide examples of some "non-routine" applications which have been customized using DHIS2, illustrating the versatility of the platform and the potential it offers, while also discussing some of the inherent challenges that exist in attempting such work.

Background South Africa: Design Principles and HISP Approach

HISP started in South Africa in 1994 as a collaborative research project between the University of Cape Town and the University of Oslo. The initial aim was to provide health care workers within poor townships in Cape Town with basic information to deliver better health services to the local population.

HISP was from the start part of the new ANC government's Reconstruction and Development Program that aimed at radically reforming health care provisions for the communities that suffered under apartheid. The project was in this way born out of the political processes of change in South Africa, and as a synergetic collaboration between public health activists from the anti-apartheid struggle and information system developers from the Scandinavian tradition of democratic and participatory technology development. A key objective in the restructuring of the health sector was to develop a decentralized system of health districts and the DHIS—District Health Information Software—was developed as a tool for integrated and decentralized information support for district health management. The key challenge which DHIS (at that time Version 1) sought to address was the extreme fragmentation due to the previous segregated health systems, which were divided between racial groups and independent "homeland" administrations.

In order to address the challenges of achieving a sense of uniformity in a constantly changing environment following the reconstruction of the health system after apartheid, key DHIS design principles that are still in use were developed, including:

1. A flexible metadata structure, which users can manage through the user interface without the need for programming.
2. A data model, built with the hierarchy of organizational units with the health facilities as end nodes, as the backbone. As administrative boundaries change, it was easy to replicate these changes in the data model by reallocating e.g. the parents of the facility to the new district.
3. After data was collected, the data elements in DHIS were handled as singular atomic units, contrary to columns in a table, making them easy to change.
4. In line with the aim of promoting "health information for action," indicators became an important building block of the health information system, and it became possible for users to easily define the indicators they needed.
5. Given the challenges of poor data quality, users were also provided with the facility to define validation rules which could help identify anomalies in data.

After being piloted first in a few districts, then in two provinces, DHIS was implemented countrywide in 2000 and has been the national standard since then. The strategy has been to empower local level management by providing them easy access to their own data and analytical tools (such as pivot tables), while at the same time being able to support national and cross-province level data requirements. This ability to support different levels and types of users made the DHIS and HISP a success in South Africa during the 90's, and currently a process of transition is taking place with the DHIS2. The

South African facility based information system is still seen as a global “best practice” that other countries like India have sought to emulate.

HISP and DHIS as a Research and Education Network

The research and educational foundation of the HISP and DHIS project in South Africa was important for its success. HISP in South Africa included the building of a Masters in Health Information at the University of the Western Cape and summer and winter school and in-service training programs educating literally thousands of health workers in various health information aspects, such as the use of DHIS, data quality management, and using information for district and health facility management. From this basis in South Africa, university collaboration on research, development, and masters and PhD programs between multiple countries in the South was developed. In this way the HISP / DHIS project was spread to other countries, first to India and Mozambique in 1999 and later on to others in Africa and Asia.

The HISP action research and educational strategy developed was to engage students from both the health and informatics disciplines in a collaborative way in the development of health information systems in their own countries. Customization and deployment of the DHIS were everywhere part of the activities providing the empirical basis for research work. Fieldwork and active development work were then used by the students in course work and in writing up research for their masters and PhD theses. With funding from Norad, HISP participated in the development of masters programs in many countries such as in Mozambique, South Africa, Malawi, Tanzania, Sri Lanka, and Ethiopia. A PhD program coordinated by the University of Oslo has so far graduated about 25 PhD candidates from Africa and Asia and with a similar number in the pipeline. This funding stream from Norad has evolved over the years, now representing core funding for developers to support the technical evolution of DHIS2.

DHIS2 Java and Web Project

While the DHIS v1 was developed in South Africa as a free and open source database application based on the Microsoft Office platform, development of the Java based and fully open source DHIS v2 started in 2004 with a base in the Department of Informatics at the University of Oslo, Norway. As HISP had no funds for such development, the first step was to set up a course in open source software and Java technologies at the University of Oslo and use students and researchers to explore new technologies and take the lead in development. However, re-implementing DHIS version 1 as a modular web application proved quite difficult. Also, the radical break in technologies as well as an over-emphasis on the new online communication platform presented a formidable obstacle to the involvement of existing technical staff from the countries already using the DHISv1. The new flexible but complex architecture made it difficult to engage HISP activists who were used to the MS Office platform in its on-site customization and further development, but

eventually DHIS2 was implemented in Kerala in India in January 2006. Much important functionality was initially lacking, but the system improved significantly over the next couple of years in India, as well as in Vietnam, through the involvement of locally recruited software developers.

Interoperability and the HMN Project

In 2007, HISP started collaboration with the WHO-based Health Metrics Network (HMN), which decided to use the DHIS2 to implement their data warehouse based 'Technical Framework" architecture approach in Sierra Leone, their first (and only) pilot country. A data warehouse containing and integrating indicator and aggregate data from all relevant data sources was the key feature in the HMN Technical Framework. DHIS2 was implemented countrywide in Sierra Leone and the process of integrating data sets from the various health programs and health services became an important learning experience. As part of the project in Sierra Leone, a proof of concept implementation of interoperability between the OpenMRS and DHIS2 was also carried out; HIV/AIDS patient records where aggregated and sent to the DHIS2. A key reason for this architecture is to ensure that effective tools exist to manage and use clinical data and that data can also be used for effective and accurate reporting at district and national levels. This should reduce redundant data collection and improve data quality with local use and feedback. Interoperability with the iHRIS human resource management system was included and the model was launched as the "Sierra Leone architecture" at a conference in Accra in 2010.

This was part of the WHO-led project to develop the SDMX-HD interoperability standard, which, however, never developed beyond the proof of concept phase. The reason was that it was too complex to implement and it was therefore never possible to achieve a "win-win" perception of mutual gain by implementing the standard among potential users. A similar project in Rwanda using SDMX-HD to link OpenMRS reports the national HIV reporting system TRACnet achieved technical success but again was too unnecessarily complex a process to be used in the field. As interoperability standards for aggregate data are much needed, the HELINA conference in Eldoret, Kenya, 2013, formed an interoperability task force with a particular focus on the needs of Africa and with two targets: 1) Semantic standards; establishing a repository of indicators and data elements used in the African context and in this way enable harmonization. 2) Develop technical standards for interoperability by taking the current data exchange format used in DHIS (DXF2) as a point of departure and make it general. Currently work is underway to make this HELINA initiative part of the subcommittee on health facility data, or HMIS, within the Open Health Information Exchange (OpenHIE) community. Establishing a stable and reasonably easy-to-use standard for exchanging report (aggregate) data from patient level systems such as EMRs to district and national level reporting and data warehouse

systems is a key goal of eHealth projects in LMICs. Both DHIS2 and OpenMRS are then viewed as example systems that support the standard.

DHIS and Online Computing

In Sierra Leone at the time, the internet was still not good enough for online deployment and the DHIS2 was implemented as stand alone instances in each district. This approach is similar to the way OpenMRS has been implemented in many low-income countries. Clinics benefit from local use of the system but the advantages of data sharing and interoperability are lost. During the next couple years, 2010-2012, however, the internet changed the technological landscape in Africa. Fiber cables were laid down the coast of Africa and, as the mobile networks were already in place, internet rapidly became a reality nearly all over the continent. The project to implement the DHIS2 in Kenya started October 2010 and given the new internet situation, the system could be deployed online, hosted by a cloud server and accessed by modems to the mobile internet. After three months pilot in the Coast region, the DHIS2 was implemented countrywide over a four-month period by way of a training scheme involving users from all districts and hospitals in the country. 'Implementation' in this new area of online computing consisted only of training as there was no software to implement, everything was in the browser. The evolving internet situation in Africa led other countries to follow suit and Ghana, Rwanda, and Uganda implemented DHIS2 online in 2012, Burkina Faso, Liberia, Tanzania, and other countries the year after.

While the internet and online computing drastically changed the condition for implementation in Africa, the server management and hosting issues became new areas of concern. To host the system in the 'cloud', at optimal conditions and for a low price, or in the 'basement', or in-house, often at sub-optimal conditions and at a much higher price, became the major question and policies in this area are much needed such as related to data ownership and privacy, as is capacity building on server management. Then there is the challenge, technical and institutional, of making data from the cloud easily accessible to the clinics on the ground to help promote the mission of "health information for local action." As noted with systems like EMRs, ensuring local staff can use and benefit from the data they are collecting is not only directly valuable in their work, but theoretically can improve data quality and completeness.

DHIS Used by Multinational Organizations – PEPFAR

Until recently, HIV/AIDS initiatives have been notorious in causing fragmentation by insisting on their own vertical systems for reporting. Now, however, PEPFAR is working to deploy DHIS2 as their tool for internal reporting globally with the stated objective to better leverage and integrate with country HIS initiatives. The idea is for PEPFAR reporting to use the same standards for facility identification and data and in that way gradually work toward stronger integration with country systems. The benefit for the

DHIS community is that PEPFAR is funding further development, including building better dashboard functionalities and making it possible to attribute partners to particular data reported from particular facilities, a key PEPFAR requirement. These improved functionalities will potentially benefit the larger, global community of DHIS users. Furthermore, PEPFAR development is potentially generating job opportunities in training and support to local and regional DHIS2 experts. By increasing the market, country capacity is being built which will benefit all users including the government systems. Shared data standards are a significant gain for PEPFAR as they will be able to evaluate their data by comparing it with data reported by the government systems. More generally, such cooperation leads to pooling of capacity and resources and will help ensure sustainability of the Ministry of Health (MoH) routine systems, as well as other systems in the countries.

Médecins Sans Frontières (MSF) is another organization that is working towards using DHIS2 for their own reporting and in their own country use cases. Their main specific requirement is to make data capture and data analysis functionalities of the DHIS2 available offline on handheld devices. In order to achieve this significant development, MSF has hired a software company to do the job; the results will be made available to the broader DHIS2 community. Various other international organizations such as PSI (Population Services International) and IPPF (International Planned Parenthood Federation) are using DHIS2 to support their data management and analysis functions globally and regionally.

But how is it possible for an "outside" software company to undertake such significant development, without risking "forking the code"—creating a separate and incompatible version of the system? The answer is: by developing apps—the new approach to modular development. These developments are being done either in house, or by third-party developers or regional HISP nodes with existing expertise in DHIS2.

Innovation and Forking - DHIS as an App Platform – Also to Prevent Forking

While users' demand for new functionalities have been a constant driving force behind the DHIS development since the beginning, the dichotomy between the users' need for rapid development of specific solutions and the overall DHIS2 strategy of investing more time in developing generic features that can provide the necessary specific solutions has been the "battleground" for operational software development. For example, the dashboard functionalities were first developed in India as a response to users' demand in a way that resulted in a fork, and were later given a generic design by the global team so that it can be used by all, including the Indian team which updated their existing dashboard. A recent case from Nepal illustrates how complicated the generic approach may be. Nepal is in the process of implementing the DHIS2, but they need a solution for their calendar, where the year is now 2071 and the number of days in the month is changing yearly

as are the months. It would have been relatively easy to implement this calendar in, say DHIS v2.16, by enabling the loading of the specific Nepali calendar every year. The problem is that then it would not be possible to later update to v2.17 and on because the code would have forked. The solution was a generic one, meaning that the users are now in principle able to select any calendar in DHIS2, such as the Gregorian or the Nepali; this was a relatively complicated task to implement.

Prototyping of specific solutions that are later given a more generic design and made part of the general system is a generic methodology for innovative development used in the HISP network and by others. With the current swell of users and new requirements, it is getting increasingly difficult to keep the pace and respond with generic solutions. The demand for multiple new functionalities and features is now being addressed by a transition from Java modules to regarding DHIS2 as an app platform. Apps are running in the browser and, provided that the DHIS2 web API is kept robust and well documented, there will be no dependencies between the underlying DHIS platform and the apps, nor between the apps themselves. Of course, the development of the major app for MSF for offline data capture mentioned above has led to new requirements for services provided through the API and involvement of the core development team was needed. Generally, however, apps represent a “clean” approach to modular development and it is relatively easy to learn to build. While in the “traditional” Java module based system, you have to build the whole system from scratch each time you reconfigure with new parts and modules. In the new approach deployment is made easy as you simply add and remove apps from the apps ecosystem. The aim is thus to develop an ecosystem of apps drawing upon a broader community of global developers, one where users can select apps in the DHIS2 app store and configure their system according to their needs. This approach is very similar to the OpenMRS modular architecture and developed for the same reasons—to allow local adaption and innovation while keeping the core code stable and reliable.

Studying the transition of the DHIS2 to an app platform reveals both pros and cons. If new development is concentrated on apps, the con side is that fewer resources will go into further development of the core, whose evolution may suffer. Furthermore, new apps may become proprietary and not shareable, or become too specific focusing on the interest of a small group of users. However, we believe the pros outweigh the cons; the drastically lowered threshold and required knowledge for individuals and groups to develop new functionalities by way of apps are opening up the DHIS2 to new developers, users, use cases, and innovations. In order to make app development even more easy and to avoid duplication of efforts, a Software Development Kit (SDK) providing common components/widgets is currently being developed as part of the DHIS2 to provide an enabling environment for rapid prototyping and innovations, which can later be made generic and become part of the core. The app platform is preventing the core development from becoming a

bottleneck while at the same time providing an environment for agile software development.

DHIS2 Entity Tracker

According to general maturity models of information systems use, users require more and more granular data as they learn and as the technologies improve. One way to support this in the context of statistical systems is to enable the registration of case-based data. This is being addressed by the DHIS2 "entity tracker". Type of entities to be registered are 'neutral' in that they can be of any kind, and can be defined for a variety of use cases such as lab samples, ambulance maintenance, drug batches or pregnant mothers or a child seeking immunization services. Entities are then tracked through "events." Already in 2003, DHISv1 developed a simple patient module where the idea was to use the same data elements for patients as were used for aggregate reporting, which made the aggregation from the patient level data to the aggregate reporting easy. The data model in DHIS 2 tracker is more complex, but the focus is still on making it easy to aggregate the data from the singular "count," and to make it possible to drill down from aggregate data to the case. Seamless connection for drilling up and drilling down between events or cases and aggregate data is the major objective for this development. Once event data is aggregated it can draw upon the existing facilities of the Dashboard and GIS to support effective visualization, analysis, and sharing of data. The relatively simple program-specific register books used in health facilities are typical tracker use cases in the patient domain. Using tracker and web-based systems generally for personal data requires high measures of security and a key approach under development is to ensure the identification and separation of attributes linked to personal data and encrypt them so they are unavailable to visualization tools.

Liberia has a well-developed routine HMIS system on DHIS2 which was extended for Ebola reporting during the crisis by including a case and contact listing system using the Tracker. As the required user interface functionalities were not (yet) there, the module was developed as an app. The system was developed and implemented under crises conditions, and poor internet was one of the major challenges. Nevertheless, hundreds of cases and thousands of contacts were registered. The Ebola crisis is now fortunately close to ending in Liberia, but work continues to incorporate the required functionality from the Ebola Tracking app into the new core DHIS2 Tracker. This demonstrates how the app platform allows for rapid and agile development. While it would not have been possible to wait for the needed additional functionalities to be developed as generic solutions in the core, the app platform allowed for innovative development, innovations that could later be included in the core system.

Data Use

While the analytic and visualizing functionalities of the DHIS2 are constantly improving, experience indicates that country MoH users are not exploring these new features adequately enough. Their focus is still predominantly on data reporting, with less attention given to dissemination and data analysis. To change the behavior of thousands of health workers and managers is of course a complex task not solvable by technology alone. To better enable data use, DHIS2 has developed features including dashboards, instant visualization tools, GIS, and pivot tables. In order to lower the threshold for data use, ways to push analysis to the users are now being developed, for example sending predefined analysis to the users on their Android smart phone with links back to the system for further analysis. DHIS2 has so far not been very 'mobile friendly, this is being addressed by developing data analysis functionality on Android.

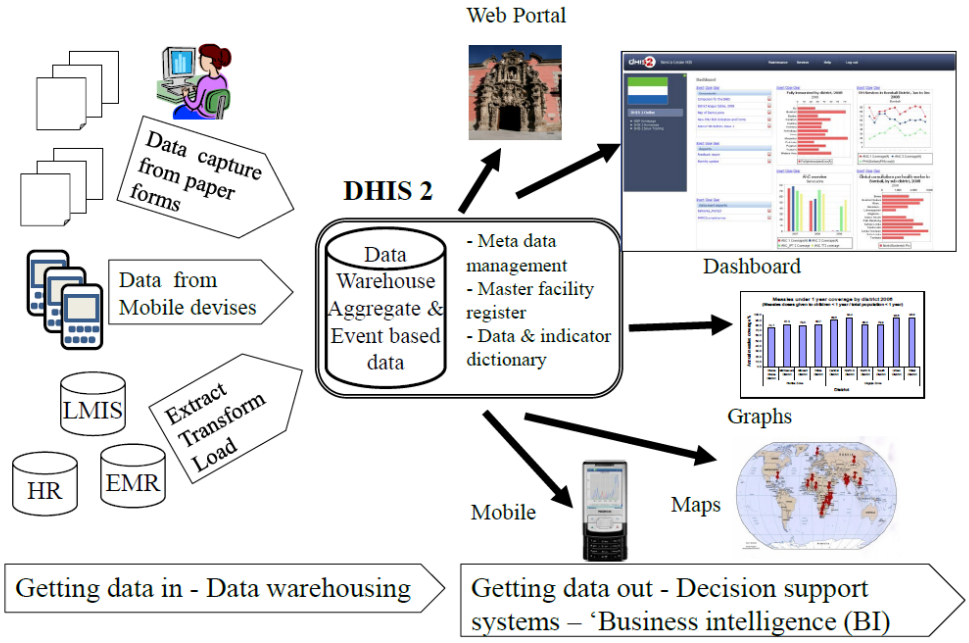

Figure 42.1
DHIS2 Architecture

The DHIS2 Community and the Future

The sustainability and future development of the DHIS will depend on the community of users, developers, and implementers. Independent HISP nodes are already established in India, South Africa, West Africa, Nigeria, Tanzania, Uganda, and Vietnam. These are all based on being able to make a living by supporting the various aspects of DHIS2. The current increase in the DHIS2 user base is therefore important for the sustainability of the community.

Examples: HISP India is hired to develop modules for Cold Chain Management with PATH, Data Quality Scorecard for WHO, and food security

monitoring for FAO in Bangladesh and globally. HISP South Africa, on their side, has grown over the years and now employs 57 consultants which are mostly working on providing health information and DHIS services in-country. HISP West Africa is working with the West Africa Health Organization to implement the DHIS2 for disease surveillance across 15 countries in the region. After the Ebola crisis, significant initiatives are underway to strengthen Health Information Systems in countries and in the region. The DHIS2 training academies, which are conducted annually in the regions of Asia, West, East, and South Africa annually, are important in keeping the community together and in including new members.

An important observation is that NGOs and organizations using the DHIS2, such as PEPFAR, MSF and PSI, are generally contributing more to the building of the community and give more feedback to the development than are the typical MoH country users of DHIS2. This is of course natural given that the organizations are expert users with better economy and capacity than the country MoHs. It is nevertheless a concern that country HMIS users are lax in taking up the various analytical tools and rarely go beyond merely the reporting function. This emphasizes the need for countries to provide continuous training. On the technical side, predefined reports and improved analytic features for handheld devices may enable more data use and make it easier for users to access data.

The core development of the DHIS2 is coordinated at the University of Oslo and with Norad and PEPFAR as the main funders. A DHIS2 “crowd-funding” meeting in Oslo in March 2015 has being organized by Norad and the University of Oslo and attended by major agencies such as PEPFAR, Global Fund, WHO, UNICEF, GAVI, and USAID. The aim of the meeting was to explore ways to enable harmonization of partner efforts to strengthen health information systems and to secure longer term financing of the DHIS2 core development and network of regional and country systems. Various regional initiatives (e.g. WAHO (West African Health Organization), EAC (East African Community), and EMRO (East Mediterranean Regional Office, WHO)) are underway to deploy DHIS2 at regional and country levels, establish regional nodes for technical support, and enable the sharing of best practices. The DHIS2 is currently being used and rolled out as national/regional health information systems in a large number of countries, among them some 30-40 of the least-developed countries in the world. This is a large undertaking with significant risk that would benefit greatly from a coordinated commitment from donors.

Ideally, a network should be able to survive the removal of any of its nodes. It has, however, proven difficult to distribute substantial parts of the core development to the other nodes and therefore the Oslo team easily becomes a bottleneck to rapid spread. Work is underway to move more development to other nodes, such as to the US. In addition, we believe that the apps strategy may help ease the dependency on the Oslo team. The cross fertilization and joint funding and work between open source communities,

such as the collaboration between OpenMRS, iHRIS, and the DHIS2 within the OpenHIE community, will also help ensure future sustainability.

Discussion questions:

1. What are some mechanisms that can ensure the longer term sustainability of DHIS2 in the future?
2. How should the HISP community seek to attract more developers to contribute to the code?
3. Open source projects such as the DHIS2 will always have to balance between the need for local flexibility for further development and the need for a strong central core to prevent "forking" and evolve over time. Can App development "solve" this dichotomy by enabling local development without the need to fork the core code?

Bibliography

Adaletey, D, Jolliffe, B, Braa, J, Ofosu, A, Peer-Performance Review as a Strategy for Strengthening Health Information Systems: A Case Study from Ghana, *Journal of Health Informatics in Africa*, Vol 2, No 2 (2014)

Braa, J., Hedberg, C. "The Struggle for District Based Health Information Systems in South Africa," *The Information Society* (18), 2002, pp. 113-127.

Braa J, Monteiro E, Sahay S (2004): Networks of action: sustainable health information systems across developing countries. *MIS Quarterly*, Vol. 28 No. 3, pp. 337-362

Braa, J, Hanseth, O, Mohammed, W, Heywood, A, Shaw, V (2007) Developing Health Information Systems in Developing Countries: The Flexible Standards Approach. *MIS Quarterly*, Vol. 31, No. 2, pp. 381-402

Braa J, Kanter AS, Lesh N, Crichton R, Jolliffe B, Sæbø J, Kossi E, Seebregts CJ. Comprehensive yet scalable health information systems for low resource settings: a collaborative effort in sierra leone. *AMIA Annual Symposium Procceedings 2010*; 12:372–376

Braa, J, Sahay, S, (2012); Integrated Health Information Architecture. Power to the users. Matrix Publishers, New Delhi (Book, 362 pages)

Garrib, A., Herbst, K., Dlamini, L., McKenzie, A., Stoops, N., Govender, T., & Rohde, J. (2008). An evaluation of the district health information system in rural South Africa. *SAMJ: South African Medical Journal*, 98(7), 549-552.

Sæbø, Johan; Kossi, Edem; Hodne Titlestad, Ola; Rolland Tohouri, Romain; Braa, Jørn (2011) Comparing strategies to integrate health information systems following a data warehouse approach in four countries. *Information Technology for Development*, 17(1)

Jolliffe, Bob; Poppe, Olav; Adaletey, Denis Leonard; Braa, Jørn (2014) Cloud computing for development: Issues and deliberations. *Information Technology for Development*; Volum 11.(1)

Kariuki, J. M., Manders, E. J., Richards, J., Oluoch, T., Mulonzi, J. M., & Kimanga, D. (2013). Automating Indicator Data Reporting from an EMR to Aggregate Data System Using OpenMRS and DHIS2. *Journal of Health Informatics in Africa*, 1(1).

Karuri, J., Waiganjo, P., Daniel, O. R. W. A., & Manya, A. (2014). DHIS2: The Tool to Improve Health Data Demand and Use in Kenya. *Journal of Health Informatics in Developing Countries*, 8(1).

Kiberu, Vincent M., et al. "Strengthening district-based health reporting through the district health management information software system: the Ugandan experience." *BMC medical informatics and decision making* 14.1 (2014): 40.

Manoj, S., Wijekoo, A., Dharmawardhana, M., Wijesuriya, D., Rodrigo, S., Hewapathirana, R., siribaddana, P., Gunasekera, T., and Dissanayake, W.H.V. (2012). Implementation of District Health Information Software 2 (DHIS2) in Sri-Lanka, *Sri Lanka Journal of Bio-Medical Informatics* 2012;3 (4), pp:109-114. pdf

Poppe, O, Jolliffe, B, Adaletey, D, Braa, J, Manya, A (2013) Cloud Computing for Health Information in Africa? Comparing the Case of Ghana to Kenya, *Journal of Health Informatics in Africa*, Vol 1, No 1 (2013)

Puri, S. K., Sahay, S., & Lewis, J. (2009). Building participatory HIS networks: A case study from Kerala, India. Information and Organization, 19(2), 63-83.

Sahay, S., Sæbø, J., Braa, J. (2013). Scaling of HIS in a global context: Same, same, but different. *Information and Organization*, 23(4), 294-323.

Saugene, Z. (2013). Leveraging from Customization to inform Generic Software Systems Development: DHIS Tracker and its introduction in Healthcare", *IFIP WG 9.4: Social Implications of Computers in Developing Countries.* Montego Bay, Jamaica.

Saugene, Z. (2011).The Challenge of Customizing Global Open source Software to Local Country Contexts: The Case of DHIS GIS for Health Management, *Proceedings of the 11th International Conference on Social Implications of Computers in Developing Countries*, Kathamandu, Nepal

Shaw, V. P., Claasen, E., & Brown, J. (2013). The Changing Landscape of HIS in SA. *Journal of Health Informatics in Africa*, 1(1).

Sheikh, Y. H., & Bakar, A. D. (2012). Open Source Software Solution for Healthcare: The Case of Health Information System in Zanzibar. *In e-Infrastructure and e-Services for Developing Countries* (pp. 146-155). Springer Berlin Heidelberg.

Staring, K., & Titlestad, O. (2006). Networks of open source health care action. In *Open Source Systems* (pp. 135-141). Springer US.

