

**Auvo Finne**

**REPORT ON**

**THE COMPARISON OF GOTHOMIS, CARE2X AND AFYAPRO  
HOSPITAL INFORMATION SYSTEMS IN TANZANIA**

**TECHNICAL ASPECTS**

**FINAL**

**May 2018**

## EXECUTIVE SUMMARY

During the eHealth Tanzania project's inception mission in October 2017 the immediate need of comparing existing hospital information systems was taken up again in a number of discussions, especially with CSSC (Christian Social Services Commission) and APHFTA (Association of Private Health Facilities in Tanzania). These organizations must be ready and able to give instructions and recommendations to member hospitals regarding purchase and introduction of digital systems.

In order to provide to CSSC and APHFTA useful material as soon as possible three well known products, GoTHoMIS, Care2X and AfyaPro were chosen under the study at hand. The comparison was carried out during March-May 2018 as case study using a purposeful sampling of cases, i.e. easily accessible but with variation by hospital size, location and experience of using other hospital information systems. Each product was observed and users interviewed in three different hospitals. The report at hand gives an account of the technical aspects of the three systems. Findings related to operational aspects and user experience will be published in a second report.

The comparison revealed that GoTHoMIS and Care2X are very much on the same level as hospital information systems. However, the module coverage, integration to external systems and sustainability of GoTHoMIS is slightly better compared to the other two systems. The latter because GoTHoMIS is a government system and not dependent on business factors. On the other hand the Care2X provider may be able take into account the special requirements of private hospitals more than the GoTHoMIS developer organization. The new AfyaPro is currently not yet fully comparable to GoTHoMIS and Care2X because of many unknown features and factors.

The required technical and human infrastructure, if the system is deployed inside hospital LAN, is essentially the same for all three products. What makes difference to user organizations are the license and technical support fees. GoTHoMIS is at present basically a free system. Even technical support is currently free due to USAID funds. Care2X licence varies from 18 million to 65 million TSH, and technical support per year from 1.6 million to 7.4 million. AfyaPro has not yet been priced.

Based on the technical analysis the main recommendations for CSSC, APHFTA and health facilities are following. 1) If the hospital is a government hospitals or getting government support, go for GoTHoMIS. 2) If the hospital is a fully private hospital and financial resources are scarce, consider GoTHoMIS. 3) If the hospital is a fully private hospital and has a well-functioning system (e.g. Care2X) and no big problems with MTUHA and other reports, wait 1-2 years and see what comes out of the new AfyaPro product and how Care2X develops. 4) If the hospital is a fully private hospital and has the old AfyaPro and need to change system soon (must be changed before 2020 anyway), consider Care2X. 5) In general fully private hospitals can consider Care2X (and maybe later AfyaPro), because, even if modifiable, GoTHoMIS may not be modified sufficiently according to the needs of private hospitals.

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## **1. INTRODUCTION**

Tanzania is experiencing a gradual proliferation of digital health and hospital information systems throughout the country. These systems come from different vendors and have to some extent different features. At the same time the government works on national eHealth system integration.

A preliminary HIS study was carried out in October 2016 in selected Tanzanian health facilities. The study was supervised by professor emerita Pirkko Nykänen from University of Tampere (UTA), Finland, by lecturers Dina Machuve and Anael Sam from NM-AIST, by lecturer Masoud Mahundi from UDSM and by Dr. Khamisi Kalegele from The Tanzania Commission for Science and Technology (COSTECH). The aim of this preliminary study was to collect and analyze the user experiences and user opinions on the use of the current health information systems and needs for further improvement and wider adoption and deployment of these systems. It used thematic interviews and questionnaires. Systems under study were Care2X, EHMS, JEEVA, MediPro and GoTHoMIS.

During the eHealth Tanzania project's inception mission in October 2017 the immediate need of comparing existing hospital information systems was taken up again in a number of discussions, especially with CSSC (Christian Social Services Commission) and APHFTA (Association of Private Health Facilities in Tanzania), because these associations want to be able to give recommendations to members regarding adoption of digital health information systems.

The comparison was carried out during March-May 2018 as case study using a purposeful sampling of cases, i.e. easily accessible but with variation by hospital size, location and experience of using other hospital information systems. Each product was observed and users interviewed in three different hospitals. In addition the lead developers from each team were interviewed. From a scientific point of view the number of cases is small and would limit the generalizability. However, for the practical goal of helping the CSSC and APHFTA the results constitute important and useful knowledge.

Data was collected through semi-structured interviews and questionnaires, review of technical documents and through observing the operation of information systems in selected health facilities. The study is a qualitative study. Measurements (metrics) were not used. Accordingly the performance of the systems, like response times, is not discussed in the report at hand. The comparison criteria for interviews, corresponding questions and answers (APPENDIX 1) were divided into two main groups: 1) technology related and 2) system use and operation related. The interviewees in health facilities included the chief medical officer, responsible IT officer and ordinary users from selected hospital sub-units. In developer organizations the main interviewee was the HIS project manager who was participating in programming as well.

The report at hand does not assess the financial sustainability of the companies or organizations responsible for the HIS products. Neither does it judge the profitability of the HIS product development for them.

## 2. THE PRODUCTS

### Care2X

Originally open source. Last update in SourceForge from November 2015. The open source community of Care2X is not very active at present. The donors pulled out in 2011. As a consequence the system is not fully open source anymore and it is since 2015 maintained and sold in Tanzania by the Lutheran Investment Company (LUICO) which started its operation in 2015. The company has 6 key result areas which are Hotel & Tourism, Real Estate, Trading, Farming, Financial Institutions and Information Technology. Care2X is mentioned in the Tanzania Digital health Investment Roadmap 2017-2023 as one of example of the existing work to build upon. 18 hospitals use the product currently in Tanzania.

### GoTHoMIS

GoTNoMIS is a HIS that is developed by the Government of Tanzania (PO-RALG). It is based on 4PAY hospital management system. The latter had patient registration, revenue collection, pharmacy management and exemption management modules. The migration started 2015. In 2017 GoTHoMIS had already been installed in about 140 health facilities across the country.

### AfyaPro

AfyaPro is a product of Africa eHealth Solutions International (AeHS). It was founded by IICD (a Netherland based NGO) and NPK Technologies (a Tanzanian IT company). In Tanzania AeHS has partnered with CSSC (Christian Social Services Commission). NPK has partnership with Hague based International Institute of Communications and Development (IICD). NPK has deployed iHMS in health facilities in Tanzania, Malawi and Zimbabwe. The total number of deployments of the old system is about 40.

## 3. PRODUCT FEATURES

Note: The description of AfyaPro description is based on the new AfyaPro system which is under development!

### 3.1. Hardware, Software and Network Architecture

#### 3.1.1. General Architecture

All of the three systems (GoTHoMIS, Care2X and AfyaPro) implement traditional MVC (Model-View-Controller) architecture. This means a top level separation of 1) handling of data model, storage and some part of business logic (model), 2) interaction between presentation and data (controller) and 3) presentation of data (view), into different interconnected partitions of the application. Often there is in addition a service layer or partition containing shared and reusable business logic.

Besides the common MVC architecture, AfyaPro differs substantially from the other two products. It is cloud based (Azure) and consequently serverless, but can be installed locally as well. It has a rule based decision support engine and a knowledge server (protocols, code lists, medical rules). There is also a configuration server (XML). On top level the system is divided into different portals: developer (studio), provider (the hospital), patient. Studio

portal is used by developers and IT staff in the facility. Provider portal is for professional employees in the facility. Patient portal gives patients access to their details and treatments.

### **3.1.2. System Requirements**

The standard (local installation) system requirements of the three products are fairly similar: server (4-8GB RAM) with backup system, workstation (2-8GB RAM), LAN, Internet connection, power backup and protection. Peripheral devices (barcode reader, specific printers, etc.) may differ according to functionalities offered by the product.

### **3.1.3. Platform Software**

GoTHoMIS and Care2X are so called LAMP (Linux, Apache, MySQL (or PostgreSQL) and PHP) applications. GoTHoMIS uses in addition open source Laravel PHP framework (first release 2011) and Angular Material JavaScript library.

AfyaPro differs essentially from the two other products by using C# programming language, XML, VitalHealth platform and IIS (Microsoft web server). VitalHealth Software was originally founded (2006) by Mayo Clinic (USA) and Noaber Foundation (the Netherlands) to develop cloud-based eHealth solutions for people with chronic diseases such as Diabetes, COPD, CHF, Depression, Cancer and Alzheimer's. Today it is a health IT application development environment. It has inherent support for healthcare integration standards, coding systems, a rules based clinical decision support engine and support for attractive browser based user interfaces, including mobile devices. VitalHealth supports different databases. All data is stored in XML.

### **3.1.4. Operating System**

GoTHoMIS and Care2X can be run both on Linux and Windows, AfyaPro only on Windows.

### **3.1.5. Network**

All three products can be run in-house in hospital LAN. However, GoTHoMIS and AfyaPro show a tendency and goal to be centralized and serverless, GoTHoMIS to a government datacentre and AfyaPro in the cloud. In cloud architecture the challenge lies in Internet connectivity and security.

### **3.1.6. Mobile Device Support**

All three products have user interfaces which adapt to mobile devices. Actual mobile applications have not been developed for GoTHoMIS and Care2X. AfyaPro has React (JavaScript library) based app for patient portal.

### **3.1.7. User Interface**

All three products are web based, support multiple browsers and have some kind of "panorama" views (e.g. patient overview). AfyaPro has in addition implemented online help and error messaging.

### **3.2. Data Model**

All products use a relational data model and database. None of the providers was willing to share the data model with interviewers.

### **3.3. Functionality**

MoHCDGEC guidelines' minimum requirements list following modules: patient management (i.e. outpatient and inpatient), laboratory, laboratory orders, operating theatre, billing, pharmacy and inventory, medical records, human resources, reports, mortuary and financial management. Most of these modules are covered by all the three products. However, they lack complete (hospital level) financial management and human resource management modules. In addition, AfyaPro does not have operating theatre and mortuary modules. And as a new product AfyaPro is missing inpatient and pharmacy stock management modules as well. On the other hand it has time based appointment scheduling and queuing functionality. Finally, all products lack the possibility of transferring EMR between facilities which use different HIS products.

Regarding other useful features AfyaPro implements patient reminders and alerts. Monitoring and evaluation, decision support and research data collection is based in all systems on standard reports without any special functionality. As a new product using new technology AfyaPro provides a specific interface (kind of "my health") for patients and telemedicine functionality in diabetes treatment. The latter contains some artificial intelligence and machine learning as well.

GoTHoMIS and Care2X generate MTUHA reports. Care2X has some additional reports as well like daily visits, income, disease cases and ward occupancy. AfyaPro does not yet generate MTUHA reports. DHIS2 reports are generated but must be manually entered into DHIS2. AfyaPro generates some financial reports as well.

### **3.4. Security and Safety**

Caring about security and especially safety is partly the responsibility of the health facility itself. Regarding the latter the provider gives recommendations and instructions (how to automate, how often to backup, incremental vs full backup, etc.). The same applies to physical security, i.e. access rights to servers etc.

GoTHoMIS and Care2X implement all standard security features, like role-based access. Care2X secures external network access with HTTPS and VPN. GoTHoMIS has audit log, concurrent account access restriction and it maintains transaction history. AfyaPro has invested in security as well. It has, in addition to standard features, database auditing and database encryption. For external traffic firewall and VPN. Many AfyaPro security features are inbuilt into the development framework.

### **3.5. Standards**

The providers of GoTHoMIS and Care2X announce that they are using Ministry's guidelines and standards in development. All three products follow ICD10 (classification of diseases, revision 10), Care2X and AfyaPro ICD9 (classification of diseases, revision 9) as well. HL7 (transfer of data between healthcare providers) is used by GoTHoMIS and AfyaPro. The



latter can support LOINC (for identifying medical laboratory observations) and SNOMED (clinical health terminology) as well.

### 3.6. Integration

The Ministry of Health in Tanzania has published its vision of highly integrated national health information system (NHIS) (Figure N). According to this vision hospital information systems (in the figure “iHFeMS” (integrated Health Facility electronic Management System)) are linked to related external systems via a Health Information Mediator (HIM) gateway. This gateway will provide routing, transformation, mediation, security, validation, queuing and staging services.

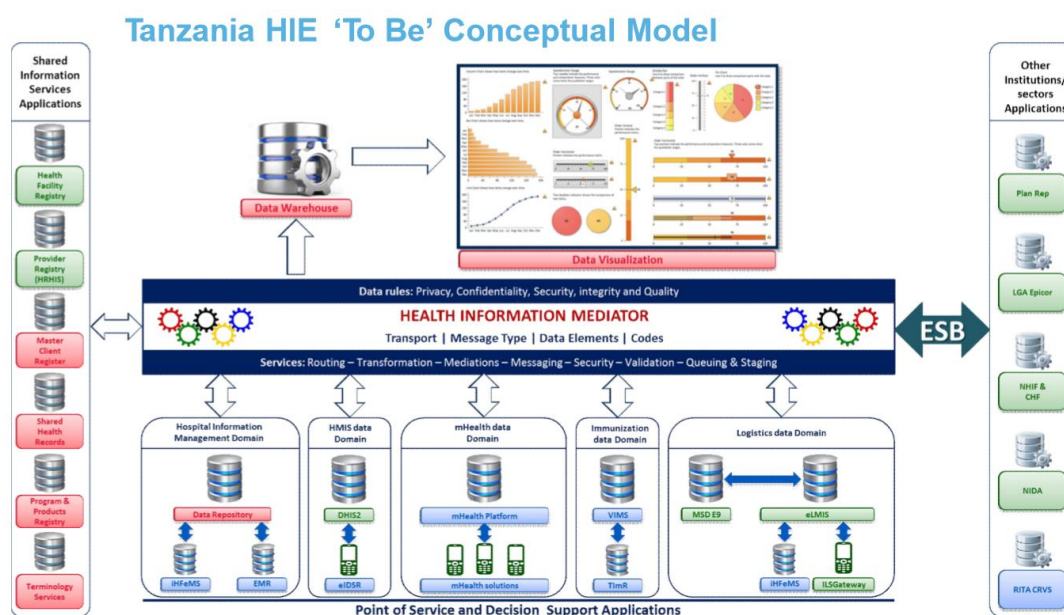


Figure 1 Vision of integrated health information system in Tanzania.

Because the HIM gateway has not yet been implemented HIS providers have started their own efforts to provide links to most important external systems. This work is however mostly in a pilot phase. GoTHoMIS has a GePG (Government electronic Payment Gateway) link via Dodoma TAMISEMI (Tawala za Mikoa na Serikali za Mitaa, i.e. regional administration and local government) system, link to MSD (Medical Stores Department) on district level and NHIF (National Health Insurance Fund) and DHIS2 (District Health Information System) links in pilot phase. Care2X has only NHIF link and AfyaPro has DHIS2 link.

The most needed internal integration would be connection to hospitals accounting or ERP system. None of the products have this link actually. However, Care2X can provide a link to WebERP (An open source web-based ERP software. It is mostly used in wholesale and manufacturing businesses. PHP application like Care2X itself. Actively developed (last update March 2018)).

## 4. DEVELOPMENT

### 4.1. Development Method and Developer Resources

GoTHoMIS and Care2X developer teams have about the same number (5-7) of developers. AfyaPro team has 11 persons in the team. Job descriptions and roles differ from team to

team. Agile development methods (prototyping and scrum) are used by GoTHoMIS and AfyaPro teams, Care2X team follows the traditional “waterfall” process.

#### **4.2. User Involvement, Feature Requests and Testing**

Users are generally involved in development process during requirements capture and acceptance testing. Care2X team offers a comment box for users and pay regular visits to hospitals and conduct meetings with personnel. In Scrum development method, used in the AfyaPro development, a representative of the product owner (user organization) belongs to the development team. In addition the AfyaPro development team has 2 so called implementors who interact with users regularly (every two weeks). And there is a plan to set up a user group in future.

No team seems to have any formal step by step procedures in place for handling new feature requests. AfyaPro team uses a ticketing system. Standard testing (unit, integration, user acceptance) is done by all teams. Care2X has a separate test server in each hospital where test are run locally. No team uses automated tests.

#### **4.3. Modifiability and Version Management**

All three products are easily modifiable and expandable due to the modular architecture. This comparison study did not have access to the actual source code. Accordingly any more detailed assessment cannot be done. Further, all products use well known and established version management systems, GoTHoMIS and Care2X GitHub and AfyaPro Apache Subversion.

#### **4.4. Quality Assurance**

Interviews with the technical persons representing the three development teams did not indicate any exact quality assurance methods and procedures in use. One interviewee of Care2X technical team mentioned that quality is assured by following Ministry’s guidelines. These guidelines state for example that “A quality assurance officer shall be appointed in the Health facility and shall be responsible for quality assurance of the iHFeMS project and shall work with the implementation team and all the respective Health facility departments involved in the project.” And there are two whole sections (4.1.8 and 4.2.7) about quality assurance in acquisition of iHFeMS. Each hospital should have its own quality guidelines and standards as well.

#### **4.5. Documentation**

All products have the standard documentation, like user manual etc. However the providers made only user manuals available for the comparison team. Consequently there is no concrete evidence and no means to review the documentation.

#### **4.6. Future Development**

All three product teams have future development plans according to customer needs and missing functionality. GoTHoMIS is merging some systems developed by University Computing Center and following the results of public sector system review. AfyaPro team was only one mentioning integration to the hospital accounting system. As a new system it has also catch the gaps compared to other two more established systems.

### **5. DEPLOYMENT**

#### **5.1. Licensing Model and Deployment Costs**

As a government project GoTHoMIS has no fee based license. Facility is responsible for infrastructure (network, computers etc.) and pays the work of the technicians who do installation, training. AfyaPro has two different licensing models: 1) per patient basis, where the charge for our solution will depend on the number of patients attended, and 2) lump sum that will depend on the size of the facility and the level of computer literacy of the staff. Care2X is distributed under GPL v2 which allows the provider charge for the distribution of the software.

In general the facility has in every case to cover infrastructure (LAN, Internet, computers, etc.) costs including work of the technicians and training costs.

#### **5.2. Training**

All three development teams have a detailed training practice and plan. Methods differ to some extent. GoTHoMIS uses the training-of-trainers method on regional level. All use extensive on-site training. AfyaPro team has introduced a certificate system. After successful test and 80 hours of system use users and super-users get a certificate.

#### **5.3. Handling Software Updates**

GoTHoMIS has both automated and manual update procedure. The former can be used if the network connection is good and continuous. Manual update can be done remotely on on-site. All products can be updated with a reasonably small break in operation.

### **6. SUMMARY AND RECOMMENDATIONS**

Technically AfyaPro differs from the other two products. Care2X and GoTHoMIS have the same general architecture and platform, have been developed from scratch for Tanzanian hospitals and are currently deployed locally inside hospital LANs. The future goal of GoTHoMIS is, however, to be nationally centralized. AfyaPro, in turn, is based on an international health IT application development environment with ready-made reusable components. In addition the recommended set-up of AfyaPro is cloud based, requiring good connectivity. Cloud solution is good for small and medium-size organizations that are unable to spend on infrastructure. It has, however, known disadvantages as well, like service outages, vulnerability to attack, vendor-lock etc. Finally, the cloud platform is not best for organizations that deal with highly sensitive and confidential customer data.

All three products have multi-browser support and user interfaces can adapt to mobile devices. The development platform of AfyaPro has in addition support for developing actual

mobile applications. Overall system requirements are fairly similar, except that the recommended deployment of AfyaPro requires a cloud service provider like Microsoft Azure.

All three products lack the possibility of transferring EMR between facilities using different HIS products. As a new system AfyaPro is missing some parts of some modules and some reports. On the other hand AfyaPro is the only system that offers patients access to their own data. It has started to use other latest technology as well, like artificial intelligence and machine learning.

All products implement the standard security features: role-based access and password protection. GoTHoMIS stores the transaction history. AfyaPro has database encryption and database auditing.

Integration to external systems of all three products is in an initial stage. The first integration efforts have been done with respect to NHIF, DHIS2, eLMIS/MSD and GePG. GoTHoMIS and AfyaPro do not have internal integration to any hospital accounting and ERP system. Integration is closely related to the use of standards. Care2X has been integrated to WebERP, an open source web-based ERP software. The software is being continuously developed (last update March 2018)). It is mostly used in wholesale and manufacturing businesses and therefore one can expect challenges in applying a system to hospitals.

All three products implement ICD10 disease classification, GoTHoMIS and AfyaPro implement HL7 as well. Regarding national standards, all providers announce that they use Ministry's guidelines as basis of development.

All products are modifiable and expandable due to modular architecture and all developer teams have future development plans and a sufficient number (5-11) of developers. As a new product AfyaPro must, however, address many development needs in order to catch up with other products. GoTHoMIS and Care2X teams can focus on external and internal (including laboratory device interfaces) integration.

Table 1 ranks (scale from 1 to 5) the HIS products by criteria which are most important to user organizations.

**Table 1 Comparison of HIS Products by Core Criteria.**

FEATURE/ASPECT	GoTHoMIS	Care2X	AfyaPro
<b>Module Coverage</b> (MoH requirements)	4	3	2
<b>Module Feature Coverage</b> (MoH requirements)	4	4	2
<b>Expandability and Modifiability</b>	4	4	4
<b>Integration (NHIF, DHIS2 etc.)</b> (current level)	4	3	1
<b>User Friendliness</b>			
<b>Safety and Security</b>	4	4	4
<b>Continuity</b>	5	4	2
<b>SUM OF RATINGS</b>	<b>25</b>	<b>22</b>	<b>15</b>

Regarding functionality the module coverage Care2X lacks operating theatre and mortuary modules. Both lack complete hospital level financial and human resource management modules. AfyaPro's module development is in progress and not complete. Individual feature coverage information of Care2X and GoTHoMIS provided by the interviewees was scattered and difficult to compare. Consequently a fair decision was to rank the products to the same

level. AfyaPro team did not provide any information regarding feature coverage required by MoHCDGEC.

All products are from the technical point of view equally modifiable and expandable. Regarding integration to external systems GoTHoMIS has done most. Care2X has only NHIF interface. All products have the basic safety features and additional hardening, although in a bit different ways.

Regarding continuity GoTHoMIS, as the government's own system, has the most solid basis. Care2X is as well an established system, but its continuity depends on its profitability to the private company. Continuity of the new AfyaPro is most uncertain.

Table 2 compares the products by the level (low, mid-range, high) of technical challenges to be met by the user facility. If installed inside the hospital LAN, all systems pose the same system administration challenges. If the servers are hosted externally by the provider, the challenges are substantially less.

**Table 2 Level of Technical Requirements.**

FEATURE/ASPECT	GoTHoMIS	Care2X	AfyaPro
Local Hw, Sw & Nw Requirements	mid-range	mid-range/low	mid-range/low

Finally, Table 3 compares the HIS products by license and technical support fees.

**Table 3 License and Technical Support Fees.**

FEATURE/ASPECT	GoTHoMIS	Care2X	AfyaPro
License	no license fee	18,500,000 – 65,000,000 (includes customization and 1 year support)	N/A
Technical Support	Currently no cost for government facilities because of USAID funds. Faith based hospitals must cover the transport and per diem for technical staff.	1,600,000 - 7,400,000 per year (integration to third party software charged separately)	N/A

The required technical infrastructure, if the system is deployed inside hospital LAN, is essentially the same for all three products. A health facility must invest in server room, Internet connectivity, local area network, server(s), workstations and peripherals (mainly printers and scanners). Hardware and software installation and training costs fall on the facility as well. The amount depends on the size of facility and how well it wants to equip its employees. Cost of deployment using national data centre or cloud hosting are difficult to estimate at the moment. Accordingly what makes actual cost differences are the license technical support fees. Table 4 lists the technical cost elements of a typical mid-size

installation. Prices vary according to providers, locations and times and must therefore be inserted by the health facility at the time of system planning and acquisition.

**Table 4 Requirements for Technical Infrastructure**

ITEM	AMOUNT	NOTE	COST TSH
Server room	1	Main expenses: renovations (walls etc.), table or rack, chair, lighting, smoke detector, fire extinguisher, UPS, AC, electric works, cabinet for storing computer stuff	
Server	1	8GB RAM, HD min 1TB	
Operating system		Windows (server, desktops, laptops)	
Platform software		MySQL supported version	
Hospital LAN	1	Local area network connecting server room and hospital units and all devices; wired and wireless options	
Firewall	1		
Antivirus software	11	Desktops, laptops and printers	
Switches/hubs	6	One in all main hospital units and server room	
Internet connection	1	5-8 Mbps, including router etc.	
Desktops	5	Minimum one in all main hospital units	
Laptops	5	For doctors	
Printers	5	Minimum one in all main hospital units	
Scanners	3		
Barcode printer and readers		Optional	
Some extra tables		E.g. for placing printers	
<b>TOTAL</b>			

On top of the technical infrastructure comes the human infrastructure. At least one or two local network and system administrators (servicing desktops and all other devices, administering operating systems and platform software) need to be hired. Helpdesk person, giving support to other users, can be an experienced user. Financial incentives must be considered as well.

Based on the analysis in previous chapters and the summary above following general recommendations can be given to hospitals:

- 1) If the hospital is a government hospitals or getting government support, go for GoTHoMIS. The system ranks slightly above Care2X in the general comparison above. In addition the Government has directed the use of GoTHoMIS at health facilities.
- 2) a) If the hospital is private hospital and financial resources are scarce, consider GoTHoMIS. GoTHoMIS has no license fee.
  - b) If the hospital is a fully private hospital and has a well-functioning system (e.g. Care2X) and no big problems with MTUHA and other reports, wait 1-2 years and see what comes out of the new AfyaPro product and how Care2X develops. GoTHoMIS is a good system but may not be in long term modified sufficiently according to the needs of private hospitals.

c) If the hospital is a fully private hospital and has AfyaPro and need to change system soon (must be changed before 2020 anyway), consider Care2X. GoTHoMIS is a good system but may not be in long term modified sufficiently according to the needs of private hospitals.

d) In general fully private hospitals can consider Care2X (and maybe later AfyaPro), because, even if modifiable, GoTHoMIS may not be modified sufficiently according to the needs of private hospitals.

One additional decision criterion is whether the hospital's technical staff's competencies match with the product's technical platform.

Recommendations to system providers and developers, in turn, are following:

- 1) The software architecture is modular and consequently expandable and modifiable. Consider in future partitioning the system into components (e.g. microservices) that can be run under separate operating system instances. This solution makes maintenance and centralization easier.
- 2) Complete and bring all architectural models and other documentation up-to-date.
- 3) Focus on designing and implementing all necessary external (NHIF, DHIS2, etc.) and internal (laboratory devices, accounting) integration. This has a big impact on the daily workload in hospitals.
- 4) Put effort on implementing all remaining necessary and useful reports/
- 5) Work together with MoHCDGEC and other providers to implement a standard EMR format that enables hospitals with different systems to exchange patient data.
- 6) Harden security and safety further. MoHCDGEC guidelines list many important security and safety features that are missing from all three HIS products.
- 7) Develop a detailed and well documented procedure (phases and steps) from requirements capture, through development and testing to deployment and system administration. A system delivery and life cycle management for both the provider and the customer. The DevOps concept. Use automation and monitoring where possible.

## REFERENCES

Guidelines and Standards for Integrated Health Facility Electronic Management Systems.  
Ministry of Health, Community Development, Gender, Elderly and Children, January 2016

## APPENDIX 1 TECHNICAL COMPARISON – CRITERIA AND DATA

### INTERVIEWEES

**GoTHoMIS:** ICT Officer, PMO-RALG, Dodoma. MSc, Computer Science. 12 years in ICT, 15 months with the product. Has been coding the product as well

**Care2X:** Sys Adm and programmer. Diploma in ICT. Since 2001 in ICT, since 2006 with the product. Has been coding the product as well.

**AfyaPro:** Lead system developer. Bachelor, Computer engineering and information technology. 4 year in business.

Note 1: AfyaPro technical data describes the new system! It does not make sense to describe an old system which is no more sold.

Note2: Text from MoHCDGEC guidelines is added where relevant to give the reader an opportunity to compare products to the requirements in the guideline document.

### PRODUCT

#### 1. Hardware, software and network architecture

##### 1.1. General architecture

**GoTHoMIS:** MVC web application. App logic and db on the server. Designed to be run centralized on national, regional, etc. level (due to the state of national infrastructure currently run on local servers). Monolithic (one single web application) but modular. Modules can be updated separately without downtime.

**Care2X:** Modular. MVC. Web based. Interfaces for mobile devices.

**AfyaPro:** Cloud based (Azure), but can be installed locally as well. Rule based decision support engine. Process driven design. Knowledge server (protocols, code lists, medical rules). Configuration server (XML). MVC. On top level the system is divided into different portals: developer (studio), professional (doctor), patient. Module, functionality, feature.

##### MoHCDGEC guidelines:

-The system shall be designed to allow expansion through additional web and mobile applications.

-Implementation of the application software and design of database structure shall be flexible enough for the necessary changes in the later phase

##### 1.2. Platform software

**GoTHoMIS:** PHP, Laravel, MySQL and PostgreSQL, Angular Material, HTML, CSS.

**Care2X:** PHP, MySQL (InnoDB), JQuery, HTML, Apache2 web server.



**AfyaPro:** C#, MySQL, IIS, XML, JavaScript, VitalHealth platform (no need for traditional programming). Layout manager.

### 1.3. Operating system

**GoTHoMIS:** Windows (in most cases) and Linux.

**Care2X:** Windows and Linux (Ubuntu).

**AfyaPro:** Windows.

#### **MoHCDGEC guidelines:**

-The software shall be flexible for migration to another Operating System platforms or Databases.

### 1.4. Network

**GoTHoMIS:** LAN. Goal centralized server in government datacentre.

**Care2X:** LAN, computers in departments.

**AfyaPro:** Default cloud based, but can be run in hospital LAN as well.

#### **MoHCDGEC guidelines:**

-Local area network (LAN) should have well structured cabling and well labeled considering quality cabling design. The design should separate access network from the backbone network that connects buildings.

-The Wide Area Network (WAN) / Internet connectivity should have the required speed capable of supporting the business requirements. Depending on the deployment architecture used, a backup or redundant connection is required.

-The LAN connection to the Internet must be restricted by the firewall.

### 1.5. Mobile device support

**GoTHoMIS:** No real mobile applications.

**Care2X:** No real mobile applications.

**AfyaPro:** Some mobile applications (React app for patient portal).

#### **MoHCDGEC guidelines:**

- The system shall be “device aware” and vary content and access based on which device a user is utilizing i.e. users can securely access the system via alternate devices, such as handheld PDAs and mobile phones.

### 1.6. User interface

**GoTHoMIS:** Browser. Only in English! Panoramic views: clerk sheet.

**Care2X:** Support IE, Mozilla, etc. browsers. Panorama views?

**AfyaPro:** Multi-browser (Explorer, Chrome, Safari, Firefox). Single sign-on. Platform supports multilingual implementation. Online help and error messaging implemented. Panorama views: patient overview (information accessed via tabs).

Dashboard or panoramic views mean views where the user can on one screen and at the same time see or access all the essential information regarding an entity (like patient, doctor, hospital unit, etc. ) or a group of entities. These views can consist of multiple panes, set of links and menus.

#### **MoHCDGEC guidelines:**

- System should communicate error messages to users reporting the likely cause and proposing solution.
- It should be easy to use and navigate from page to page.
- Other tools like search options and alphabetical arrangement of items can be implemented to help user obtain specific information easily and quickly.
- Well-designed graphical interface to help users identify the proper choice on the screen.
- An online help shall be provided for the users.
- The system should provide interactive touch screen interface for ease and fast access.
- The system should help users to avoid doing mistakes.
- The system should provide screen, mouse and keyboard navigation.
- The system should be easy to navigate by using clear words, menus and drop-down lists.
- System accessibility shall encompass all disabilities that affect access to the web-based systems, including visual, auditory, physical, speech, cognitive, and neurological disabilities.
- The system shall provide handicap access and must provide multilingual support.
- As a web-based application, the system shall support the latest version of the majority of browsers such as Internet Explorer, Firefox Mozilla, Chrome and Safari, as well as common mobile devices.

### **1.7. System requirements**

**GoTHoMIS:** Server (8GB RAM, HD min 1TB), Workstation (2GB RAM), Internet connection, thermal printer, barcode printer, barcode reader. LAN.

**Care2X:** LAN. Server (Xeon, quad-core, RAM 4GB, HD 500GB). Workstation. Data backup facility. Power backup and protection 24/7. Internet connection.

**AfyaPro:** Server (RAM 8GB, HD 1TB, Intel core i5). Workstation (RAM 8GB, Intel core i3). LAN. Internet speed 5-8 Mbps. Centralized power backup. Cloud service provider.

## **2. Data Model**

All products use a relational data model and database. AfyaPro has configuration data in a NoSQL data store. None of the providers was willing to share the data model with interviewers.

## **3. Functionality**

List of existing department specific modules and other major functionalities:

**GoTHoMIS:** Patient registration (Y), outpatient (Y), inpatient (Y), EMR (Electronic Medical Record) (Y), EMR transfer between hospitals that use different HIS products (N), laboratory (Y), pharmacy (Y), operating theatre (Y), mortuary (Y), emergency (Y), billing (Y), appointment (Y), appointment scheduling (N), patient tracking (Y), queuing (N).

**Care2X:** Patient registration (Y), outpatient (Y), inpatient (Y), EMR (Electronic Medical Record) (Y), EMR transfer between hospitals that use different HIS products (N), laboratory (Y), pharmacy (Y), billing (Y), appointment (Y), appointment scheduling (Y), patient tracking (Y), queuing (N).

**AfyaPro:** Patient registration (Y), outpatient (Y), inpatient (N), EMR (Electronic Medical Record) (Y), EMR transfer between hospitals that use different HIS products (N), laboratory (Y), pharmacy (Y, stock management missing), emergency (Y), billing (Y, invoices can be produced as reports), appointment scheduling (Y), patient tracking (N), queuing (Y).

(Patient tracking means that using the HIS health care personnel can find any time the location of a certain patient inside the facility. It shows also under which treatment and in which sub-unit of the facility the patient currently is.)

Other useful features:

**GoTHoMIS:** patient reminders and alerts (N), alerts and messages between hospital sub-units (Y, from lab), monitoring and evaluation (using reports), decision support (using reports), research data collection (N), UI for patients (N), telemedicine (N).

**Care2X:** patient reminders and alerts (N), alerts and messages between hospital sub-units (Y, from lab), monitoring and evaluation (using reports), decision support (using reports), research data collection (Y), UI for patients (N), telemedicine (N).

**AfyaPro:** patient reminders and alerts (Y), alerts and messages between hospital sub-units (Y, from lab), monitoring and evaluation (using reports), decision support (using reports, dev platform for its part supports AI and machine learning (used now in diabetes care)), research data collection (N), UI for patients (Y), telemedicine (Y, for diabetes treatment).

(Patient reminders are sent to individual patients by SMS, email, etc. Reminders are about appointment dates and times, medication etc.)

Reports:

**GoTHoMIS:** MTUHA. Only reports that are submitted to the ministry; local, hospital specific reports not implemented.

**Care2X:** Daily visits, income, disease cases, ward occupancy etc. MTUHA.

**AfyaPro:** MTUHA (not generated yet). DHIS reports generated but must be manually entered into DHIS. Financial summary reports generated.

**MoHCDGEC guidelines:**

-MoHCDGEC guidelines' minimum requirements list following modules: patient management (i.e. outpatient and inpatient), laboratory, laboratory orders, operating theatre, billing, pharmacy and inventory, medical records, human resources, reports, mortuary and financial management.

#### 4. Security and Safety

**GoTHoMIS: Security:** role-based access (Y), password protection (application) (Y), password protection (database) (Y), database auditing (N), concurrent account access restriction (Y), transaction history (Y), encryption (N) and network access (only within facility). **Safety:** backup (manual and automatic, incremental, once or several times per day).

**Care2X: Security:** role-based access (Y), password protection (application) (Y), password protection (database) (Y), database auditing (N), encryption (Y, connections from outside HTTPS or VPN), network access (connections from outside HTTPS or VPN, LAN firewall). **Safety:** backup (manual and automatic, incremental, once or several times per day) (facility responsible). Server redundancy: master and slave server.

**AfyaPro: Security:** role-based access (Y), password protection (application) (Y, default: must be changes every 30 days (but the number of days can be configured)), password protection (database) (Y), database auditing (Y), encryption (Y, db encrypted), SQL injection prevention (Y), activity logs (Y), network access (external traffic: firewall, VPN). **Safety:** backup (manual and automatic, incremental, once or several times per day) (facility responsible).

#### MoHCDGEC guidelines:

- The threats mentioned above (denial of Service, malicious attacks, etc.) can be reduced/avoided by implementation of stronger firewall, antivirus, patches, and standard policy for access control
- All sensitive data entered into the system must be encrypted by strong cryptographic techniques.
- Additionally the system should provide security means to protect itself from automated attacks by using methods such as "CAPTCHA" when processing login requests in special cases.
- The system shall provide the users with a secure way to change their passwords.
- The system should use the HTTPS protocol in subsequent iterations in order to prevent unauthorized third-party viewing of the contents.
- The system shall provide access for authorized users while screening out those who do not need to view confidential data.
- The system shall provide transparent and automated security management of IDs, security policy enforcement and automated password resets.
- First Login password generation followed by mandatory account password be changed on next login.
- Passwords must adhere to complex password rules including encryption.
- Credential Control (Official Government Email as username for Public Institution).
- Password Expiry (3 months Max).
- Password Reset (automated).
- Maximum number of login failures (4 times) followed by inactivity (5 minutes).
- Minimum number of inactivity events (2 times) followed by account lockout.
- Issue (automated) alert on inactivity events.
- Provide log records for audit and traceability on authentication violation.

- Provide authorized access on role based and need to know basis.
- Roles mapped with Groups.
- Limit session inactivity/idleness (5 minutes).
- Limit concurrent account access i.e. inactivate any other live sessions should another session get.
- Allow only web access to all users.
- System administrator SSH only from intranet and VPN for remote access.
- The transaction history should be maintained.
- The system should retain partial data from interrupted entry for 15 minutes.
- The system must have reliable primary and backup power supply. Backup power supply solutions may include uninterrupted power supply (UPS), Inverter with battery bank, generator or solar power system enough to power all servers and network devices for at least 8 hours (preferably 12 hrs.).
- It must have proper security including physical access controls and all visits must be recorded. Logbook or an automatic access control system should be registering all visits to the server room/ Data Center.
- The hosting environment must be temperature controlled with air conditioner and well furnished. Furthermore, it must be free from dust, water leaks and humidity.
- The servers should be rack mountable servers installed in lockable rack cabinets, together with required backup storage.
- The hosting environment must have fire extinguishers and fire detection systems (alarms).

## 5. Accessibility and Availability

### MoHCDGEC guidelines:

- All LAN and/or WAN infrastructure must be fully resilient so that the failure of any single component or link cannot cause interruption of service.
- All computer hardware (particularly all servers) and associated equipment including power supply, network interfaces, air conditioning etc. must offer full fail over capability so that the failure of any one server or other component cannot cause interruption of service.
- The systems shall be designed to allow for continuous operation on a 24 hour, 365 day per year basis.
- The system shall deliver an overall availability of 99.95% with the maximum length of a single downtime incident in any one calendar (January - January) year being 4 hours.
- If downtime is experienced for any application delivered through the system, a notice should be displayed on the system stating the expected time to repair.
- Within one hour of any malfunction, the problem will be logged, analyzed to gauge the severity of the problem and a course of remedial action identified with appropriate persons notified.
- If network/hardware failures occur, other link should pick up and continue operation without user noticing. This can be accomplished by deploying redundant network links and hardware.

## 6. Standards

**GoTHoMIS: National:** In general ministry's guidelines and standards as basis for development. **International:** ICD10, HL7.

**Care2X: National:** In general ministry's guidelines and standards as basis for development. **International:** ICD10, ICD9.

**AfyaPro: National:** N/A. **International:** ICD10, ICD9, LOINC, SNOMED, HL7.

**MoHCDGEC guidelines:**

- The project development in public health facility must comply with all the relevant e-Government related standards, guidelines, procedures and other best practices
- The system may also use the communications resources provided by the Government such as National ICT Backbone, GovNet, etc using HTTP/HTTPS protocol for communication with the web browser and the web server and TCP/IP network protocol with HTTP/HTTPS protocol.
- Open non-proprietary standards will be given preference over proprietary ones.
- International standards, which have been implemented and validated, will be preferred.
- The system must have the capability to transmit and receive a defined minimum set of patient data via standardized HL7 messaging.
- The system should be able to build up the data for medical records using standard the International Classification of Diseases (ICD) version 10.

**7. Integration**

**GoTHoMIS: External:** GePG (Y, via Dodoma TAMISEMI), NHIF (pilot phase), DHIS2 (pilot phase), eLMIS/MSD (Y, district level), HI Mediator (under planning). **Internal:** accounting/ERP (N).

**Care2X: External:** GePG (N), NHIF (Y), DHIS2 (N), eLMIS/MSD (N), HI Mediator (N). **Internal:** accounting/ERP (API with WebERP).

**AfyaPro: External:** GePG (N), NHIF (N), DHIS2 (N, development started), eLMIS/MSD (N), HI Mediator (N). **Internal:** accounting/ERP (N).

**MoHCDGEC guidelines:**

- The system should be capable to talk with other systems.
- The system must be able to share data with other systems such as DHIS2, HRHIS, PACS, financial systems etc. using data exchange standards /communication interfaces e.g. Application Programming Interfaces (APIs) developed based on different technologies such as JSON, XML, DXML etc.
- The system shall also be able to interface seamlessly with third party diagnostic devices such as digital X-Rays, MRIs etc.
- In addition to the above, Health Facilities should adhere to eGovernment related standards and guidelines such as eGovernment Interoperability Framework (eGIF), Data Architecture etc.

**DEVELOPMENT**

**1. Method**

**GoTHoMIS:** Prototyping (no strict procedure followed). Incremental.

**Care2X:** Waterfall.

**AfyaPro:** Model driven development. Scrum.

## 2. Developer Resources

**GoTHoMIS:** 7 (3 with effective contract, 3 under contract renewal, 1 intern). All full time. Roles: project coordinator, developer, document writer.

**Care2X:** 6: 2 part time 4 full time.

**AfyaPro:** 5 at present. 4 new coming soon. Each has been assigned to develop a set of modules. 2 implementors do the testing. Total 11 people.

### MoHCDGEC guidelines:

-Several tests must be conducted prior to system acceptance.

## 3. User Involvement, Feature Requests and Testing

**GoTHoMIS: User involvement:** User are involved in requirements capture and acceptance testing. **Feature requests:** No exact procedure currently followed. Prioritizing case by case. **Testing:** Technical team is first testing (integration and module). Then user acceptance tests. No automation.

**Care2X: User involvement:** A comment box is available for users. Users prefer to make phone calls. Developers pay regular visits to hospitals and conduct meetings with personnel. **Feature requests:** N/A. **Testing:** Test are run locally. Each hospital has a test environment (server). Each module is tested manually. Changes are tested with live data for two weeks. No automation.

**AfyaPro: User involvement:** According to scrum method the product owner is one of the team members. The AfyaPro development team has 2 so called implementors who interact with users regularly (every two weeks). Plan to set up a user group in future. **Feature requests:** Ticketing system. **Testing:** Series of tests (unit etc.). Test scripts are used. No automation.

## 4. Modifiability and Version Management

**GoTHoMIS: Modifiability:** Due to modular structure fairly easy to modify and expand. Current changes are very small. Product has not been modified during deployment. **Version management:** GitHub.

**Care2X: Modifiability:** Due to modular structure fairly easy to modify and expand. **Version management:** GitHub.

**AfyaPro: Modifiability:** Due to modular structure fairly easy to modify and expand. **Version management:** Subversion.

### MoHCDGEC guidelines:

-It will have the capability to integrate with more stakeholders that are not specified for the time being.

## 5. Quality Assurance

**GoTHoMIS:** No exact procedure currently in use but under planning.

**Care2X:** By following MoH guidelines.

**AfyaPro:** Embedded into scrum method. Feature prioritization. High quality as goal.

## 6. Documentation

**GoTHoMIS:** The standard ones (UI design, data model, User Manual etc.). May not be up-to-date due to continuous development. Source code has inline documentation.

**Care2X:** The standard ones (Data model, User Manual etc.). Source code not documented.

**AfyaPro:** The standard ones (user manual, developer manual and implementors guide). Source code documentation?

## 7. Future Development

**GoTHoMIS:** Deployment to national level hospitals requires certain changes. Some changes to reports. Some systems (EMR, TB, ...) developed by UCC will be merged to GoTHoMIS. USAID funded public sector system review may result in some new features.

**Care2X:** Team keeps on developing the system daily to meet compatibility with new changes such as changes in databases technology, php frameworks etc. More reports.

**AfyaPro:** Cue management 2018. Integration to accounting. NHIF integration. Surgery. Inpatient. Connection to lab devices. Maternity. Hypertension. HIV. More reports.

## DEPLOYMENT

### 1. Licensing Model

**GoTHoMIS: License:** No fee based license. Financed by government. **Fee:** N/A.

**Care2X: License:** GPL v2 (<http://oss-watch.ac.uk/resources/gpl>). **Fee:** N/A.

**AfyaPro: License:** Two models: 1) Per patient basis, where the charge for our solution will depend on the number of patients attended. 2) Lump sum that will depend on the size of the facility and the level of computer literacy of the staff. **Fee:** N/A. Fee depends on the type and size of facility.

### 2. Deployment Costs

**GoTHoMIS:** Infrastructure (LAN, computers, etc.) costs including work of technicians. Training costs.

**Care2X:** Costs depend on the type and size of facility.



**AfyaPro:** Licence fee. Infrastructure (LAN, computers, etc.) costs including work of technicians. Training costs. If cloud based solution: Hosting and Internet costs.

### 3. Training

**GoTHoMIS:** Training of trainers on regional level. Lab training in groups according to role. The on-site training. Length of training according to module.

**Care2X:** 2 week training for users. One user gets training 2 hours per week.

**AfyaPro:** Classroom per each department. Up to 3 days training. Users assist each other during training. Thereafter practice and test. After successful test and 80 hours of system use users get a certificate. Additional training session and certificate for superusers.

### 4. Handling Software Updates

**GoTHoMIS:** Automated update if server connection is good and continuous. Otherwise remote access or on-site update.

**Care2X:** First testing in provider's environment. Then second test at client environment. After that final update and commit of the changes.

**AfyaPro:** About 15 min break in operation.

#### **MoHCDGEC guidelines:**

- Essential maintenance to the system and all associated applications shall be capable of performance without interruption to service.
- If downtime is experienced for any application delivered through the system, a notice should be displayed on the system stating the expected time to repair.