MINISTRY OF HEALTH

DEVELOPMENT OF THE KHRO DATA WAREHOUSE AND WEB PORTAL FOR THE MINISTRY OF HEALTH

PROJECT LOCATION:	KENYA
PROJECT OWNER:	MINISTRY OF HEALTH - KENYA
SPONSOR:	WORLD BANK
PROJECT START DATE:	16th MAY 2019
PROJECT END DATE:	30th JULY 2019
INITIAL PROTOTYPE:	15TH JULY 2019
DATA WAREHOUSE CONSULTANT:	DR. STEPHEN MBURU

WORLD BANK GROUP

World Health Organization

EXECUTIVE SUMMARY

The Ministry of Health (MOH) is committed to supporting global efforts to increase accountability and improve quality of data for decision-making. To this effect, the Kenyan Government has invested a lot in multiple health information systems to monitor health systems performance, and the country compiles data through these systems. The District Health Information Software version 2 (DHIS2) is the main database where both private and public health facilities are required to enter routine data on service utilization and inputs. Moreover, Information related to health facilities is captured through the Kenya Health Master Facility List (KHMFL), while human resources data are also managed separately through multiple human resources information systems. Additionally, several households and facility surveys (e.g. malaria indicator surveys, and household health surveys) are conducted regularly to capture data on service coverage and financial risk protection. While these routine and non-routine systems provide useful data for Kenya, better value can be achieved by integrating and strengthening capacity for timely generation and use of quality data and statistics.

To realize this goal, Health Data Collaborative Partnership (HDC) has brought together global health agencies to support countries towards improving the availability and use of quality data for evidence-based planning and decision making. The Kenya HDC chapter launched during May 2016, identifies, among other priorities, the need demand for health data through shared platforms. This is the motivation behind development of Kenya Health and Research Observatory (KHRO) that that will enhance monitoring and reporting of progress towards attainment of Universal Health Coverage (UHC) and Sustainable Development Goals (SDGs). During the launch of HDC, MOH noted that the KHRO will improve availability, quality and use of health information for evidence-based policy and decision-making. Furthermore, KHRO is aimed at facilitating multi-stakeholder collaboration and partnership in accessing health-related research from local universities, research institutions, and county research units.

Based on the landscape report, KHRO is designed as an integrated platform comprising of two distinct but interrelated functions: **Data and Statistics Platform**, and **Research Knowledge Translation Platform**. The two components will be used to generate evidence and intelligence critical to country's progress towards UHC and SDG.

To realize this agenda, MOH with support from the World Bank and technical support from the World Health Organization (WHO) contracted me to work with iLabAfrica of Strathmore University Research Consultancy Center in developing KHRO data warehouse. The Data Warehouse (backend) will be customized based on the new WHO's Integrated Africa Health Observatory (AHO) data warehouse. Based on the architecture of the warehouse, @iLabAfrica team will develop the initial version of KHRO web interface that will serve as a centralized dashboard for access to health data, statistics, and research products.

In summary, this inception report provides detailed data warehouse development methodologies and workplan running from May to July 2019. The report stipulates how the project will be governed through a joint development team.

ACKNOWLEDGEMENT

Development of Kenya Health and Research Observatory (KHRO) has been conceptualized and conducted through the tremendous efforts and support from Ministry of Health-Kenya, World Bank (WB), World Health Organization (WHO), AMREF Health Africa, and the Academia among other in-country partners under the umbrella of the Kenya Health Data Collaborative. I acknowledge the leadership and strong support being provided by Dr. Charles Nzioka to make KHRO development process a success. Given that the development process is an expensive undertaking in terms of human and material resources, I wish to appreciate the role played by World Bank through Dr. Jane Chuma; WHO via Leonard Cosmas (WHO), AMREF Health Africa; Dr. Joseph Sevilla of Strathmore University; and Prof. Peter Waiganjo of University of Nairobi's.

Further, I wish to acknowledge the role being played by MoH Core Team comprising of Onesmus Kamau (Head of eHealth Development Unit-MoH); Jane Otoko (Head of ICT - MoH); and Peter Wanjohi (Health Research & Development Unit); Dr. Wesley of HIS; and M&E representatives. Their commitment to regular and ad hoc meetings to guide and assess the development process is very encouraging. At WHO AFRO and HQ levels, I wish to thank Dr. Humphrey Karamagi (AFRO) and Dr. Benson Droti; and Phillipe Bouche from WHO headquarter for an opportunity to redevelop the new African Health AHO.

My sincere gratitude to KHRO Technical Working Group (TWG) members, health professionals and ICT experts who have sacrificed their time during our inception meetings to provide pre-design considerations. Thanks to Steve Wanyee; Gitahi Nganga; Dr. Margaret Makumi, Dr. Wanyee (Ms); and James Kariuki of KEMRI. I cannot forget to thank my Wife Esther; Kids: Laura, Collins and Olivia who have given me a node to undertake this demanding task for the betterment of the health sector. Last but not least, my prayers to the Almighty God to give me good health, sober mind, and strength to perform this task of national and global importance.

ABBREVIATIONS

ACID	Atomicity, Consistency, Isolation, Durability (database transaction properties)
AHO	Africa Health Observatory
AFRO	African Regional Office - WHO
API	Application Programming Interface
BI	Business Intelligence
CDC	Change Data Capture (data warehousing context)
CRF	Change Request Form
DHIS2	District Health Information System version 2
DWH	Data Warehouse
ETL	Extract, Transform and Load
HDC	Health Data Collaborative
HSS	Health Systems Strengthening
IT	Information Technology
ITM	Information Technology Management
ICT	Information and Communication Technology
JAD	Joint Application Development
KHRO	Kenya Health and Research Observatory
KTP	Knowledge Translation Platform
MoH	Ministry of Health, Kenya
NDA	Non-disclosure Agreement
QA	Quality Assurance
RAID	Redundant Array of Independent Disks
RAM	Random Access Memory
SDG	Sustainable Development Goals
SCD	Slowly Changing Dimensions

TOR	Terms of Reference
TOS	Talend Open Studio
UHC	Universal Health Coverage
WHO	World Health Organization
YoY	Year-on-Year Support
ZIP	In this context, file(s) stored in compressed format

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INTRODUCTION

The purpose of developing Kenya Health and Research Observatory (KHRO) as an integrated repository is to make it more responsive to demands for evidence-based decision making at the country level. To develop KHRO, we will employ **user-centred**, collaborative and participatory approach. It has been agreed with the MoH Core Team lead by Dr. Charles Nzioka that bi-weekly meetings will be held to monitor and guide the development process. During review meetings held on 17/04/2019, 24/04/2019, 02/05/2019 and 22/05/2019 the following factors that will determine success of KHRO were identified:

1. Strategies to fulfill user requirements at county and national levels;
2. Readiness of MoH to support development, implementation and sustainable utilization of KHRO at subnational and national level;
3. Commitment to the process by the hired consultants in terms of availability of technical skills and capacity to deliver KHRO;
4. Strategies for availability and performance of KHRO to be hosted on MOH data centres and her technology partner (University of Nairobi);
5. Mechanism for data acquisition, adequacy and quality assurance from counties and health support programmes.

Project Vision

It is envisioned that once KHRO Project is completed, the repository will help in evidence-based decision making, and monitoring of health sector performance. The solution will also seek to empower end users to be more productive; and at the same time enable health providers use data provided to make informed decisions.

Project Scope

The Data warehouse consultant together with @iLabAfrica will work closely with the MOH, WHO and World Bank, and the KHRO TWG in development of the KHRO platforms. As outlined in the Terms of Reference (Annex 2), the scope of work includes planning, documentation, development and installation of a data warehouse on MOH Data Centre.

The Gantt Chart in Annex 1 shows a detailed workplan developed jointly with the consulting firm, i.e. iLabAfrica. Key considerations that informed our joint work plan include:

- Co-design of an integrated data warehouse that receives cleaned and approved data from aggregate and national-level health systems like DHIS2, iHRIS and KEMSA's LMIS. Data available in the warehouse will be filterable with different parameters to track, monitor and report on the health indicators.
- Establish mechanisms to ensure the data warehouse is interoperable and seamlessly able to exchange information with existing National Health Information Systems, Integrated African Health Observatory (AHO), and the Global Health Observatory (GHO).
- The data warehouse developer expects @iLabAfrica team to put in place strong access control mechanisms to guarantee security of data accessed from the warehouse.
- Open APIs and data filtering tools will be developed to allow stakeholders to interact and engage with various health indicators. The filters will be used on visualization objects like maps and charts.
- The platform will be optimized for incoming and outgoing data velocity, and load balancing through replication, data sharing, and distributed mobile computing infrastructure.
- The data warehouse consultant will require additional facilitation to provide technical training and capacity building to the Ministry Core Team on how to manage and update the new repository.
- Design a user-friendly and fit-for-purpose front-end web portal.
- The data warehouse will be content-heavy to provide enough data for visualization and generation of triangulated datasets from integrated source systems identified in KHO landscape.
- Upon successful testing and validation of the beta version, the data warehouse physical schemas and related metadata will be installed on MOH data centres and handed over to the Ministry.

- Deliver a detailed technical specification documents and all artifacts including the source code. The ownership of KHRO artifacts will henceforth belong to the Ministry of Health.

Specific Tasks

Development of KHRO from Back-end to Front-end will be a collaborative assignment that began on 1st May, 2019 upon receiving Terms of Reference. The Gantt chart in Annex 1 gives detailed breakdown of activities that practically requires *about 83 days but only 45 have been contracted*. The following is a brief outline of the activities I will be undertaking as an individual consultant but in close collaboration with iLabAfrica team (See Annex 2):

1. Develop a tentative project workplan for KHRO Data warehouse and web portal (*in consultation with iLabAfrica Team*)
2. Develop a tentative business specification based on the TOR and stakeholders' feedback
3. Develop a high-level technical model from design review based on WHO framework *of action*
4. Develop a high-level dimensional model from design reviews based on WHO framework *of action*
5. Present the first prototype version of the *KHRO* data warehouse
6. Present the first prototype version of the web portal *(in collaboration with iLabAfrica)*
7. Present the second version of the data warehouse prototype incorporating stakeholder input from the first version *(in collaboration with iLabAfrica)*
8. Present the second version of the web portal prototype incorporating stakeholder input from the initial prototype *(in collaboration with iLabAfrica)*
9. Present the final version of the data warehouse
10. Present the final version of the web portal *(in collaboration with iLabAfrica)*
11. Conduct training to MOH members on the KHRO web portal *(in collaboration with iLabAfrica)*
12. Present the End User Manual for Management and Maintenance of KHRO *(back-end technologies)*

The activities imply that I will be required to continue working with iLabAfrica up to the end of the development lifecycle. Consequently, additional time will be required for the extra support to MoH and iLabAfrica team.

KHRO DEVELOPMENT PROCESS

The Kenya Health Sector make use of several health information systems to collect clinical, financial and performance indicators. To optimize decision and policy making, these systems need to be integrated. In fact, a centralized access to KHRO dashboard will improve performance and monitoring of progress towards achievement of Universal Health Coverage (UHC) and Sustainable Development Goals (SDGs). For this assignment, KHRO Development Team will capitalize on existing health information systems to develop an integrated repository that will be used to access health data and statistics, knowledge products, and Community of Practice (CoPs).

The development phase started with two inception meetings held on 17th and 24th April 2019. The meeting of 17th was held in Afya House to introduce the consultants, i.e., iLabAfrica team and Data warehouse focal person (Dr. Stephen Mburu) to Dr. Charles Nzioka, Acting Director of Research and Development Directorate. The session was also attended by Steve Wanyee and Gitahi Nganga to give insight into the outcomes of KHO landscape assessment conducted in 2018. The second meeting held at World Bank premises brought together the team of consultants, Dr. Jane Chuma (World Bank), and Cosmas Leonard of WHO. During this meeting, various items in the TOR for the assignment were discussed with an aim of coming up with detailed workplan for the development and implementation of KHRO. The following were some of the key points agreed upon in the two crucial meetings:

1. Submit detailed an inception report containing detailed workplan that will be used as a guide to monitoring progress towards implementation of KHRO;
2. The Ministry of Health, World Bank, and WHO will provide technical, financial, administrative, and advisory support in order for the consultants to provide required deliverables within constraints of time and budget;
3. Agree on the action plan that will guide the team in setting the objectives, activities and deliverables during the design and development of the data warehouse and web portal.

Furthermore, during the inception meetings, strategies for process quality assurance and best practices were formulated in order to increase satisfaction while reducing overall development costs. Some of the of factors considered during the two meetings and our internal design reviews include:

1. Employ collaborative, and user-centred approach to gather functional and non-functional specifications.
2. For consistency and conflict management, iLabAfrica team was also required to submit an inception report that provides details on roles and responsibilities played by the two parties.
3. The Ministry of Health through assistance of Dr. Nzioka to provide privileged access to systems key among them the DHIS2, KHMFL, iHRIS, Situation Room and LMIS. This will help the data warehouse designer populate the matrix provided in Annex 3.
4. The data warehouse focal person (myself) to work seamlessly with iLabAfrica team to develop and provide technical input required to serve data to the web portal and Data visualization tools like Tableau and Power BI.
5. Formulate strategies for improving and optimizing KHRO back-end and front-end access using open API and transactional query transactions (ACID).

The inception phase also includes other tasks like technical design workshops for KHRO design, systems review and versions control. These workshops will have generated the following artifacts:

- Validated KHRO Design Checklist to be used for the identification and management of design issues, requirements and recommendations.
- KHRO Project Management Charter stating the current state and deliverables of the data warehouse at the moment of review.
- Detailed work plan that states specific objectives, roles and activities that will be undertaken by each member of the Development Team, and the stakeholders.

Project Management

Project management is important because it ensures whatever is being delivered meets the client's needs and expectations. To optimize post-deployment success of KHRO, we have formulated a predictable project management process coordinated by three key people; a Team lead (Emmanuel Kweyu), Coordinator (Ms. Imelda Mueni) and WB/WHO Focal Point (Mburu). Table 1 below shows roles and responsibilities assigned to each actor. The term actor in this context means anyone who has a stake in the development of KHRO.

Table 1: KHRO Roles and Responsibilities

PROJECT ROLE	RESPONSIBILITIES	ACTOR
Project Sponsor	Resolving major issues escalated by project manager Chair Project Steering Committee meetings Disseminate Project Status Reports to Key Stakeholders Overall Project Advisory	World Bank – Dr. Jane Chuma World Health Organization - Cosmas Leonard
Project Managers:	Manage day to day running of the project Issuing Project Status Reports (at predetermined intervals) Coordination of project activities in the various business areas Escalation of pertinent issues to Project Sponsor Overall project Quality Control Identify and manage project risks Chair Project Implementation Team Meeting Internal Resource Mobilization	@iLabAfrica – Dr. Emmanuel Kweyu Data Warehouse Consultant - Dr. Stephen Mburu WHO - Cosmas Leonard MOH - Dr. Charles Nzioka
Project Steering Committee	Sanction major communication to external stakeholders on project progress (e.g. press announcements) Approve Project Plan Approve the major project milestones Advisory Role	WHO -Cosmas Leonard TWG – Onesmus Kamau MOH - Dr. Charles Nzioka
Project Implementation Team	Business Area process owners Subject Matter Expert (SME) Business Area project deliverables and milestones Manage project scope within respective business area Sign off on business model user requirements and processes Authorizing Change Requests Change Agent in respective functional area	Web Portal Consultant - Strathmore University Data Ware House Consultant – Dr. Stephen Mburu WHO – Cosmas Leonard MOH – Dr. Charles Nzioka

Back-end Design Checklist

During intensive technical review workshops health between 9th and 17th May at Strathmore University, KHRO Development Team came up with design checklist summarized in Table 2. Note that checklist is part of our project management tools that will be populated with actors and remarks details during our JAD sessions.

Table 2: Template of KHRO Design Checklist Populated During JAD Sessions

#	DESIGN FACTOR	ACTOR(S)	REMARKS
1.	Who is missing in the design review process? (Representation from DA, DBA, Programmer, Operations, Analyst, Support, management, and end users?)		
2.	Have the end-user requirements been anticipated at all? If so, to what extent have they been anticipated or involved?		
3.	How much of the data warehouse has already been built in the current environment? On what subjects, details or data?		
4.	How many major subjects have been identified from the data model and how many are currently implemented?		
5.	Does any major processing server exist outside the data warehouse environment? If so, what is the chance of conflict or overlap?		
6.	Have the major subjects that have been identified been broken down into lower levels of detail? Keys, attributes and relationships for star/snowflakes models		
7.	Is data being used directly from the data warehouse? If not, will a multidimensional database design be used for the data warehouse? Will data marts and OLAP cubes be placed on the same physical storage as the data warehouse?		
8.	Is the design and business model discussed periodically reviewed? If so, how often? Informally or formally?		
9.	Have the operational systems to be warehoused been identified? If so, has the technology that houses the systems been identified?		
10.	Has the frequency of data extraction from data sources been identified? If so, how will changes to the source data be identified?		
11.	What volume of data will normally be contained in the data warehouse environment? To what level of granularity? Has the velocity of data accessed being determined?		
12.	What data will be filtered out of the operational environment as extract processing is done to create the data warehouse environment?		
13.	Will an ETL tool be used for moving data from the operational systems to the data warehouse, or will the transformation be done manually? If software will be used, what are the implications in terms of Cost, licensing, robustness and technical support (Compare opensource vs proprietary middleware – e.g. **Talend vs TIBCO**)		
14.	How will the ETL tools be used to capture unstructured data (research articles from indexed journals, databases, academic institutions and individuals?		
15.	Will the research items in the knowledge translation platform be analyzed and indexed before being placed in the data warehouse?		

16.	Since unstructured data can take up large amounts of space, how can the space required be minimized?		
17.	What software interface will be required for the feeding of web portal and BI tools like Tableau out of the data warehouse environment?		
18.	What physical organization of data will be used in the data warehouse environment? Can the data be directly accessed? Can indexes be easily and cheaply created?		
19.	How easy will it be to add more storage to the data warehouse environment at a later point in time?		
20.	What is the likelihood that data in the warehouse will need to be restructured frequently (columns added, dropped, enlarged, or keys modified?)		
21.	What are the expected levels of performance in the data warehouse environment? Has service-level agreement been drawn up either formally or informally? – availability and support?		
22.	How will the data in the data warehouse environment be indexed or accessed? *Hashed*, *Primary*, *Surrogate*, or *Secondary* keys?		
23.	What volumes of processing in the data warehouse are to be expected? What about peak periods? What will the profile of the average day look like? The peak rate?		
24.	What criteria will be used to purge data from the warehouse? What are the legal requirements?		
25.	What is the total processing capacity requirements for initial implementation and maturity?		
26.	What relationships between major subject areas will be recognized? Will their implementation cause foreign keys to be kept up-to-date or make use of artifacts?		
27.	Do the data structures (schemas) internal to the data warehouse environment make use of data structures like arrays, merged tables?		
28.	In case of failure, how long will a recovery take? What level of preparedness is exhibited b Development of the web-interface by support, DA, DBA, programmer?		
29.	What level of preparation is there for reorganization or restructuring of the data warehouse, operations, and system support? Have written instructions and procedures been made and tested?		
30.	If there is possibility of controversy as to the accuracy of a piece of data in the data warehouse environment, how will the conflict be resolved?		
31.	How will corrections to data be made once data is placed in the data warehouse environment? How frequently will corrections be made? Will corrections be monitored?		
32.	Will public web summary statistics (facts) be stored separately from dimension data? Will the algorithm required to create public summary data be stored?		
33.	What security requirements will there be for the databases in the data warehouse environment? How will security be enforced?		
34.	Have audit requirements have been established? If so, how will they be met?		
35.	Will encoding or compaction of data be used? Has encoding, compacting and de-compacting overheads been considered? What is the overhead?		
36.	Will metadata (connection and reference schemas) be stored for the data warehouse environment?		
37.	What catalog or dictionary will be maintained for the data warehouse? Who will maintain it? How will it be kept up-to-date? To whom will it be made available?		
38.	Will update (as opposed to loading and access of data) be allowed in the data warehouse environment? Why? How much? Under what circumstances?		

39.	What time lag will there be in getting data from the operational data sources? Will the extraction be "push -CDC" or a "pull- Trigger" process?		
40.	What logging of data warehouse activity will be done? Who will have access to the logs		
41.	What external data (e.g. partners, individual or facility level systems will be linked to the warehouse? What rate of growth will there be for the data?		
42.	How will major subjects be partitioned? (By year? By geography? By functional unit?		
43.	What documentation will there be at the regional and national levels for technical and end-users of the regional warehouse?		
44.	If the data warehouse environment is to be distributed, have the common parts of the warehouse been identified? What testing facility will be used during implementation?		
45.	What desktop, mobile or web applications will be fed from the data warehouse? Does data flow directly from the data warehouse to the desktop, mobile, web environment?		
46.	What resources are required for loading data into the data warehouse? Will the loading have to be parallelized?		
47.	If the data warehouse is a regional data warehouse, what data will be stored locally and what data will be stored in the regional office?		
48.	For a regional data warehouse, is there assurance that data can be transported across boundaries?		
49.	How regular will the data warehouse monitored in terms of use? If so, what are the tools and/or metrics that will be used to measure usage?		
50.	What kind of capacity building or training will the end users be receiving before and during usage of the data warehouse? How will they be kept abreast with changes made in the data warehouse?		

Detailed KHRO Workplan

The development process began with an inception meeting to develop a comprehensive work plan. It is during this meeting that we had a brainstorming session with key stakeholders in order to gain in-depth understanding of the KRHO deliverables, expected outcome and administrative logistics. The work breakdown structure (WBS) shown in Figure 1 begins with project planning. The goal at this stage was to assess the MoH readiness to the KHRO development processes, establish scope and justification for KHRO.

The Planning Phase was followed by requirements specifications used as input into the design of technical architecture, dimensional models and visualizations models. Technical architectures and framework has been established to support integration of heterogeneous systems and platforms implemented on the operational systems. Dimensional modeling will focus on data by translating the requirements into a dimensional model comprising of

starflake schemas. The visualizations to be undertaken by iLabAfrica team focuses more on implementation of the front-end dashboards, web portals, and mobile interfaces.

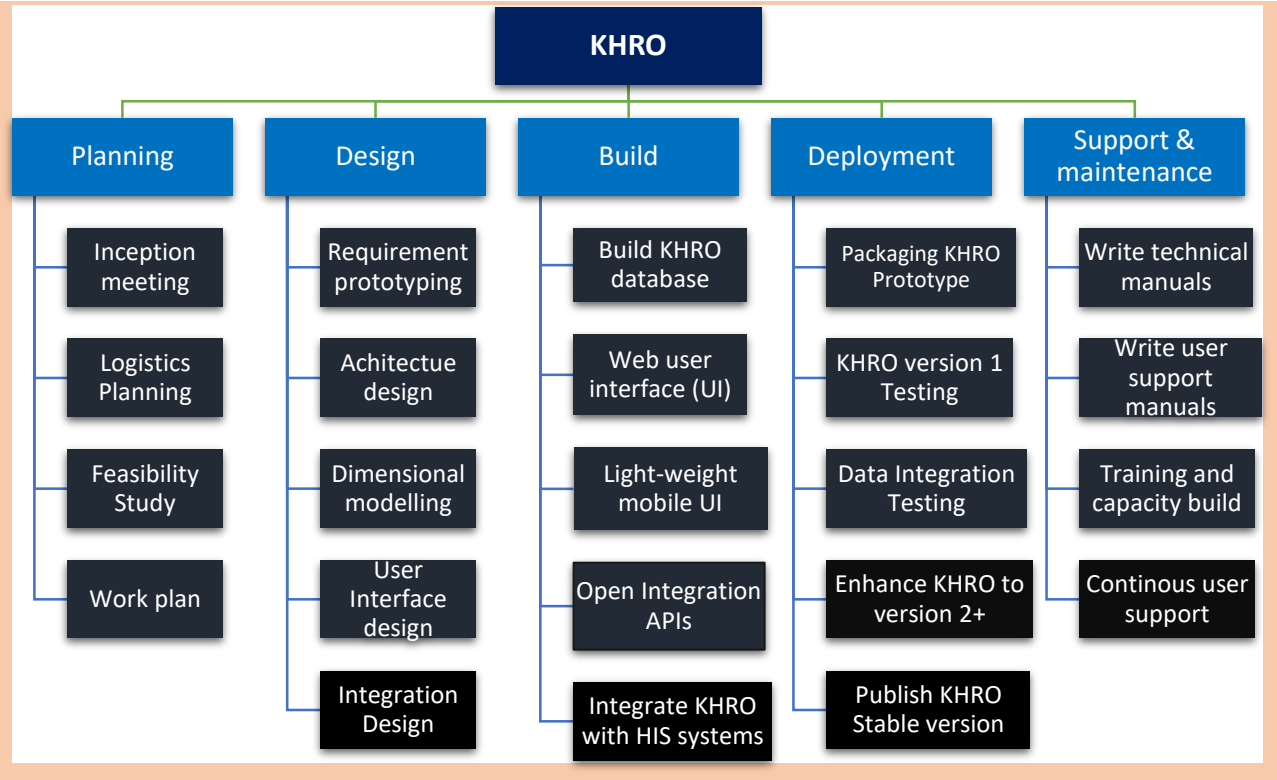

Figure 1: KHRO Work Breakdown Structure

It is after the design phase that the models will be translated into physical specifications using Database Management System like MySQL, MariaDB or PostgreSQL. The physical design will also focus on data validation, source selection, creating schemas, query optimization and performance tuning. Choice of this development tools, models, and data visualization forms the core support of the data warehouse implementation in order to support a well-orchestrated deployment KHRO web portal. The Year-on-Year (Y-o-Y) support and maintenance of the data warehouse along with training users will be provided to ensure that technologies supporting KHRO back-end remains healthy to its lifetime.

KHRO Architectural Model

To conceptualize end-to-end KHRO architecture, we were guided by the Kenya Health Enterprise Architecture (KHEA). The outcome of the Joint Application Development (JAD)

sessions held on 9th May 2019 was a high-level architectural model shown in Figure 2. Similar to AHO model provided in Annex 4, KHRO is designed as an integrated platform comprising of external data sources, Extraction Transformation, and Loading (ETL), Staging Database, Data Warehouse, BI visualization tools, and Web Portal. The data warehouse will be used as central repository for health indicator data, knowledge products, health information tools, data visualization.

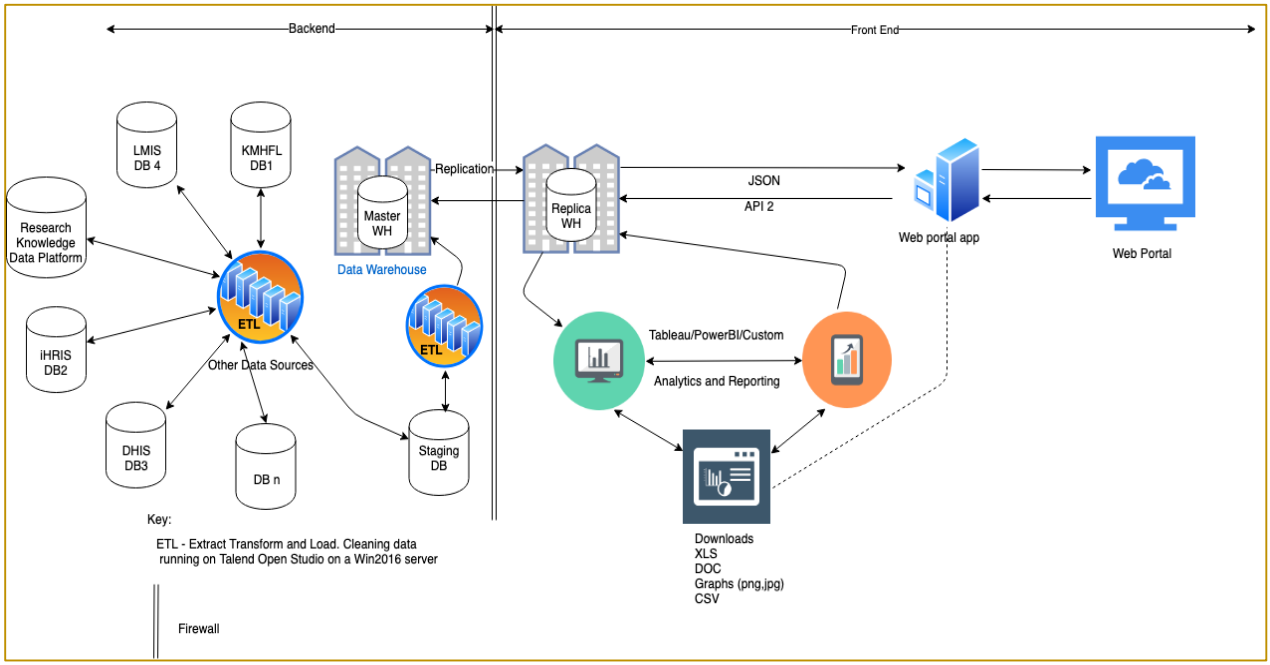

Figure 2: High-level KHRO architectural model

The following is a brief overview of the components that are expected to inform on practical development and implementation of KHRO back-end and frond-end artifacts:

1. Seeding databases (DB1, DB2, DB3, DB4, DB n). These databases represent different data sources from which data will be extracted. The key systems prioritized in KHRO include the DHIS2, KHMFL, KEMSA LMIS, and iHRIS. Data integration tools like Talend Open Studio (TOS) will be used to extract data from disparate sources.
2. The Extract, Transform, and Load (ETL) workflows will be used to process data from heterogeneous data sources. After extraction, the transform process will be used to perform data cleanup and de-duplication before the input is loaded into the Staging Database.

3. The Staging Database (Stage DB) is conceptualized as a database that will serve as a temporary repository for data extracted from source systems. This is comparable to rain water harvesting analogy (Figure 3) in which; ***rain water is first feed into a sedimentation tank (Staging) before withdrawal from the storage tank (Warehouse)***. Thus minimal processes like data verification and validation is expected to be realized by the second ETL process.
4. The Master Warehouse (WH) will be an enterprise data warehouse that will be used for maintaining the data that will be used for visualization and generation of reports such as policy briefs, and health intelligence.
5. Firewall will be installed in order to control access to sensitive health data and research. The firewall will be configured based on MoH data governance policy to determine who, where and when the repository data can be accessed from the warehouse.

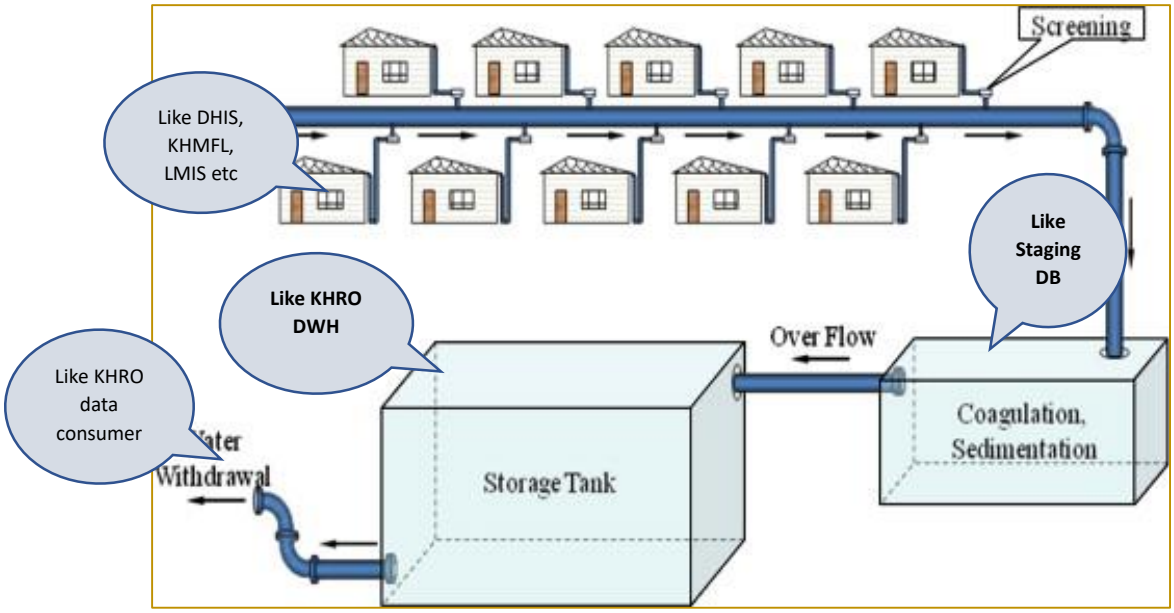

Figure 3: Rain Water harvesting analogy to KHRO Warehouse architecture (source: Internet)

Besides developing the back-end stack of technologies, the data warehouse consultant will assist the front-end team in the development of the following artifacts:

1. *Replica Warehouse*: The replica will be storing a copy of data that will be pulled on request from the master warehouse.

2. *Mobile and web portal*: This will be the primary channels as defined in KHEA that will be providing access to KHRO aggregate data and reports.
3. *Authentication database:* The database will store the authentication data and the API scripts for access to the replica warehouse.
4. *Data visualization:* This will be one of the primary interface providing dynamic visualizations on maps, charts and pivot tables. This will be done primarily by JSON and/or BI tools like Tableau, Microsoft Power BI or Knowage (SpagoBI).

Data Warehouse Model

The data warehouse industry has well-tested set of best practices developed over the last 30 years for relationally-based data warehouses. The following are the six guiding principles that will drive our design and physical implementation of KHRO data warehouse:

1. Drive the choice of data sources feeding the warehouse from business needs;
2. Focus incessantly on user interface simplicity and performance;
3. Think dimensionally: Divide the world into dimensions and facts;
4. Integrate separate data sources with conformed dimensions;
5. Track time variance with slowly changing dimensions (SCDs);
6. Anchor all dimensions with durable surrogate keys for semantic interoperability.

Based on these principles, KHRO data warehouse will be modeled as a galaxy-starflake schema comprising of dimensions and fact tables. We expect to use such a constellated model because it is obvious data triangulated to answer a question like:

Why did Facility MSH001 in CountyX with X number of trained staff and Y drugs report Y% increase or decrease in indicator Q with Period X to Y?

Figure 4 shows one of the starflake of the galaxy model representing one fact table fed by several dimensions. Note that the read balloon represents disaggregation dimensions similar to custom dimensions used in DHIS2 schema.

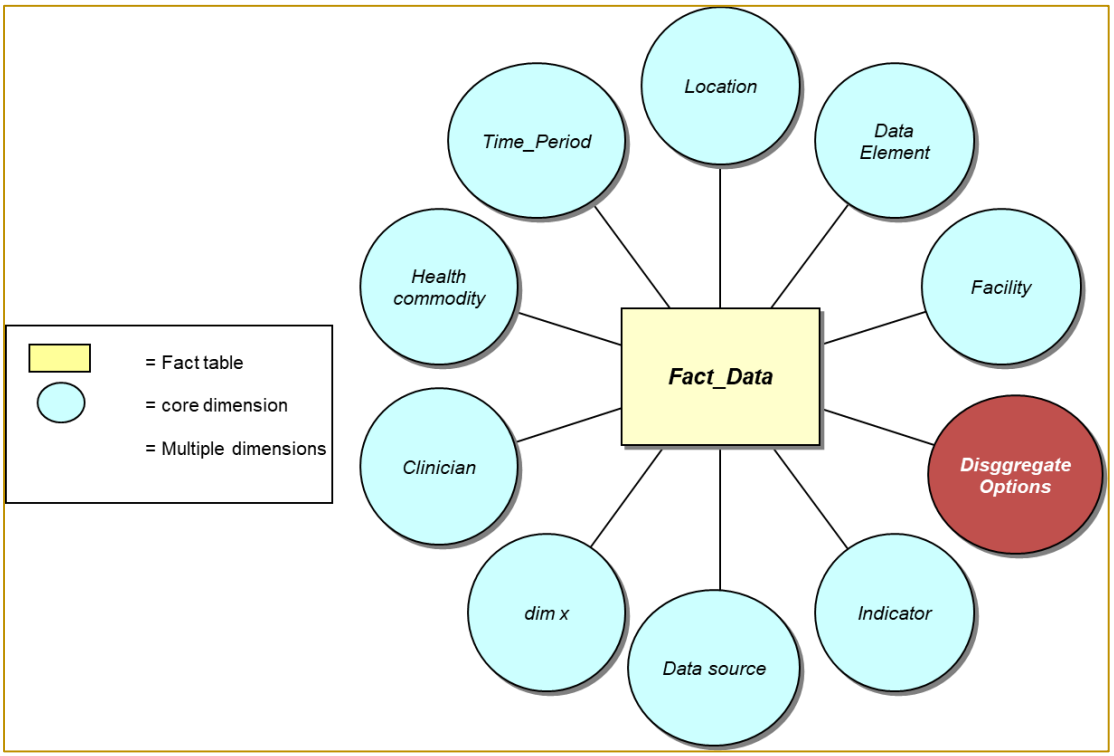

Fig. 4: KHRO Data Warehouse starflake model (source: data warehouse consultant)

Data Integration

Talend Open Studio (TOS) is a powerful Java-based Open Source Data Integration tool responsible for the Extraction, Transformation and Loading (ETL). Once data is pulled from multiple sources, we use Talend to extract, validate, clean, de-duplicate and transform it before loading into the staging database. As a proof of concept, Figure 5 depicts how we implemented ETL processes for data integration from 47 AFRO member states. The workflow shows that data is first extracted, transformed and then loaded into staging database before being integrated and loaded into the repository for presentation onto the web portal (visit *aho2.aho.afro.who.int*). Once staging table receives the entire data stream, another ETL process is used to load further clean and load the extracted data into the data warehouse. The cleaned data is published onto AHO web portal using JSON APIs. More fine-grained analytics can be performed on the data that dates back to 1990 using BI tools like Tableau, Microsoft Power BI, and Knowage (SpagoBI).

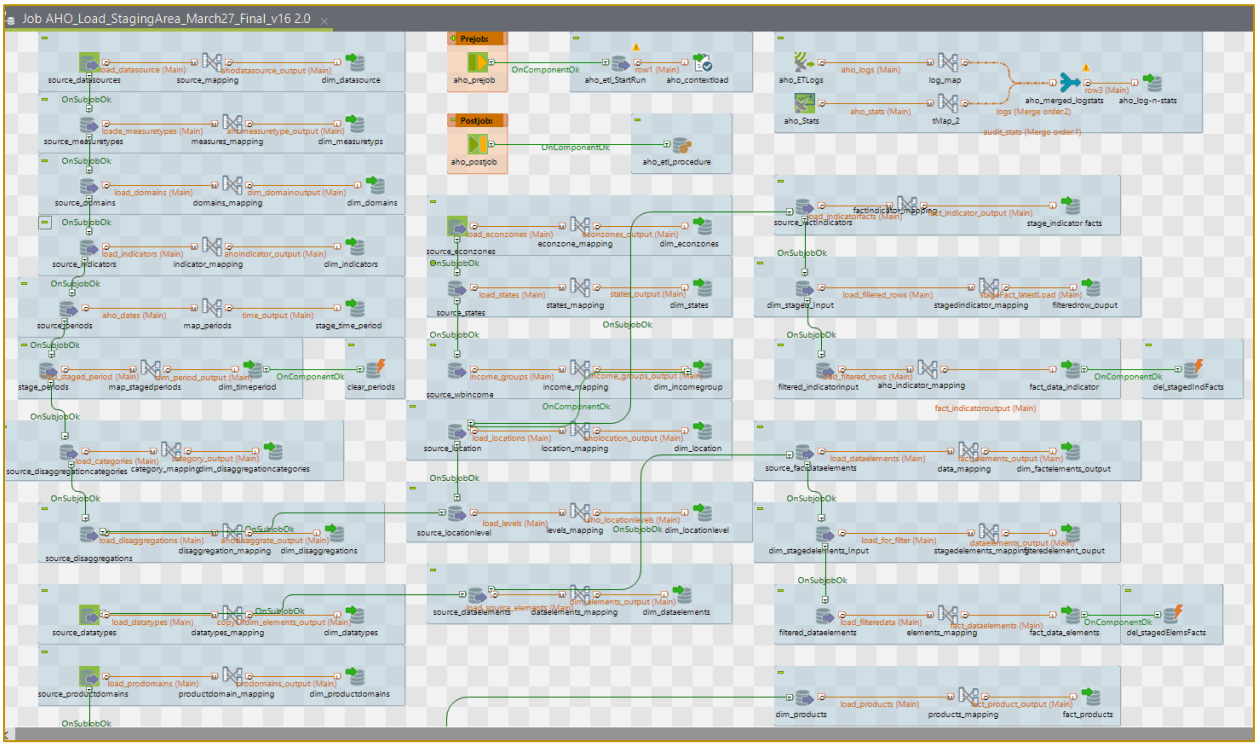

Figure 5: Data Integration Workflow using Talend Studio (Source: AHO-AFRO backend ETL)

Back-end tools and specifications

The data warehouse and related stack of technologies that will be used to implement KHRO were agreed on in our JAD sessions held in Strathmore on 17th May 2019. In a break-away session for back-end team, specific development and collaboration tools and processes that will be used for collaborative development of KHRO back-end were identified.

Table 3 provide a summary of the methodology, software tools and process that will be used to implement KHRO in Windows and Linux-based environments. Note that more specific details on deployment environment, tools and security requirements to be considered before going live are provided in Annex 5.

Table 3: Software methodologies and tools for development of KHRO

STACK	TOOL
Agile Methodologies	Scrum, Lean
Version Control Systems	Git, Bitbucket
Operating Systems	Mac OSX, Linux and Windows

Server	Ubuntu , Cent Os, Kali Linux , Windows 2016 Server
Database Management	MySQL, MS SQL, Oracle RDBMS, PostgreSQL
Networking Systems	Network fundamentals, Routing Protocols, Reverse proxy NGINX, HTTP, HTTPS, SSL
Collaboration and project Management	Slack, Trello, Email, MS - Project
Continuous Integration	Jenkins, Docker,
API documentation and testing	Markdown, MarkdownPad, Github Pages, Swagger, Postman, Insomnia

PROJECT IMPLEMENTATION PLAN

To achieve the desired results in the most cost effective manner, the following steps will be followed:

1. Project Inception
2. Project Scoping and requirements refinement
3. Project Chartering
4. Business Process Definition and Re-engineering
5. Development and configuration of KHRO back-end
6. Training and capacity building
7. User Acceptance Testing
8. Pre-Commissioning Test
9. Go Live and Commissioning
10. Project Handover
11. Y-o-Y monitoring and Review of KHRO
12. Maintenance, Monitoring and Evaluation

KHRO Development Methodology

The team comprising of @iLabAfrica and data warehouse expert will use agile development methodology providing opportunities to assess the direction of a project throughout the

development life-cycle. This will be achieved through sprints or iterations, at the end of which a potentially stable product increments.

KHRO prototypes will be tested after which improvements will be implemented. In this way, the development team knows whether it is heading in the right direction and a new iteration can be started without any risk. Not only the product is assessed, so is the development process. The goal here is to strive towards continuous improvement. Another characteristic is that agile is a method that produces a sub product that functions after each iteration, which can be immediately incorporated to an existing software to test whether everything works well. Constant attention is paid to quality and good design. Agile methodology follows a number of principles that are listed below:

- Customer satisfaction through fast and consistent supply of operational software;
- Late changes to the specifications of the customer are actually welcome;
- Software that performs well supplied within a period of a few weeks;
- Closer cooperation on regular and ad hoc basis between developers and the people who are familiar with the health processes;
- Projects carried out by motivated and reliable people;
- Ideal communication is verbal communication;
- Supply of working software is a yardstick for progress.

Modelling of the KHRO data warehouse will be done using tools like MySQL *Workbench*, *UML* and *Freemind*. The output of this phase will be low-fidelity schemas from which development of logical and physical models will commence. Once the development is completed, peer developers will perform technical reviews on the models before physical implementation using MySQL, MariaDB or PostgreSQL. The validated schemas together with related metadata, APIs and documentations will be handed over to the Ministry.

Critical Success Factors

The following are Critical Success Factors (CSF) identified by @iLabAfrica team and the data warehouse consultant that will be KEY to successful implementation of KHRO:

- *Support from MOH:* For the Project to be successful, MOH top Management and Key Decision Makers require to actively and openly support the project. This will ensure that all resources required are made available and will motivate all to take ownership and responsibility.
- *Effective Project Management:* Project planning and effective communication to avoid misunderstanding and conflicts
- *Good Project Management Methodology*: Skills and practice need to be in place for successful Implementation and to put in place systems to be used Post Implementation. Project Manager(s) from both @iLabAfrica, World bank, WHO, MOH and need to be in place to Initiate, Plan, Coordinate, Execute, and Close the project activities.
- *End-user Involvement and Acceptance:* MOH End Users and Top managers need to be involved from the beginning of the project. This will enable the potential users to take ownership of their requirements and the system ensuring success of the project.
- *Change Management, Sensitization and Awareness Creation:* Projects of this nature involve a lot of changes that the consultants need to be prepared to manage.
- *Dedicated and Consistent Project Team*: @iLabAfrica Team, MOH, World Bank, and WHO will establish a core project team that cuts across various services. The core team, if possible, need to have dedicated personnel available to see the project through the entire lifecycle.
- *Necessary infrastructure for effective implementation of the systems:* Required for successful rollout of the system is available and dependable infrastructure (connectivity, hardware, software, and personnel) to support the new platform.
- *Training and Knowledge Transfer*: The project team should have a sound Knowledge transfer mechanism to enable system administrators, and End users to be able to effectively use and change the system according to their needs.
- *Quality Data:* Quality of data that will be uploaded into the system will to a very large extent define success of KHRO. Simply put, the system will only be as good as the data in it.

- MOH provision of Access rights to key data sources: The consultants have requested MOH to give access rights to the various HIS data sources that we need to pull data from. As per the time of compiling this report, the request has been honoured with the only remain part being signing of a Non-Disclosure Agreement (NDA) by the consultants.

Scope Management

The Scope and Change Control Plan describes the processes, tools and responsibilities for controlling the necessary changes to project scope cost and schedule. The plan discusses change identification, submission, authorization and implementation. The plan identifies the tools used to track, document and communicate project changes. All change requests will be documented using a Change Request Form (CRF).

Together with the iLabAfrica team, we have instituted a project management process that will allow the evaluation and impact assessment on scope changes. It is instructive to note that any change in scope will have some impact on cost, time and quality of the project. Before decisions can be made regarding the proposed change the impact of that change must be known. Suggested changes will be discussed by *KHRO Core Team* before being submitted to the technical team for consideration. Daily logs (Annex 6) will be used to record issues, actions or significant events. In recording the logs, I will observe the following quality criteria:

- Make the log entries precise and understandable for ease of future reference;
- Document progress metadata like date, person responsible and target dates for ease of tracking;
- Share change logs with the iLabAfrica team in order to avoid configuration breakdowns.

ANNEXES

A1: Gantt Chart of Project Timelines

	Project Name	Consultancy to Support the Ministry of Health, Kenya to develop the Kenya Health and Research Observatory Data warehouse for Tracking and Analysis of Health Data												
	Individual Consultant	Stephen Mburu,PhD												
	Project Deliverable	Data Warehouse for KHRO Web Portal												
	Start Date	1st May 2019												
	End Date	31st July 2019*												
	Tasks	**Days**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	Project Planning Phase													
1	Inception Meetings	2												
2	Logistics planning together with iLabAfrica	2												
3	Writing Inception report and Detailed Workplan	3												
	Sub-total	**7**												
	Data Warehouse Design													
4	Rrequirements definition with iLabAfrica and MoH Core Team	3												
5	Technical review of data sources including their databases	5												
6	Design high-level architectural model	3												
7	Design of dimensional models and phsical schemas	3												
9	Design review workshops by MoH Core Team	5												
	Sub-total	**19**												
	Construction of Data Warehouse													
10	Creating Data Dictionaries and physical Schemas	4												
11	Testing physical schemas and connectors	3												
12	Configuring access to Warehouse Schemas and Metadata	3												
13	Writing Talend ETL workflows and/or Fetch APIs	5												
14	Perform Data Integration using ETL and APIs	10												
15	KHRO version 1.0 review workshops by MoH Core Team	2												
	Sub-total	**27**												
	KHRO Deployment Phase													
16	Package warehouse and Web prototype for deployment	2												
17	Hardware and software configuration on MoH Data Centres	3												
18	Installation of Warehouse and Web portal MoH data centres	3												
19	Perform Unit and Integration testing on MoH data Centres	5												
21	KHRO version 2.0 review workshops by MoH Core Team	2												
	Sub-total	**15**												
	Documentation and Support													
22	Write data warehouse technical manuals	5												
23	Conduct training and capacity building	10												
24	Provide continouse support to MoH (beyond scope of this contract)	Open												
	Sub-total	**15**												
	Grand-total	**83**												
	***Note: Project Total Days = 83 But only 45 Contracted**													

A2: Terms of Reference (Verbatim)

Consultancy to Support the Ministry of Health, Kenya to develop the Kenya Health and Research Observatory Data warehouse for tracking and Analysis of Health Data

Background

The Ministry of Health (MOH) is committed to supporting global efforts to increase accountability and improve quality data for decision-making. The Government of Kenya has invested in systems to monitor health systems performance. The country compiles data through multiple systems. The District Health Information Systems2 (DHIS2) is the main database where both private and public health facilities are required to enter monthly data on service utilization and inputs. Information related to health facilities is captured through the master facility list (MFL), while human resources data are also managed separately through multiple human resources information systems. Additionally, several households and facility surveys (e.g. malaria indicator surveys, household health utilization and expenditure surveys, service provision assessment surveys) are conducted regularly to capture data on service coverage and financial risk protection among others. While these databases provide useful data for Kenya, better value can be generated by integrating and strengthening capacity for timely generation and use of quality data.

Kenya is part of the global Health Data Collaborative (HDC) initiative**.** The HDC brings together global health agencies to work with countries towards improving the availability and use of quality data for evidence-based planning and tracking progress towards the health-related Sustainable Development Goals (SDGs). The Kenya HDC, which was launched during May 2017, identifies, among other priorities, the need for data demand and use through a shared platform for all stakeholders and operationalization of the Kenya Health Observatory (KHO) to enable reporting on progress on SDG indicators. During the launch, the MOH noted that health observatories can improve the availability, quality and use of information and evidence for policy and decision-making by strengthening health information systems, including public health surveillance.

The MoH intends to establish a Kenya Health and Research Observatory web portal as information technology platform designed to facilitate multi-stakeholder collaboration and partnership in accessing and using information for strengthening national health information systems as well as serving as repositories for the best available information and provide tools to strengthen the monitoring of health sector performance. As designed, KHRO will have two distinct but interrelated functions, namely ‘’Data and Statistics Platform’’ and ‘’Research Knowledge Translation Platform. The KHRO will play an instrumental role in monitoring the country’s progress towards universal health coverage (UHC).

To realize this noble goal, the MoH with support from the World Bank and WHO intends to hire a consultant to provide technical and advisory support towards the development of the integrated Kenya Health and Research Observatory web portal. The integrated web portal comprises but not limited to a back-end Data warehouse that is interoperable with existing Health Information Data

sources (as identified in the landscape assessment report 2018), and a front-end data visualization web portal with business intelligence and analytical capabilities.

Purpose of the Consultancy and Scope of Work

WHO-AFRO has been re-developing the African Health Observatory (AHO) to re-align its role for UHC/SDG monitoring and increase its role to respond to and answer policy and critical questions on health system performance. The Consultant will be expected to study and customize the WHO AFRO African Health Observatory Data warehouse to fit the Kenyan context taking into account the devolved units. The Data warehouse will be a repository of both National and County level data and is expected to be interoperable and able to exchange information with existing National Health Information Systems (refer to the landscape assessment report 2018).

The consultant will work closely with the MoH, WHO and World Bank focal point for the National Health Observatory in the development of the Kenya Health and Research Observatory (KHRO) Data warehouse.

Objectives and Tasks of the Consultant

1. To customize the WHO AFRO Data warehouse to the Kenyan context and develop a standard data capture tool to allow for online and offline entry of data to the Kenya Health and Research Observatory portal.
2. To develop APIs which will ensure that the web portal is interoperable and able to exchange information with currently existing Health information systems data sources.
3. Training of the MOH team and KHO TWG on the management and use of the Kenya Health and Research Observatory, including development of a training guide that will be used for future trainings to stakeholders.

Required Skills/Expertise

Expertise	**Skillset and competence**
Education	PhD in Information Systems, with over 12 years' experience supporting in the health sector. Experience working with the Ministry of Health, Kenya is required
Database systems	The back-end developer should have specialized skills and proven competence in design and development of database systems using software tools like Oracle, PostgreSQL, MySQL, Ms Access, Ms SQL Server, IBM DB2, SAP HANA, Sybase, Teradata, and/or Firebase. In addition, he/she should be proficient in flat-file management software like spreadsheets, word processors and PDF.
Programming	The back-end developer should have specialized skills and proven competence in programming using web, mobile and desktop application development technologies. These include but not limited to Java, Python, HTML5, JavaScript, PHP, R, Perl and/or Microsoft Visual Studio.
Business intelligence	The hired person should have specialized skills in business re-engineering, process modeling, data analytics and prediction. The technical assistants show be conversant with the current

	health systems including but not limited to DHIS2, KHMFL, LMIS, iHRIS, and EID/VL.
Systems integration	Must be highly skilled in systems and data integration using Extraction, Transformation and Loading (ETL) tools like Talend, Pentaho Kettle, Mulesoft, Informatica, TIBCO or any other proprietary or opensource integration tools.
Data science	Must demonstrate clear understanding and implementation of enterprise-wide data warehouses and repositories. His or her principles should be guided by data science principles and practices such as data mining, data modeling, and predictive analytics.
Data visualization	The technical assistant should be able to guide on the best tools to use to perform data analytics and visualization. He/she should also advise on the most cost-effective Business Intelligence (BI) tools from a list of proprietary and open source tools like Knowledge, Microsoft Power BI, or Tableau).

Deliverables

The deliverable is a fully functional Data warehouse for the Kenya Health and Research Observatory and data capture tool that allows for entry of both quantitative and qualitative data.

Deliverable	**Activities**	**Timeline**
Inception Report & Project Workplan	Develop a tentative project workplan for KHRO Data warehouse and web portal	1 week after contract signing
Requirements Specifications	Develop a tentative business specification based on TOR and Stakeholders' feedback input	Two weeks after signing contract
Architectural Model	Develop a highly technical model from design review based on WHO framework	3 weeks after signing contract
Dimensional Model	Develop a high-level dimensional model from design review based on WHO framework	3 weeks after signing contract
Design and customization of Data Warehouse	Present the first prototype version of the Data Warehouse	4 weeks after signing contract
Design of Web portal	Present the first prototype version of the web portal	4 weeks after signing contract
Design and customization of version2 of Data warehouse	Present the second version of the Data Warehouse prototype incorporating stakeholder input from the first version	6 weeks after signing contract
Design and development of version 2 of web portal	Present the second version of the web portal prototype incorporating stakeholder input from the first version	8 weeks after signing contract
Fully functional final version of Data warehouse	Present the final version of the Data Warehouse	10 weeks after signing contract

Fully functional final version of web portal	Present the final version of the web portal	10 weeks after signing contract
Training and Capacity building to MOH and KHO TWG members	Conduct training to MOH members on the KHRO web portal	Continuous throughout the contract period
End User Manual for KHRO	Present the End User Manual for Management and Maintenance of KHRO	12 weeks after signing contract

Expected Outcomes

Improved availability, quality and use of health information and evidence for policy and decision-making by strengthening health information systems. Kenya intends to use the National Health Observatory to facilitate multi-stakeholder collaboration and partnership in accessing and using information for strengthening national health information systems as well as to strengthen the monitoring of health sector performance.

Duration

This assignment will be undertaken by the consultant for **45 days** with a beta-version completed by the first 25 days (70% completion rate) ready for testing, recommendations, amendments, documentation and training. An iterative process is expected, whereby the designers will submit various drafts and incorporate feedback from core MOH staff and KHO TWG members before the final beta version of the web portal is agreed upon. The substantive work is expected to start in **May 2019**.

A3: KHRO Data Warehouse Bus Matrix

KHRO data warehouse will be modelled based on bus matrix whose template is shown below. The parameters to be used to populate the matrix will be informed by review of the source systems that include but not limited to DHIS2, KHMFL, iHRIS, and KEMSA's LMIS. It is from each of these systems that we will clearly define the dimensions and fact tables that will be implemented in the physical schema of KHRO data warehouse.

Dimensions / Categories of Facts (WHO)	Knowledge Products	Data elements	Users	Period	Indicator Taxonomy	Organization Unit	Health worker	Health commodity	Disaggregation option
1. Health Information (Input)									
Fact 1									
Fact 2									
:									
Fact n									
2. Information Systems									
3. Products and Knowledge									
4. Health Workforce (input)									
5. Universal Health Coverage (Outcome)									
6. Health Governance (Input)									
7. Health promotion									
8. Health Financing (Input)									
9. Health Security (outcome)									
10. SDG 3 Targets (outcome)									
11. Essential Services (Outputs)									

A4: Overview of AHO High-level Architecture

The African Health Observatory (AHO) is an integrated platform comprising of external data sources, Extraction Transformation, and Loading (ETL) workflow, Staging Area, Data Warehouse, Data marts and Data Presentation Layer. The data warehouse is now used as repository for indicator data, knowledge products, health information tools and resources, and data elements received from member countries. It is important to point out that the new Observatory is a highly customized model that greatly extended and re-modelled the previous observatory that only relied on centralized data entry at the regional level. The architectural diagram shows that, as the usage behaviour grows, there will be a need to replicate the warehouse into Data marts. Such replication will provide more optimized access to data, statistics and knowledge products.

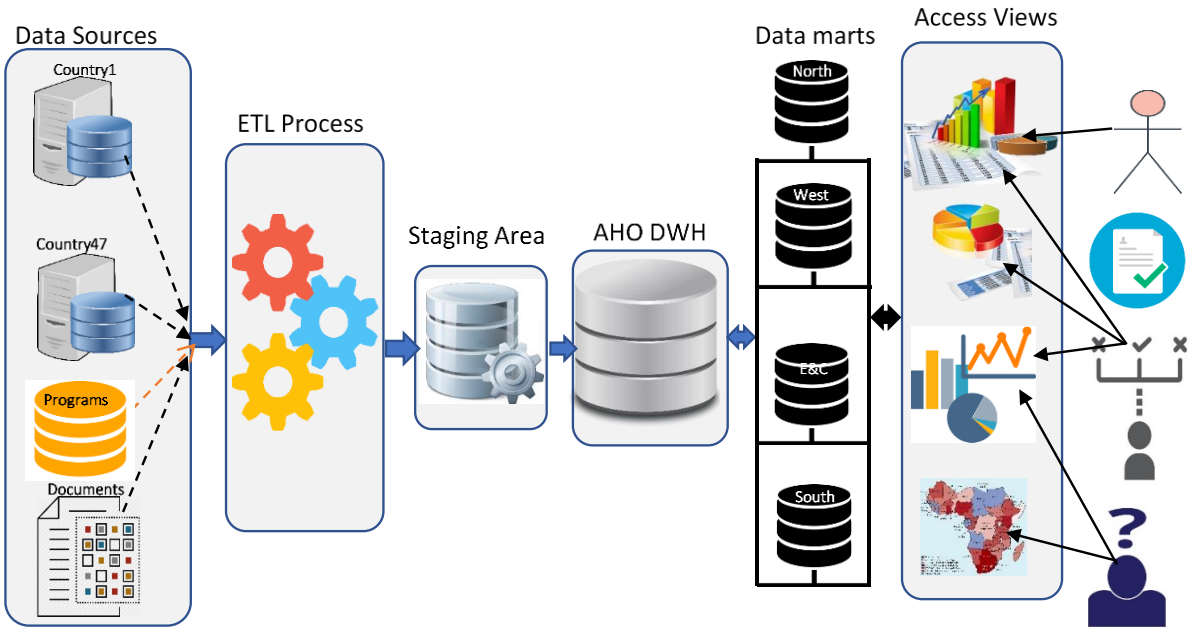

Figure A1: AFRO's Redeveloped AHO technology stack

To extract data and resources from disparate sources, we developed ETL workflow using an open source Java-based tool called Talend Open Studio (TOS). The Staging Area (SA) shown on the diagram is a database hosted on AFRO servers that receives data from online data capture tool *(dw.aho.afro.who.int)* and Excel templates. The purpose of Staging Area is to validate data received from source systems before final loading into the warehouse for analytics and visualization.

A5: Proposed Deployment Environment

HARDWARE CONSIDERATIONS

Generally, the following are tentative specification for the KHRO data warehouse and web-portal servers:

Hardware Option 1:

Single application and database server that will host the **data warehouse**, the web-portal and authentication database for the data capture tool. Precise server specifications are provided in Table 1 below:

SEVER	VCPU(S)	RAM (GB)	STORAGE (GB)	DATA
Web app its DB, and the data warehouse Server	8	32	512 SSD	App, App-DB, and Data warehouse

The following are pros and cons of housing the three products i.e. the warehouse, application and its database.

Benefits:

1. Cost efficient for a start.
2. Easier to monitor performance

Limitations:

1. To some extent insecure. When one gains unauthorized access, he/she has access to the data warehouse and the web app.
2. Denial of Service due to single point of failure. This means that once the server goes down, all the services are rendered inaccessible

Hardware Option 2:

The second option is to have the application and database servers in different virtual servers. Precise server specifications are provided in Table 1 below

SEVER NAME	VCPU(S)	RAM (GB)	STORAGE (GB)	DATA
Database and data warehouse server	4	16	512 SSD	DB server
Web App Server	8	16	100 HDD	App server

Benefits

1. Availability – due to distribution of services on multiple servers, it is possible to minimize denial of services experienced in a single server deployment approach.
2. More secure. This is because access to once server may not guarantee access to all the services provided by the three products. Furthermore, unauthorized access to the python-based app server does not necessarily mean access to the app database server.
3. Scalability. – Easy to upgrade and downgrade according to resource consumption.
4. Better performance – No sharing of resources.

Limitations

1. Relatively more expensive.
2. Relatively difficult to monitor service level agreements

HARDWARE CONSIDERATIONS

The database and applications and tools used to develop the data capture tool, it's database and the data warehouse can run on Windows and Unix-based environments. For deployment, I strongly recommend provision of the following operating systems or virtual machines *(note the + symbol means the stated version and above).*

OS	Version	Filesystem	Processor
Microsoft Windows	Server 2012 +	NTFS	32/64-bit
Unix/Linux	Ubuntu 18.04+	EXT3+, FAT32,NTFS	32/64-bit

BACK-END SOFTWARE TOOLS

Software Tool	Usage	OS
HTML3/Python	Data capture tool code	Windows/Linux
Java	SDK for data integration code	Windows/Linux
MySQL/MariaDB/ PostgreSQL	Web app database and data warehouse	Windows/Linux
Django	Data capture tool web interface	Windows/Linux
Apache/Nginx*	Web server for handling Django HTTP requests	Linux
Gunicorn	Serving web request between client and web server	Linux
Talend	Java-based data (ETL) integration tool	Windows/ Ubuntu Linux (GUI)
Batch and Bash	These are used to automate data extraction, backup and restoration of data repositories	Windows/Linux
GitLab, Slack,Trello	Collaboration and version control tools	Windows/Linux

A6: Daily Change Control Log

Project Name:	Redevelopment of AHO Data Warehouse		
Date:		**Release:**	Draft/Final
Author:	Stephen Mburu		
Owner:	Ministry of Health - Kenya		
Client:	World Bank and World Health Organization		
Document Number:	1.0		

Revision History

Date of next revision:

Revision Date	Previous Revision Date	Summary of Changes	Changes Marked

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Approvals

This document requires the following approvals. A signed copy should be placed in the project files.

Name	Signature	Title	Date of Issue	Version

Distribution

This document has been distributed to:

Name	Title	Date of Issue	Version

A7: Curriculum Vitae

PERSONAL AND CONTACT INFORMATION

Name and Salutation:	Stephen Ng'ang'a Mburu, PhD
Date of Birth:	5th October, 1973
Gender:	Male
Marital Status:	Married
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SUMMARY OF PROFESSIONAL EXPERIENCE

Dr. Stephen N. Mburu is a Scientific Researcher and Consultant in the field of Health Informatics and Data Science at the University of Nairobi. Dr. Mburu has a wealth of experience in user-centred development of mobile and web-based applications using modern server-side and client-side tools. For the last fifteen years, he has supported the Kenya's Ministries of Health (MoH) in the development and implementation of various digital health solutions such as mHealth Apps, DHIS2, and telemedicine.

In the research domain, Dr. Mburu has contributed to digital health across various aspects including digital health landscape mapping, systems strengthening and promotion technology innovations. He has worked with global institutions like World Health Organization (WHO), USAID, KPMG and the African Network for Soil Biology and Fertility (AfNET). Currently, Dr. Mburu is a consultant in health informatics with the WHO and World Bank. The project involve technical assessment and mapping of digital health systems implemented across the 47 counties to inform on key indicators and data attributes that are crucial to the design and implementation of a national health observatory.

EDUCATION PROFILE

2011– 2014: University of Nairobi and Technische Universität Dresden. PhD in Information Systems of University of Nairobi in collaboration with Technische Universität Dresden. My PhD research area was Health Informatics from which I published a dissertation entitled: *A Model for Design of mHealth Solutions Fit for Deployment in Low-resource Settings.* In the course of my PhD study, I received scholarship from European Commission through Erasmus Mundus to develop of mobile health (mHealth) interventions suitable for deployment in the low-income countries.

2007– 2009: University of Nairobi. Graduated with MSc. (Information Systems) on 18th September 2009. The study outcome was a framework for safeguarding privacy and security of transactions in mobile money transfer services.

1993– 1997: Kenyatta University. Graduated with B.ED (Double Mathematics), and awarded second class upper division. My areas of specialization during undergraduate studies are Probability, Applied Statistics and Computer Science.

PROFESSIONAL EXPERIENCE

2007–Date: Lecturer, University of Nairobi. Lecturer of Computer Science and Health Informatics in the School of Computing and Informatics (SCI). Apart from teaching, I'm the Coordinator of Computer Science undergraduate programmes. Other responsibilities include design, implementation and evaluation of computer science projects, health informatics research, and promoting ICT innovations in the health sector.

2005– Date: Modern Technology Computer Centre Ltd. Currently, I act as a non-executive director for the Modern Technology Computer Centre Ltd (MTCCL). MTCCL is a company that offers consultancy services in systems development, project management and research on digital health interventions. In the company, I also provide consultancy services in policy development, capacity building, and mobile money solutions.

2012– Date: Ministry of Health- Kenya. I have played the role of the lead consultant in formulation and development of the Kenya eHealth Policy (2016-2013); Kenya Standards Guidelines for mHealth Systems mHealth; and the draft Kenya eHealth Strategy (2018-2022).

2012– Date: Ministry of Defense. I'm a member of Telemedicine Technical Working Group (TWG) under the Ministry of Defense's National Space Secretariat (Kenya Space Agency). The TWG is an Inter-ministerial subcommittee responsible for planning, development and implementation national-level telemedicine programme.

TECHNICAL EXPERIENCE

1998–Date: Programming skills. Developer of enterprise systems using programming language for mobile, desktop and mobile platforms. I have wide experience in programming languages like Java, C, C#, Visual Basic, Pascal, HTML5, CSS, JavaScript and Python. For the back-end technologies, I have experience in Apache web server, IIS, PHP, MySQL, Microsoft SQL Server, and Oracle.

2015–Date: World Health Organization (WHO). Consultant for development of the Kenya eHealth Policy (2016-2030) and Strategy for the Ministry of Health. Apart from providing technical support in the implementation and maintenance of DHIS2, I also provide support in design of data collection tools and models. I've also been involved in the technical review of digital health systems like DHIS2, Kenya Health Master Facilities List (KHMFL, iHRIS, Logistic Management Information System (LMIS), Data Services Layer (DSL) and Tibu. Currently, I'm supporting the African Regional Office (AFRO) in redevelopment of the African Health Observatory (AHO) Data Warehouse, web portal (aho2.aho.afro.who.int), and data capture tool (dw.aho.afro.who.int). The new platform that will be integrated with 47 national level Observatories will be used to support decision making through easily accessible and synthesized data and statistics; and knowledge products.

2017– Date: MEASURE Evaluation and USAID. Development and review of global health Informatics tools and models such as Health Information Systems (HIS) Interoperability Maturity Model, and the Kenya Guidelines for mHealth Data Privacy, Confidentiality and Security. I'm also involved in supporting policy review and implementation through HealthIT project hosted by the University of Nairobi.

2016 – Date: Klynveld Peat Marwick Goerdeler (KPMG). Engaged as a digital health expert for the County Innovations Challenge Fund (CICF) projects. As the KPMG advisor on technology innovations, my responsibility is to support CICF Grant Selection Committee (GSC) in the process of evaluating and recommending suitable maternal healthcare innovations deployed in six priority Counties.

Totohealth Ltd Advisory Board. I'm a member of the advisory board for the Totohealth supporting the organization in scaling up digital health innovations. Totohealth is one of the most successful startups in mHealth ecosystem that develops mHealth solutions focusing on maternal and child mortality in underserved counties across Kenya. My role as technical advisor is to guide the company on strategies for design, deployment and evaluation of health innovations that have impact on maternal and newborn health outcomes.

African Network for Soil Biology and Fertility (AFNet). From January to September 2010, I was the lead consultant in AFNet landscape assessment in Burkina Faso. The purpose was to provide support for the development of integrated-multilingual Data Warehouse suitable for knowledge sharing and management by AfNet researchers and scientists across Africa.

Regenstrief Institute, Indiana University: Since March 2017, I have worked with the Director of Regenstrief Institute, Indiana University in development of a simplified version of the Kenya Health Enterprise Architecture (KHEA). I'm also involved in the HIGDA project, focusing on the strategies for deployment of interoperable platforms that will facilitate data exchange.

PUBLISHING PROFILE

1. Mburu S. and Kamau O. *"Framework for Development and Implementation of Digital Health Policies to Accelerate the Attainment of Sustainable Development Goals: Case of Kenya eHealth Policy (2016-2030)",* Journal of Health Informatics in Africa, 5(2). https://doi.org/10.12856/JHIA-2018-v5-i2-210, Vol. 5, No 2, pp 32-38, 2018.
2. Mburu S. and Oboko R. "*A model for predicting utilization of mHealth interventions in low-resource settings: Case of maternal and newborn care in Kenya",* BMC Medical Informatics and Decision Making Journal (https://doi.org/10.1186/s12911-018-0649-z) July 4 2018.
3. Mburu S., "*A Predictive Model for Optimizing Acceptance and Use of mHealth Interventions in Low-Resource Settings: A Case of Mamacare Prototype"*, in the IEEE Africon Proceedings 2017 conference held in Cape Town, South Africa, pp 518-528, September 2017.
4. Mburu S., *"Application of Structural Equation Modelling to Predict Acceptance and Use of mHealth Interventions at the Design Stage"*, Journal of Health Informatics in Developing Countries, Vol. 11, No. 2, August 2017.
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PROFESSIONAL MEMBERSHIP

1. *Institute of Electrical and Electronics Engineers (IEEE)*: Professional member of IEEE, the world leading global organization for electronic engineers and computing professionals dedicated to advancing the theory of and application of computer and information processing technologies.
2. *Association of Computing Machinery (ACM)*: Professional member of ACM, the world largest educational and scientific computing body that advances computing field as science.
3. *Kenya Health Informatics Association* (KeHIA)*:* Member of Kenya Health Informatics Association (KeHIA). KeHIA is a professional association registered in Kenya to promote application and integration of information and communication technology in healthcare system locally and regionally.

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