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Final thesis

Electronic Prescribing Management System for Rural Settings of Developing Countries: A Patient Centric System

by

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This report is the result of my master thesis carried out under the ICT4MPOWER project at Karolinska University Hospital in Stockholm.

For me, it has been a great pleasure and a learning opportunity working under ICT4MPOWER project. The journey of experiencing and attempting to solve some of the real world problems in healthcare industry in the developing nations has been very interesting and challenging. This thesis provided a platform to apply my knowledge and skills that I have acquired during the Masters study. During the research, I have worked in agile based software development environment with new and unknown technologies, multidisciplinary fields, multicultural and remote teams; under the rural setting where there was only one thing constant and that was “changes”.

First of all, I wish to thank my supervisor Rustam Nabiev for providing this wonderful opportunity and guidance throughout the research. I would also like to thank my examiner Henrik Eriksson for providing valuable suggestions and feedback. Furthermore, I would also like to thank all the colleagues at the Karolinska University Hospital and Ugandan development team of ICT4MPOWER for the meetings, information, help and support.

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ABSTRACT

During the last decade, electronic prescribing has been a point of focus in healthcare industry and is rapidly becoming a standard of practice. It has proven as an important element in improving the quality of patient care, mitigating or eliminating the phone calls back and forth from pharmacies to point of care/health centers. Many e-prescribing systems were developed and marketed but these usually were unsuccessful because of the lack of direct electronic connectivity to local pharmacies and the lack of up-to-date formulary information, clinical guidelines, health plans & services among other reasons. Despite their benefits, the adoption and usage of electronic prescribing systems has been low. In some of the developing countries like Uganda, the problem is even worst. Due to lack of essential resources and manpower, healthcare services have significantly impacted on the productivity and quality of patient care.

In an effort to improve, promote and maintain the quality of health services in rural settings of developing countries like Uganda, a high level design for e-prescribing system has been proposed. Design specifications for Electronic Prescribing Management System (EPMS) along with functional prototype are built based on ICT4MPOWER project requirements and previous research and publications in this area.

Initially research began with Drug and Stock Management System and EPMS emerged as one of its essential components. In order to strengthen and establish connection between ongoing electronic health record system and drug and stock management development, EPMS component came into lime light. Mare prescription management is not enough to serve patient centric needs. Hence, clinical decision support has been introduced into e-prescribing system to improve the quality of prescribing decisions. In order to develop a patient-centric e-prescribing system that is self-evolving and self sustaining, it is important to update the clinical decision-support system, formularies & guidelines on regular basis. In order to make it usable, it is required to formulate effective health plans and increase associations between pharmacies and other health organizational units. The principal benefit of introducing E-prescribing system into Electronic Health Record (EHR) System is to connect open ended systems to form a strong knowledge base for future.
INTRODUCTION

Information Technology plays a vital role in bridging the gap between developed countries and developing countries. On one hand we have those countries which use technology in everyday life for example power (electricity), communication, infrastructure, social benefits, healthcare, etc and on the other hand there are countries that have low mortality rate, absolutely no infrastructure nor any kind of benefits. In this report, I will propose one such solution in the field of healthcare which would help narrow the above spread.

Uganda, a developing country with one of the highest growth rates in the world [2], has put immense effort in strengthening the healthcare services to provide National Integrated Health Management Information System. Ministry of Health Uganda has embraced on the national project “ICT4MPOWER” [3]. Karolinska University Hospital initiated an Electronic Health Record (EHR) system under the international project called ICT4MPOWER. It is a collaboration between Karolinska University Hospital, Karolinska Institute, Royal Institute of Technology, Ericsson Sweden AB and Ministry of Health in Uganda. This project emphasizes development and implementation of a National EHR System in order to store life-long records of patients [3]. The ICT4MPOWER System resulting from the project will provide a roadmap for implementation and maintenance of low-cost EHR System in developing countries.

One of the core modules of an EHR is Drugs and Stock Management. Information and Communication Technology can play vital role to assist in proper drug and stock management, and enable better drug stocks in rural health units of developing countries. The issue of drug management is crucial in developing countries because many health units in rural areas face constant drug stock-outs, and there is no proper logistics support and supervision for health workers and others involved in the drug distribution and management.

The research was initially aimed at an integrated Drug and Stock Management System. However, it unfolded various essential components. Each of these components has a potential to evolve as an individual system. One such component, the E-Prescribing Management System (EPMS) has been chosen for further study in this article. In my opinion, E-Prescribing Management System is one of the essential components of the Drug and Stock Management System. This study addressed some of the major challenges to EPMS development and adoption with focus on developing countries.

The framework of EPMS proposed in this project work is based on the information received from the research articles, interviews and from the ICT4MPOWER development team in Sweden and Uganda. An attempt has been made to suggest a solution that could closely match the needs of Uganda to improve the quality of the health services at different healthcare levels. For the proposed solution to work effectively in Uganda, some health organizational units need to work in synchronization with each other. Although, the framework is designed to suit resource-constrained settings of Uganda; it could also be useful in promoting improved healthcare services in other developing and developed countries.

1.1 Research Problem Description

ICT4MPOWER project started in the year 2009 with the goals to improve healthcare services and bring transparency in information exchange among various levels of healthcare within the Healthcare System of Uganda using Information and Communication Technology. The goal of this report is to propose a design solution, and workflow process for EPMS under Ugandan settings.
1.2 Disposition

This thesis consists of 8 chapters and 2 appendices and is structured in the following way.

Chapter 1: provides introduction to ICT4MPOWER project, briefly introduces to problem area, the issues that are dealt with in the research. It also includes the abbreviations and keywords used in this report.

Chapter 2: describes about the background of Ugandan healthcare system, how ICT4MPOWER initiated Electronic health record (EHR) system and explains about how various components within EHR system emerged.

Chapter 3: Following the introduction and background is a presentation of the methodology describing the scientific methods and approaches used in the research.

Chapter 4: addresses the challenges and prerequisites during the development of E-prescribing system prototype.

Chapter 5: the main results of the research work are presented in this chapter which explains about the architecture, implementation of prototype and workflow diagram in detail.

Chapter 6: discussion of the results is presented in this chapter and also explains some of the advantages of the proposed system.

Chapter 7: concludes the whole research work carried out and summarized the thesis. It also briefly describes the future research possibilities.

Chapters 8: provides references that are used during the research.

1.3 Abbreviations

EHR: Electronic Health Record

HC I: Health Center 1

HC2: Health Center 2

HC3: Health Center 3

HC4: Health Center 4

HC5: Health Center 5

MOH: Minister of Health

UCG: Ugandan Clinical Guidelines

CHW: Community Health Workers

ICT: Information and communication technology
NDA National Drug Authority
NHP National Health Policy
NMS National Medical Stores
VHT Village Health Team
WHO World Health Organization
EPMS Electronic Prescribing Management System

1.4 Keywords

E-prescribing, developing countries, E-prescribing management system, E-prescription management system, Electronic health records, Clinical decision support system, Uganda healthcare system, Ugandan clinical guidelines, Patient care, Rural healthcare, Health systems.
2 BACKGROUND

2.1 Ugandan Healthcare System

“Health is wealth” indeed is true. All developing nations bank on ever growing economy. However, the growth in economy cannot be instigated by unhealthy citizens. Like many developing nations, Uganda also believes that health is an important sector and a key to achieve target like eradication of national poverty. Uganda thus aims to reduce poverty level to less than 10% of the population by 2017. It has shown great dedication to address such socioeconomic problem at a national level [2].

The population of Uganda is around 30 million people. According to censuses between 1991 and 2002 Uganda had an average growth rate of 3.4% [2]. About 80% of overall population lives in rural areas [3]. “The percentage of the population living below the poverty line was at 38% in 2003.” [2] Though Uganda has more than 30,000 health professionals, the health facilities in this part of the world are poor. The Ugandan government has identified the health sector as one such area which could benefit from current Information and Communication Technology (ICT). Using ICT as a platform the ruling body of the nation was quick to analyze few thematic areas like unique patient identification which could benefit patient referral system, management of patient records, disease surveillance, staffing and identification of roles and responsibilities. A detailed account of these requirements is provided by Ministry of Health in the article “Improved Effectiveness of Health Systems and Empowerment of Healthcare Communities in Uganda for Better Health Outcomes of Rural Population using Information and Communication Technologies”.

“The focus of the project will be on Isingiro district. This district was selected because:
1. It has very low healthcare indices
2. It has the millennium village project on which it is possible to create a model of how innovations in a project area can be spread to the rest of the district by efforts from the government. The project site offers an opportunity to develop a model for networking with these different organizations for improved health.”

Isingiro district is located in the south western part of Uganda as shown in Figure 1:1, bordering the Republic of Tanzania on the South, Rakai on the East, Ntungamo district in the West and Mbarara and Kiruhura districts to the North. The projected population of the district plus refugees (is estimated to be around 47,000) in two Refugee settlements for 2008/09 is 405,263. The district has total population of 394,110 with eleven sub-counties and one town council. The health sector comprises of four HC IVs, seventeen HC IIIs and thirty three HC IIs. Out of the 68,745 households in the district 51,926 households (76%) of them have toilets which meet the recommended standard.” [2]
2.2 Electronic Health Record (EHR)

Electronic Health Record as defined by WHO [4].

The Electronic Health Record:
- Contains all personal health information belonging to an individual
- Is entered and accessed electronically by healthcare providers over the person’s lifetime; and
- Extends beyond acute inpatient situations including all ambulatory care settings at which the patient receives care.

EHR Systems are in use in many countries however; these systems are limited to one health unit, or small geographical region, which consists of 4-5 health units [3]. Few hospitals in countries like Malaysia and Korea have already gone paperless with EHR. Countries like China, Indonesia and Uganda have implemented EHR systems but are not fully electronic. Australia on the other hand has provided much needed impetus for a nation-wide EHR System. EHR System envisions of an Integrated Health Management Information System where all health units are connected, hence amplifying the problem for the governing bodies, technical designers and modern technologies [4].

Technical Architecture of EHR System in ICT4MPOWER has been closely designed to meet requirements from Ministry of Health, Uganda & EHR Manual by WHO [4]. The attributes considered during design phase are scalability, performance, availability, security and maintainability. (All design issues are enumerated in article [3] by Rustam Nabiev (Supervisor @ KI)) Some of the existing infrastructures have softened the level of satisfaction on proposed requirements. One such example is availability of networking technologies in urban areas, such as Kampala and Mbarara of Uganda. Hospitals here have access to broadband network and rural located health units have access to mobile networks. More than 80% of rural areas are covered by mobile networks, which provide GSM and GPRS connections [3]. However, challenges of EHR System in ICT4MPOWER are low cost implementation and maintenance of the system, lack of resources to maintain and provide local technical support to rural health units and unable to redesigning existing EHR solutions.

Currently, there does not exists any standard or functioning EHR system in Uganda, however the work is in progress. Many challenges remain to be solved before developing and standardizing any healthcare system in Uganda. The problem cannot be solved by replicating current EHR solutions, which are too expensive and difficult to maintain. Therefore, new technical architecture must be developed, which will consider the issues of low-cost implementation and affordable maintenance. The following section will describe the same.

2.3 Background of ICT4MPOWER

This project is a national initiative by Ministry of Health Uganda, in coordination with many organizations who look at health of an individual as a future asset. Through this project the partners believe to achieve few common goals like: empowerment of communities and their personal with knowledge base, common platform for communication among communities and their personal, immortalize referral procedure and feedback process through digital record system, uphold healthcare at lowest of community levels and mobilize community health workers.

In order to construct a structure with these goals the project first, has to build a solid foundation, in terms of infrastructure, equipment, personal, training and mutual interest. The E-Infrastructure covers fiber optic backbone, mobile networks with maximum coverage, necessary hardware and power for overall consumption of resources. Although some systems are in-use in other areas of healthcare system, a fully functional EHR System is a demand at hand. This will not only create unique ID system but also will improve patient referral system and feedback system. The data collection, storage, analysis, retrieval and reporting standards for the national patient
identifier system would be community health worker centric. This is vital because information gathered by community health worker makes him/her the main focal point of the system. For this system to work as intended it has to be robust, secure, specific and accurate at all times. With well designed EHR system and unique patient ID system in place, it is now evident to increase the scope of this project by adding useful features like Electronic Patient Referral and Feedback System. A traceable patient record would indeed increase efficiency while offering feedback and continual medical education. “By improving the flow of information throughout the system the project will create opportunities for increased efficiency and transparency leading to a better quality of service for the final consumer in the healthcare system.” [2][3]

A robust system would always lead to numerous possibilities and additional features. The once at hand are Tele-Consultation support, National Drug and Stock Management System, Human Resource Development and E-Prescription Management System.

2.4 Drug and Stock Management System

“Essential drugs play a crucial role in the prevention and control of diseases. After immunization for common childhood illnesses, appropriate use of essential drugs is one of the most cost-effective components of modern healthcare.” [5] Estimating requirements of drugs is well described in “Estimating Drug Requirements: A Practical Manual” by WHO and “Essential Drugs Monitor” [Issue No 25 & 26 (1998)]. Many leading healthcare organizations around the world have provided such articles and manuals which are freely available over World Wide Web. These articles contain vital information about various diseases, their remedies and availability of drugs. Drug and Stock Management System encompasses prescribing, monitoring, ordering, logistics, registration, billing, feedback reporting and learning. This system will simplify the process of ordering, forecasting and maintaining drugs. The system provides a clear and transparent vision for the government to make savings with more effective control of drugs.

Drug and Stock Management System appeared as an important part of EHR System because of less accessibility towards essential drugs, irrational usage of drugs and poor quality. Some facts in this regards are:

1. “Today over one-third of the world's population still lacks access to essential drugs in the poorest parts of Africa and Asia.
2. Up to 75% of antibiotics are prescribed inappropriately.
3. Worldwide average of only 50% of patients, take their medicines correctly.
4. Anti-microbial resistance is growing for most major infectious diseases, including HIV/AIDS, tuberculosis and malaria.
5. Quality & safety issues:
   a. Less than 1 in 3 developing countries have fully functioning drug regulatory authorities.
   b. 10 to 20% of sampled drugs fail quality control tests in many developing countries.
   c. Failure in good manufacturing practices too often results in toxic, sometimes lethal, products.
   d. Expanding global trade is making it increasingly difficult to implement quality assurance.” [5]
The various components of Drug and Stock Management in ICT4MPOWER are as follows (shown in the following figure):

1. E-Prescribing Management System
2. Drug Requirement and Utilization Monitoring System (DRUMS)
3. Drug Ordering System(DOS)
4. Drug Logistics Management System(DLMS)
5. Drug Interaction Verifier(DIV)
6. Health Facilities Management(HFM)
7. National Drug Information Registry(NDIR)
8. Human Resource Management System(HRMS)
9. Secure Billing System(SBS)
10. Feedback and Reporting System(FRS)
11. E-Learning
2.5 E-Prescribing Management System

Physicians have been prescribing over 50 years since FDA (Food & Drug Administration) has regularized it. This system began with physicians calling the closet pharmacies in 1950s and has evolved since then. It was not until the worldwide web burst that these systems became more robust. E-prescribing is simply an electronic way of generating and transmitting accurate, error-free and understandable prescriptions directly from the point of care to the pharmacy. E-Prescribing Management System is one of the integral components to achieve broad deployment of the EHR system in Uganda.

“A physician who reads all day long for six weeks will already be a century behind.” –D.F. Criswell, 2002

“Physicians are required to read a staggering and continually increasing amount of information to stay current with recommended practices. More than 40,000 Medline citations are added every month, 1 to 2 new drugs approved by the U.S. FDA each week, and a dozen or so changes in indications, etc., for current medications already approved each week as well. In addition, a rapidly increasing number of diagnostic tests and patient specific data are available for the clinician to consider.”[6]

Medication errors are common and may cause potentially serious injuries. Prescribing errors may be classified into two categories. The first concerns errors such as incorrect dose, drug interactions or contraindications. This corresponds to either incorrect use of a drug or an inappropriate combination of drugs. The second type of error involves the choice of an inappropriate therapeutic strategy leading (for instance) to the prescription of an inadequate drug or to the non prescription of the most appropriate drugs.

2.6 Stand alone E-prescribing or Integrated HER

An E-prescribing system can be a stand-alone system or can be used within an EHR system. Article [7] is one such example. Stand alone and integrated systems have their own advantages and disadvantages in terms of time, cost, interoperability with other electronic health information system, adaptability and adoption with existing workflow process, training & learning effort, legal aspects, organizational challenges, resources, finances and maintenance [1]. To address these barriers, E-prescribing management system has been developed. It is an attempt to solve some of above challenges and to develop a powerful tool which suits requirements of developing countries. There are many potential benefits of e-prescribing compared to the current paper based approach. E-prescribing can significantly benefit patients, prescribers, dispensers and thus empower more informed decision making. However, this transition is not possible without overcoming its challenges.
ICT4MPOWER consists of many components. These components are at different stages of software development life cycle. One of the components, which is in feasibility study phase, is DSDM. Further research on DSDM revealed many sub-components which have the potential to evolve as an individual system. One such sub-component is EPMS. My research began with general understanding of ICT4MPOWER project goals, Ugandan healthcare system and Case study of different healthcare system in developed and developing countries. I have used case study research method, interview & questionnaire technique and a mix of agile based methodology. Often questions like “how” and “why” are answered by case study research methodology. Observation, documentation, interviews and other tools are some the data collection methods for case studies [8]. The data obtained by various means and from multiple perspectives helped to understand the real problem. The process of collecting information verbally is known as Interview technique [8]. Types of interviews are: structured, semi-structured, unstructured, one-to-one, group and focus groups. Unstructured interview technique was employed initially for acquiring overall knowledge of the project and their goals. More structured information was gathered using semi-structured interview technique. During this project one-to-one interview technique was handy to collect usability information. These techniques proved extremely convenient as it allowed participants to convey their situation with a personal perspective. Some examples of participants are doctors at KI, pharmacists in Stockholm, Sweden, field workers and development team in Uganda.

Above diagram shows the different levels of Ugandan healthcare system. I have framed questions based on different levels of the healthcare system in order to understand individual role during prescribing process.
The primary focus was to get answer for “who prescribes, what type of drugs, at which level and how?” These questions were aimed at understanding end-user requirements along with potential usability parameters. Detailed questionnaire at each level of healthcare system can be found in appendix. There exists another questionnaire, in appendix, for understanding how clinical decision support system integrates into e-prescribing process effectively.

Documentation technique includes both written and non-written documents. An extensive document study was conducted in order to understand the scope of the project. Few examples of documents are letters, books, journals and organizational documents. Feasibility articles [2] [3] are proposed by Ministry of Health Uganda and ICT4MPOWER project team. Research articles [A] [B] [C] are proposed by researchers in Uganda. Other documents involved articles published by major health organization like WHO, UNHCR, etc. This indeed provided concrete platform for the research work.

Qualitative information gathered via above mentioned techniques provided vital insight into requirements and specifications of the project. Understanding the work flow process of Ugandan healthcare system was challenging. Mapping constrains into the real-world scenarios was competitive.

3.1 Agile Based Software Development

Traditional software development methods are not always feasible in the rapidly changing business environment. However, agile software development methodology has claimed to serve purpose in such conditions. Agile software development methodologies have proven to be a boon during the implementation of the prototype. A mix of one or more agile methodologies was necessary because of the following reasons: rapidly changing environment, relatively new teams in Uganda and at KI, lack of facilities for communication, lack of flow of information, technological difficulties and dependencies.

I started by defining the scope of the prototype since it would not be possible to implement all the tabled features. Along with my supervisor I prepared a product back log and timeline. The biggest impediment according to me was technology. However, I have learnt technologies such as Perl Scripting, Catalyst framework and Ubuntu Operating system used for the development. Initially, pair programming helped me overcome this hurdle. Progress was done in smaller sprints. My supervisor gave proper feedback at the end of each sprint which helped to improve system with every sprint.

The developed prototype resulted in expected outcome and provided more ideas for future development. One such idea was the development of Clinical Decision Support System. This is discussed in section 4.3.
4 EPMS in ICT4MPOWER: Addressing Challenges and Prerequisites

4.1 Challenges faced during the development of EPMS in ICT4MPOWER project

Developing a system within the requirements of a particular project and constrained resource setting environment, is inspiring and exciting but equally challenging. EPMS is no exception. Some of the challenges encountered during the development of EPMS system are listed below:

- **Technology**: The current EHR system has been developing over the years. Development platform and technology were already chosen. Hence the prototype had to be developed with chosen technology for the ease of integration. Learning new technologies and implementing prototype consumed extra time.

- **Information Gathering**: It was not possible to interact personally with the people involved at different healthcare center to gather information because of the distance, technology, language, cost and legal constrains. However, the project had a point of contact or representative at various stages to gather required information. The representatives were from Ugandan’s development team.

- **EPMS for developing and developed Countries**: The system design not only required to suit the needs of the developing countries but also to open prospects for future EPMS in other countries.

- **Changes/Modifications**: Since ICT4MPOWER project is under research certain changes in the requirements were quite expected. Hence, the system had to be redesigned at various stages to adapt to these ongoing changes.

- **Workflow of Healthcare System**: Every country has its own healthcare system and different way of functioning. System had to be designed taking into account present workflow process and incorporating in the healthcare system.

- **Cost Effective**: The designed system should be cost effective in terms of development, time, installation, training and maintenance. This is one of the most important design constraints, when developing system for developing countries.

- **Unique Patient Identification**: This is another major issue which is addressed in other components of the EHR system.

- **Usability**: The system should be easy to use and should work in line with the approved workflow process. The system should provide sufficient help and support information, when required.

- **Lack of active Participation**: Involvement of clinical officers, medical professionals and hospital administration staff for providing accurate information was considerably low. Thus, long waiting for correct information made it difficult to understand current problems in the existing system.

- **Adaptability**: System should not only provide ease of use but should reduce the learning and training efforts by health providers for smooth transition.

- **Concerns on electronically generated information**: The quality and accuracy of electronically generated information is a point of concern for many healthcare professionals, patients and general community. Hence, the generated information needs medical expert’s opinions, verification and confirmation before actual usage of the system.
4.2 Prerequisites of EPMS to work under Ugandan settings

In order to develop a system, one needs to know the essential prerequisites. Many requirements were found during the research study but the most essential elements according to the study results for building EPMS in Uganda are listed below:

1. **Essential Drug List of Uganda (EDLU, 2007):** “Essential drugs are those which satisfy the needs of the majority of the population and should therefore always be available in adequate amounts and appropriate dose forms. EDLU lists those essential drugs considered to be the most appropriate for use in the Uganda public health system”. [A] It is to be used together with National Standard Clinical Guidelines (NSCG) of Uganda for the appropriate selection and distribution of drugs at various healthcare levels. These publications are also used as training materials for drug usage. It is not only considered as a primary drug management tool at all levels of the health system but also intended to strengthen and harmonize the essential drugs selection process at national and district levels for public and private sectors. [A]

2. **National Standard Clinical Guidelines (NSCG/ UCG):** “The UCG has evolved directly from the National Standard Treatment Guidelines 1993 which were the first such guidelines published in Uganda”. [C] It serves as a tool for practical guidance on diagnosis and appropriate therapeutic approaches. It is meant to help both upper and lower levels of the public and private health system. “Ugandan Clinical Guidelines are regarded as nationally recognized standard treatments and in many cases they are the same as, or directly derived from, those recommended in current evidence-based WHO guidelines”. [C]

3. The **National Formulary (NF), Essential Drug List of Uganda (EDLU) and UCG or NSCG** are aimed to join in near future to establish strong foundation for the appropriate selection and utilization of essential medicines in Uganda. [C] This would provide a base for effective usage of essential drugs and thus avoids wastage. It would also maximize the potential health benefits. It is to be noted that UCG text is not fully clinical but it provides all the necessary information in easily accessible format, which helps in diagnosis and treatment decision process.

4. **National Drug Registry of Uganda:** A researched and existing list of all types of drugs as per Ugandan standards. This registry is provided by National Drug Authority of Uganda which has to be adhered to.

5. **National Drug Authority (NDA):** “The National Drug Authority (NDA) is responsible for regulating the pharmaceutical market, licensing premises, drug information, pharmacovigilance, quality assurance, import permissions and disposal of expired medicines but has a limited capacity with insufficient outreach”. [B] It is responsible for control measure to ensure drugs of proven quality and safety are licensed to importation into Uganda. It is also responsible for providing National Drug Registry.

6. **Drug Formulation Classification file:** Ugandan Clinical Guidelines are not organized in a way that can be easily incorporated into the EPMS clinical decision support. It has been written to serve as a guiding tool during treatment process. Hence, it is required to build a method or a technique to categorize drugs and classify wide variety of symptoms, signs, diseases and other health conditions that can be formulated into the clinical decision support system. The organization of such classification is termed as Drug Formulation Classification file. It can also be used as a statistical tool for morbidity and mortality, international comparison and reimbursement systems. However, it needs to be updated with UCG.
7. **Sophisticated Drug-Food-Condition Interaction Database**: Drug-drug or drug-food and drug-condition interactions occur when two or more drugs, drug & food and drug & existing medical condition respectively react with each other. These interactions may cause unexpected side effects, reactions, allergies etc. The ability to recognize and manage these interactions is a crucial role of the pharmacist and medical professional involved in the drug prescribing and dispensing process. In order to optimize patient outcomes, a system needs to provide clinically significant interactions and treatment advice to the prescriber and dispenser. For that, we need sophisticated Drug-Food-Condition Interaction Database.
5 RESULT

5.1 Architecture of E-prescribing Management System

1. Substance Registry
2. National Drug Registry
3. Prescriptions Database
4. Prescriptions Refills Database
5. Adverse Drug Reaction Database
6. Drug and Drug Interaction Database
7. Drug and Food Interaction Database
8. Drug’s Side Effects and allergies Database
9. Clinical Guidelines and Formularies Database

DDG : Drug Dictionary and Guide
DAS : Drug Assessment System (Clinical Decision Support System)
PDL : Pharmacy and dispensary Lookup
FRS : Feedback and Reporting System
MSE : Medical Search Engine
ADRR : Adverse Drug Reaction Reporting

General overview of the system is outlined in this section. The above diagram illustrates the architecture of EPMS consisting of various sub-components. Some of the sub-components have a potential to evolve as an individual system like DAS, FRS and ADRR.
A brief description and responsibility of each of these sub-components are given below:

- **Drug Assessment System (DAS):** It is a clinical decision support system. This subcomponent is responsible for verifying appropriate drug dosage, appropriate therapeutic strategy, drug-to-drug interactions, food-to-drug interactions, duplicate therapy or drugs, route of administration, allergies and side effects. It also works like a notification system to trigger warnings, cautions, pregnancy or lactation alerts, etc. A drug interaction is a situation in which a substance affects the activity of a drug, i.e. the effects are increased or decreased, or they produce a new effect. This component verifies interactions and displays status of severity as normal, moderate or severe. It is used to recommend appropriate drugs depending on patient conditions. It also suggests alternative drugs. However, careful considerations and professional advice is vital in alternative drug suggestion.

- **Pharmacy & Dispensary Lookup (PDL):** This subcomponent locates and list all registered pharmacies with an ICT4MPOWER- EHR system. It displays this list in both tabular format and in the form of Google maps pointing to pharmacy locations. The list can be limited and customized to locate pharmacies based on search criteria. The search can be made with following criteria.
  - Nearby pharmacies within X meters/km range
  - Stock Availability of prescribed drugs
  - Pharmacy Name

  The list can also be sorted either alphabetically by pharmacy name or based on cost of drugs or nearest pharmacy location.

- **Feedback and Reporting System (FRS):** This subcomponent is responsible for collecting feedback information on treatment and prescription from the patients. It is also used to log complaints against health facilities, drugs, stock, late arrivals or unavailability of essential drugs, health equipments etc. The collected information would be used as a knowledge base to improve the clinical decision support and health services.

- **Medical Search Engine:** This component is simply a search tool to search and view various medical documentation online. This tool helps the health providers with required medical information. The search criteria can however be customized to view desired results.

- **Drug Dictionary and Guide:** This component is also a search tool but for drugs. The search results show brief information about searched drug. However detailed information can be found by clicking on searched drug in the results. Drugs can be searched by brand name, generic name, ATC codes or by the conditions.

- **Adverse Drug Reaction Reporting (ADRR):** The safety of medicine is directly proportional to patient safety but it is to be noted that no medicine is risk free. An unintended and harmful reaction to drugs/ medicines on normal treatment dosage is called adverse drug reaction. It’s one of the major problems across the world and has a significant impact on the public health. This subcomponent is a computerized tool to report and register adverse drug events and reactions from the point of care/health centers to NDA, Uganda.

Additional Functionality of the EPMS System includes:
- Scheduling meeting and appointments.
- Creating favorite drug Lists
- View recent history of activities
- Upload, download and bookmark medical documents, e-books and medical videos as favorites.
- Watch and save treatment videos
- View medical documentations and formularies etc
- Print prescription, and other documents in required format.
- Dispensary stock information verification
- Create role based profiles and restrict functionality
Once the patient has been examined, lab results are then recorded in the patient database. EPMS system then fetches patient information such as patient id, age, gender, weight, medication history, health issues, allergies, pregnancy, diagnosis, clinical notes and other information from the patient database. This abstracted information together with various sub-components would be then used by EPMS to make treatment suggestion according to the patient conditions.

5.2 Implementation of E-prescribing Management System prototype

![Figure 1: The figure shows the main page of the system containing vertical menu with different functions to perform and the horizontal menu depicting sequential process of diagnosis and treatment. The content in the center shows relevant information relating to each step involved in the process. For example, in this figure, it’s showing the treatment page.](image)

Overview:

Figure 1: Shows an overview page of the treatment process. Once the patient is fully examined and diagnosed then the next step is the treatment process. To the left located is the menu consists of options such as, Journals: consist of list of medical journals, Drug Dictionary: to search and view particular drug information, Drug Manuals: list all the relevant drug manuals required for the treatment process, Favorites: to bookmark books, journals, videos and drugs as favorites, Adverse Drug Reporting: as the name indicates it is used for reporting adverse drug reactions and rest of the options relating to other parts of the EHR system.

On the main page, there exists horizontal menu consist of registration, education, signs-symptoms, diagnosis, treatment, and overview. Treatment tab is the main point of focus and rest others tabs are relating to other parts of EHR system. The first section in the treatment page list the abstracted information required for prescribing process. The second section lists the suggested treatment from the Ugandan clinical guidelines based on information from the first section. The last section is treatment section where prescriptions are created, edited and deleted.
Figure 2: shows the popup asking whether to open the suggested document or save it in the system. This action is triggered by clicking Click Here link in the suggested treatment section.

Figure 3: Shows the opened document which provides information relating to malaria (for example) and its treatment process and drugs
Figure 4: shows the form for creating prescriptions.

Figure 5: shows the list of all drugs sorted with the letter ‘s’ first. This is an automated dynamic search box implemented using Jquery. It sorts the drugs with the same letters as typed in the search box. Example: Typing ‘s’ in the generic drug name box gives all the drugs starting with first letter as ‘s’ followed by rest, Typing ‘st’ in the generic drug name box gives all the drugs starting with first letter as ‘st’ followed by rest, so on and so forth.
Ugandan clinical Guidelines recommend using generic drug names during prescribing, dispensing, medicines administration and medication record procedures. Therefore generic names have been chosen for drug names. Note that generic drug name is a combination of generic name of the drug, amount of dosage and form of drug. This combination format is inspired from the Ugandan clinical guidelines, which makes the prescribing process easier without worrying about the different brands.

Figure 6: shows the list of all brands sorted with ‘br’ first. This is also an automated dynamic search box, similar to generic drug name box, implemented using JQuery. It sorts the brand names with the same letters as typed in the search box. This box lists only those brands that are available for the chosen drug in the previous box.
Figure 7: After the selection of drug and its brand name, next step is to select appropriate dosage, form of drug, start date, refills, quantity, drug substitution and write usage instructions. The figure illustrates the same.

Figure 8: shows remarks and comments written for the pharmacies and dispensers.
Figure 9: shows the list of all prescribed drugs. Drugs are listed in an interactive panel which can be minimized or maximized on double click. Head of the panel consists of green/yellow/red button depending on the drug assessment, pencil icon for editing prescription and trash icon for deleting prescribed drug.

Figure 10: Prescribed drugs can be edited by clicking pencil icon in the interactive drug list panel. Once it is edited, it can be saved using save button. The same is shown in the above figure. It is an AJAX based form.
Figure 11: Figure shows the minimized list of prescribed drugs. Suggested prevention panel belongs to other component of EHR system.

Figure 12: Shows the prescription containing prescriber, patient and drug information. A prescription is ready to send electronically to pharmacy or dispensary.
5.3 Work-flow Diagram of E-prescribing process

Figure 13: Workflow Process of EPMS
Figure 13: Workflow Process of EPMS continued

Figure 13 depicts the workflow of EPMS system. A workflow is a term used to describe the sequence of procedural steps, operations, and tasks, declared as work of a person, a group and organization involved. In other words, a workflow diagram depicts the real world scenario. In the proposed solution, I have found the workflow approach to be quite useful in analyzing and presenting treatment process in simple and systematic way. The workflow is constructed based on my research study and workflow analysis of Ugandan Healthcare System. The above diagram supports out-patient departmental visit. The end-users involved in e-prescribing process include nursing assistant, administrative staff, clinical officers and medical professionals. Not all steps can be performed by all the end-users and purely depends on the role defined by the Ugandan MOH. This workflow is applicable at all health levels of Uganda but only certain steps are relevant to a particular health level. It could also be used as a guide for future e-prescribing business processes.
5.4 Role of Clinical Decision-Support in E-prescribing

The main goal of the e-prescribing system is to reduce medication errors (such as drug-drug/food interactions, allergy interaction, incorrect dosage of drugs and incorrect medical practice used in prescribing drugs) in order to improve the quality, standards and cost-effectiveness of patient safety [9][10][11].

In order to achieve this goal, there is a need for more powerful system that can make critical decisions and alert healthcare providers whenever necessary. In other words, there is a need of Clinical decision support in e-prescribing system. However, it must be implemented well, with thorough expert opinions, maintaining uniform standards and vocabularies, and centralized knowledge bases. Health providers must also be willing and able to support technology in order for such system to reach its full potential, reducing risk. Otherwise, the system can itself create unintended errors risking patient safety [9][10][11].

Therefore, the very important to maintain and assure the quality of clinical decision support at all the time, which could help identifying hidden flaws, discovering and foreseeing possible medication errors. It is also important that system is self-learning and self-evolving under expert guidance in order to achieve maximum benefits. This can be possible with some kind of feedback reporting system.

The end of the e-prescribing process is when patient leaves with prescription. In my opinion, this should be the starting point for clinical decision support where the most valuable feedback is entered into the system to support the future of patient centric care. Hence contributing towards a self-learning, self-sustaining and self-evolving system.

I have also incorporated these two vital components as drug assessment and feedback reporting in my e-prescribing prototype described in section 5.1
The side effects of rural poverty are multidimensional and complex. They begin from public policy of the country to culture, climate, gender, markets and more. People from these areas are often diverse both in terms of their problems and possible solutions. But, customized solutions not only require critical resources but also skilled personal to manage them. There is a paucity of both in Uganda. This poses high demand on general solutions with possible customization and scalability. One such solution is to automated prescribing process. In other words, we need an electronic prescribing management system which should be self learning, self evolving, and self sustaining.

The advantages of the presented system/ prototype in the result section are:

1. Transparency: Flow of information between different levels of healthcare should be transparent. For example; if there are 10 reports of Malaria from HC1 then all other healthcare levels are made aware of the situation. If HC4 has an abundance of malarial drugs which can meet the demands of HC1, they can be communicated effectively. This will reduce the expense of ordering and delivering additional drugs and helps in better drug stock management.

2. Connectivity: Few components such as EHR and DSDM can be connected via EPMS. For example; the drugs that are listed in EHR system can be verified for availability and/or dealer so as to place an order via Drug Ordering System of DSDM. Thus, a way forward to more powerful system.

3. Centralized system: A centralized system adds immensely to the entire system. In an event of an epidemic the governing bodies can take informed decisions. This saves enormous time and cost for developing countries. It helps to keep track of vital health resources like equipment, drugs, etc. It helps in tracking down unauthorized access of health resources. It helps in auditing the process, personal and transactions. It opens reliable communication channel between various levels. It helps incorporating drug promotions and health awareness as “Prevention is better than cure.”

4. Cost effectiveness: Open source design and self evolving (wherein system learns from its feedback and growing knowledge base) nature of the system adds to cost effectiveness. This decreases maintenance and gives more scope for future research.

5. Patient centric care: The existing prescribing systems are mostly drug centric and disease centric. However, these systems do not consider individual patient health conditions. For example allergies, chronic conditions, etc. In order to develop a patient centric system, a sophisticated clinical decision support system needs to be incorporated into EHR system. It is evident for the countries to maintain clinical guidelines specific to their citizens.

6. Scalability: Open source design, implementation and technologies will provide sufficient platform for the system to scale.

7. Flexibility: The system can not only be used by developing countries but also by developed countries because of the above mentioned advantages. A common framework for EPMS has been proposed along with various components, which could be in-turn customized. For example; the work flow process, clinical guide lines, drug list, etc.

8. Statistical Analysis: Forecasting availability and requirement of critical resources. Other statistical results can also be obtained for different kinds of quantitative research.

The uniqueness of EPMS when compared to existing systems is open source design, open source with respect to technologies, patient centric system and framework based architecture for different countries and their settings.

Every system has some ground rules. The ground rules for EPMS to give best possible results are: legal bindings, thoroughly verified expert opinions, constant updates, roles and responsibilities.
Legal binding between health organizational unit such as pharmacies, national drug authorities, government and private health centers are necessary to work in harmony. Contracts and collaboration agreements should be well defined. National documents like Clinical guidelines, Formularies and Essential Drug List should be standardized. The data in the system should comply with National health policies. The system is designed to decrease the complication of prescribing rather than increase it. Every modification such as drug list, any documents, etc should be updated at the earliest. This provides accurate information. Roles and responsibilities should be well defined. The boundaries should be drawn to adhere standard hierarchy.
7 CONCLUSIONS

Complex decentralized healthcare delivery system not only increases the expenditure of health services but also risks the lives of rural population. Poor data management, inadequate staffing and no transparency of information exchange among health units leads to poor communication links between health units at different levels. In an effort to improve the quality of health services in rural settings of developing countries like Uganda, a high level design for e-prescribing system has been proposed in this research. E-prescribing plays a vital role in improving the quality of the healthcare and hence this area has been chosen for research. The proposed solution is a centralized solution that safeguards, monitors and promotes effective use of drug by mitigating communication gap between different health units.

EMPS is a knowledge-based decision support system for e-prescribing process. EMPS can be served as a guiding tool that facilitates health provider with required information and support at the point of patient care in a cost effective way. It can help health providers in making appropriate healthcare decisions. Workflow process can be broken down to roles and responsibilities of healthcare providers in order to carry out efficient prescribing process. Proposed solution is practical and can be customized to fit user’s need.

However, for the proposed solution to work effectively in specific rural settings like Uganda, it is important to update the clinical decision-support system, formularies & guidelines on regular basis. In order to make it usable, it is required to formulate effective health plans and increase associations between pharmacies and other health organizational units. Thoroughly verified expert opinions on the dosage and usage of the drugs, alternative treatment suggestions are required. Equally important is also regular monitoring and updating medical knowledge bases that are part of clinical decision support, constant feedback for the improvements, well defined roles and responsibilities of the healthcare providers.

By ensuring the above, we can achieve a way forward towards a patient-centric e-prescribing system that is self-evolving, self-learning and self sustaining. With the introduction of such a kind of prescribing solution into electronic health record system could connect open ended systems to form a strong knowledge base for future.
8 REFERENCES

A. Essential Drug List of Uganda (EDLU) by the National Drug Authority, Uganda.
B. Ugandan Health Sector Strategic plan III 2010-2014 by Ministry of Health, Uganda.

2. ICT4MPOWER Executive Summary Approved by Ministry of Health Uganda. (ICT4MPOWER internal project article).
9. SFINX—a drug-drug interaction database designed for clinical decision support system by Ylva Böttiger, Kari Laine, Marine L. Andersson, Tuomas Korhonen, Björn Molin, Marie-Louise Ovesjö, Tuire Tirkkonen, Anders Rane, Lars L. Gustafsson and Birgit Eierman.
9 APPENDIX

9.1 Drug Units and Conversions [C]
Drug names: the relevant International Non-proprietary Name (INN) or generic names are used throughout the list.

Level of Use: For each item the lowest level of health care facility at which the item may be used is indicated as shown in the table below.

<table>
<thead>
<tr>
<th>HC1</th>
<th>Health Centre 1 (Community Level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC2</td>
<td>Health Centre 2 (Enrolled Comprehensive Nurse)</td>
</tr>
<tr>
<td>HC3</td>
<td>Health Centre 3 (Clinical Officer)</td>
</tr>
<tr>
<td>HC4</td>
<td>Health Centre 4 (Medical Officer)</td>
</tr>
<tr>
<td>H</td>
<td>Hospital</td>
</tr>
<tr>
<td>R</td>
<td>Restricted Use (i.e. needs high level diagnostic/clinical skills only available in specialized institutions. For example: Cancer Institute, National Psychiatric Hospital, etc.)</td>
</tr>
<tr>
<td>Ref</td>
<td>Referral Hospital</td>
</tr>
</tbody>
</table>

9.2 Abbreviations and Units[C]
BNF = British National Formulary
BP = British Pharmacopoeia
BPC = British Pharmaceutical Codex
INF = infusion
IM = intramuscular
Inj = injection
IT = intrathecal
IU = international units
IV = intravenous
MU = Mega Unit = one million (1,000,000) units
PFR = powder for reconstitution
SC = subcutaneous
SR = slow-release
G = gram = 1,000 mg = 0.001 kg
mg = milligram = 1,000 μg
μg = microgram = 0.001mg
L = litre = 1,000 mL
mL = milliliter = 0.001 L

UNITs OF MEASUREMENT
kg = 1,000g
g = gram = 1,000mg = 0.001kg
mg = milligram = 1,000μg = 0.001g
μg = microgram = 0.001mg
L = litre = 1,000mL
mL = milliliter = 0.001L
9.3 E-prescribing Questionnaire

Main Question: “Who prescribes what kind of drugs at which level of health care unit and how?”

The following questions were asked at every health level of Ugandan Healthcare.

1. What types of drugs are prescribed by CHWs, HC2, HC3, HC4, General and National hospitals?
2. Who all are involved in drug prescribing process?
3. What kind of medical documents are used in prescribing drugs? Manual or electronic?
   a. Are these documents same at every health level?
4. What activities or steps does drug prescribers performs in drugs prescribing process?
5. Does verification of drug interaction and allergy takes place?
   a. If yes, how is it done? What documents are used?
   b. If no, why? What is lacking?
6. How does different health levels reports adverse drug reaction?
7. How should Electronic-prescribing system help them in drug prescribing process and with what information?
8. How many skilled personal are available at every health center?
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