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DEVELOPING AN INFORMATICS MODEL FOR EFFECTIVE HEALTHCARE IN MILITARY HEALTH FACILITIES IN NIGERIA

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ABSTRACT

Management, exchange and control of clinical information flow, and decision support have remained a challenge in most secondary/tertiary healthcare institutions in Nigeria amidst the continued advancement in Information Technology. Many of those in need of healthcare are often attracted to Military health facilities owing to the public perception that such establishments have better facilities, dedicated personnel, and affordable cost. The common scenario is a high traffic of healthcare seekers thronging such facilities and invariably leading to poor care as available facilities are overstretched. This paper is an integral part of a series of investigations on how the large data generated during clinical care in public military health institutions in Nigeria could be used to aid effective planning and decision-support in health delivery. The study adopted a mix of design science and object-oriented methods to problem identification and analysis. First, a systematic study conducted revealed lack of integration of meaningful Information technologies into the practices and operations of most military hospitals as all information exchange is largely done manually. The study also revealed that the health facilities remain technologically disconnected to the

outside world as there is no public information exchange interface as to clinical management and appointments such as portals, etc. To address this problem, we proposed a simple realistic and cost-effective model that integrates a decision support system to provide a reliable intelligence as regards the planning and management of patients.

KEYWORDS: Clinical Informatics, Decision Support Systems, Health Informatics, Military facilities

INTRODUCTION

Effective and efficient healthcare in developing countries remains a dream that must be realized. Nigeria, the world's most populous black nation is faced with health care delivery challenges which seem to have had no clear solution over the past two decades. This is against the backdrop of the clear provision of Constitution of the Federal Republic of Nigeria 1999[as amended] which states thus: "the State shall direct policy towards ensuring that there are adequate medical and health facilities for all persons". Therefore, this study appreciates the optimism that Nigeria and Nigerians have the requisite potential to influence its destiny. Thus, having considered the need for healthcare delivery in Nigeria, this study exploits the convergence of Computing and Information Communications Technology with Healthcare in remodeling the nation's healthcare system. Global Healthcare delivery systems have for over two decades embraced the application of various tools afforded to it by the continuously evolving technology of Computing and Information Technology, to effect significant positive changes in the scheme of medical and healthcare delivery. An area that has been widely embraced in developed countries is healthcare informatics (also called medical or clinical informatics in some parlance), a field that greatly integrates healthcare delivery with modern information technologies to enhance clinical information generation, patient management, information exchange, intelligence planning and decision support in healthcare delivery with a major aim of achieving satisfaction in patient care and support for clinical research.

There is no gainsaying that we are living in the Information revolution age where Information Technology (IT) has become part of every sector of the society **(**Nwankwo, 2016). In modern times, every organization revolves around an information architecture; which forms a bridge between the past and the future, containing knowledge of the past (i.e., observations and trends), knowledge of the future (i.e., predictions and prognostications) and perhaps decisions about the way things "ought" to be. The effectiveness and efficiency of such information architecture may be dependent on three major factors: Management commitment;

Information Infrastructure; and People. The advancement and reengineering of many vital processes that were not open to computer technology a few decades ago into technology-driven task chains have contributed to the popular assertion that without the appropriate information infrastructure it may be difficult to drive complex decision making processes in medium and large organizations. With emergence of databases, database management systems, data warehousing, data mining, intelligent analytics, knowledge discovery technologies, and the internet of things IT has played a significant role in the way things are done and it cuts across every sector of human endeavor; healthcare inclusive.

The Domain of Health Informatics (HI)

Healthcare informatics may be described as an evolving specialized area that is concerned with developing methods, techniques and theory to create IT systems for health care and the related study of information and communication processes in health care. Health informatics deals with systems including but not limited to electronic health records (EHR), electronic medical records (EMR), health information exchange (Health Information Exchange, 2017) standards such as Health Level 7(HL7 International), medical terminologies such as Systematized Nomenclature of Medicine--Clinical Terms (SNOMED CT) (IPRR 2009, Benson 2012,US NLM 2015), and portable medical devices for the collection of health data.

Healthcare information technology as a field of study has giving rise to such other fields like: Electronic Health Information Systems (EHIS); CyberMedicine; Telemedicine; Health IT systems; Consumer health IT Data; Virtual healthcare, e-Health, Health informatics, etc. It has become evident that information exchange and sharing is next to none to the success of every healthcare project in developed societies hence the divide in expert healthcare knowledge across the globe is likely to be broken by the careful integration of these relevant technologies into the national healthcare systems in developing countries such as Nigeria. Our area of concern in this study is Health informatics. The first use of health informatics occurred in the 1950s with dental data collected by the National Bureau of Standards(in the United States of America), now known as the National Institute of Standards and Technology (NIST). Today, the International Medical Informatics Association (IMIA) oversees member organizations involved in health informatics worldwide.

Health informatics is an evolving discipline, currently; the American Informatics Association (AMIA) supports five domains of informatics (AMIA Mission) connected to healthcare:

a. Clinical Informatics

b. Translational Bioinformatics
c. Clinical Research Informatics
d. Consumer Health Informatics
e. Public Health Informatics

AMIA defines Clinical Informatics as the application of informatics and information technology to deliver healthcare services. It also referred to it as applied clinical informatics and operational informatics. Clinical informatics includes areas ranging from clinical decision support to visual imaging (e.g. radiological, pathological, dermatological, ophthalmological, etc); from clinical documentation to provider order entry systems; and from system design to system implementation and adoption issues. Clinical informatics is also described as the implementation and evaluation of communication systems that improve patients' health and care, as well as the relationship between patients and their physicians. Health informatics is an interdisciplinary field of study that utilizes technology to organize, analyze, manage, and use information to improve healthcare with its chief goals being the developments of standards and clinical care guidelines that enhance electronic health records by facilitating information management (AHIMA, 2016).

Cyber Medicine (CM)

In most climes such as Nigeria and other developing countries, the number of medical experts is not commensurate with the number of patients needing healthcare. This trend has led to seeking help via the internet to solutions to some health disorders either by checking medical expert databases or contacting and taking treatment virtually via the internet. Applying internet to medicine is an evolving area since the last decade. This trend has been appreciated by many in developed world but yet to be appreciated in developing world irrespective of the extent of penetration of internet in developing countries especially in Sub Saharan Africa as identified by International Telecommunications Union in its report of 2014. Applying internet to medicine otherwise known as cyber medicine has come handy in educating, innovating and communication in ways that promote medical practice between the healthcare professionals and patients; this has led to efficient and effective patient care thereby promoting healthcare.

Cyber-medicine may be described as a preventive medicine and public health approach involving the exchange of open, non-clinical information, mostly between patient and patient, sometimes between patient and physician, or between physicians. CM breaks boundaries thus bringing experts to the homes of patients and healthcare practitioners in different parts of the

world thereby making the world of medicine a global village. Medical research have benefitted in the use of expert repositories such as PubMed, WebMed, MedScape, etc. to arrive at solutions to some medical situations, and enhance knowledge. Cyber Medicine gives patients a wider range of knowledge about their problems and the variety of drugs that can lead to their cure.

Telemedicine

Telemedicine is the use of information and communication technologies to provide or support health services where distance separates the healthcare providers and users. According to the 2016 world health indicators of the World Health Organization (WHO 2000). Nigeria has a ratio of 1 physician to 2500 persons that need medical attention. This report indeed is not a favourable statistic hence there is need for channels through which a larger population could have access to healthcare. Telemedicine focuses primarily on a restricted exchange of clinical, confidential data with a limited number of participants, to a large extent, between patient and physician or between physicians. Telemedicine could be greatly applied to diagnostic and curative medicine (Egsenbach, Enu & Diepgen 1999).

Health Informatics in Public Healthcare delivery

The role of health informatics and related information technologies in public health delivery cannot be overemphasized. Management Information Systems are important tools in public health institutions (Yan, Chen & Zeng 2008) They have been deployed to aid in combating and monitoring the outbreak of communicable diseases, bio-attacks, etc. Information systems played key roles in the eradication of small pox in the 1970s and controlling Severe Acute Respiratory Syndrome (SARS) in 2003 (Knobler, Mahmoud, Lemon, Mack, Sivitiz & Oberholtzer 2004).

Applied health informatics has the potential for extensive benefits for the healthcare industry, from decreasing admission wait times to reducing duplication of tests. Public health informatics will become increasingly important to the management of public and population health as more data will be available for analysis with the increase of electronically generated and stored data. A multitude of external forces and trends such as pressure to contain rising healthcare costs, expansion of information exchange, tracking and reporting meaningful use of EHR criteria, and reduction of medical errors all call for the application of informatics (AHIMA 2016). Health informatics addresses a number of fundamental research problems as well as planning and policy issues; these tools are aimed at physicians and other health care

managers and professionals - to support education, decision making, communication, and may other aspects of professional activity (Open Clinical 2013)

Challenges of Clinical Informatics

The emergence and development of EMR, CRI, and Bio informatics has tremendously progresses patient care to an acceptable stage. These large data generated by clinical trials, clinical research whether structure or unstructured has some challenges of storage, speedy analysis, knowledge generation, and presentation of clinically relevant information at the point of care (Choi, Kim, Kim, Mun, & Chung 2013). As summarized by Gajic "these are information overload, disrupting workflow, increasing false alarms" and more time is spent on computers by clinical professional with limited computer literacy (Gajic 2015). Internal data interoperability caused by differences in vocabulary, use of different models, implementation guide and software design is also a challenge. Irrespective of advancement in technology, harmonized standards (HL 7), other human challenges affect the adoption and implementation of CI. Government policy, Organisation objectives, global regulatory requirements, level of IT competence among professionals, and human attitude towards new innovations are some of the human challenges that CI faces.

Healthcare delivery problems in Nigeria

According to Nwankwo (2017), the problems of public healthcare delivery in Nigeria range from poor funding, poor maintenance culture, corruption, poor medical facilities, inadequate trained manpower leading to existing workers working under pressure to attend to long queues of patients, inadequate facilities, use of substandard drugs, lack of supervision, etc. The high demand for medical attention amidst the dwindling manpower and health supplies often result to unrealistic expectations as the available personnel must work under pressure the effect of what generally manifests as high rate of misdiagnosed cases some of which may be grave. Due to the insufficient skilled manpower, there is internal and external supervision crisis that culminates into professional negligence, increased risk of adverse events arising from treatment errors.

Location of the Case

The 68 Nigerian Army Reference Hospital Yaba is a secondary and tertiary healthcare service. Though established to provide healthcare service and support to the Nigerian Army, it does not however discriminate between military personnel and the non-military public in rendering its public healthcare services. The hospital is one of the five(5) public hospitals

providing secondary and tertiary care located in the Lagos mainland local government area of Lagos state, the others being the Federal medical centre Yaba, the Federal Neuro-Psychiatric hospital Yaba, the National Orthopaedic hospital Igbobi, and the General hospital Yaba. The hospital is one of the medical facilities in the Nigerian Army (NA) under the command of the Nigerian Army Medical Corps (NAMC). It was established in 1968 (hence the prefix "68" attached to its name) to cater for the military casualties of the Nigerian civil war between year 1967 and 1970, in the Southwestern Nigeria. It is second in hierarchy of the NA's tertiary hospitals. The hospital operates as a system with different units/ departments which work towards ensuring efficient patient care and service delivery. The hospital is recognized by the Medical and Dental Council of Nigeria (MDCN) and other health professional bodies for the training of Medical house officers and interns in Pharmacy, Physiotherapy, Laboratory sciences, etc.

Rationale of the Location of the Study

In addition to its strategic location that connects the Lagos mainland local area with other local government areas such as Somolu and Surulere respectively, the 68 Nigeria Army reference hospital provides healthcare services at different levels unlike the Federal Neuro-Psychiatric and Orthopaedic hospitals that provide specialist care only. The hospital is also a military hospital and conventionally, it is believed that military hospitals in Nigeria are better funded, disciplined and employ advanced technologies in their services than other hospitals of relative cadre. In other words, a technology that is not employed in a military environment such as the Army reference hospital may not exist in other public hospitals of same level.

Organization of the hospital

The 68 Nigerian Army Reference Hospital is headed by a director of the rank of Brigadier General, who oversees the general administration of the hospital in addition to his routine clinical duties. The hospital comprises has 1 stand-alone clinic (Audiological Centre), 23 departments and 5 operational committees. The departments are presented in Table 2.1

Table I: Departments in the hospital.

#	Department	#	Department
1	Surgery	13	Ear, Nose, and Throat
2	Medicine	14	Nutrition and Dietetics
3	Obstetrics and Gynecology (O&G)	15	Public Health
4	Paediatrics	16	Social Welfare
5	Dentistry	17	Centre for Infectious Diseases (CID)
6	Pharmacy	18	Civilian Personnel Services
7	Pathology	19	Administration
8	Radiology	20	Accident and Emergency/ Medical Centre
9	Anaesthesia	21	Ophthalmology
10	Nursing	22	Psychiatry
11	Environmental Health	23	Physiotherapy
12	Health Information Management		

To enable it coordinate its functions effectively, the hospital also saddles responsibility to some committees. They are: Clinical and Training, Ethical, Mess, Drug Revolving Scheme, and the National Health Insurance Scheme (NHIS) Committee.

MATERIALS AND METHODS

Methodology may simply be regarded as a research strategy or the set of procedures that encompasses a system of methods applied to achieve the objectives of a study, research or project. This system of methods includes the theoretical analysis of each component method as well as the principles associated with the particular spectrum of knowledge to which the methods apply. A methodology defines the means or modes of data collection or, sometimes, how a specific result is to be calculated but does not define specific methods (Howell 2013). A methodology is "a system of principles, practices, and procedures applied to a specific branch of knowledge (IHTSDO). In the context of software engineering and project management, a methodology is usually a codified set of practices that may be repeatedly carried out to produce software. We have tried to review the various context of methodology in order to create a niche for this study; that is, to enable us employ what we consider the appropriate methodology. We adopted a hybrid methodology that exploits the Design Science Research Methodology (DSRM) (Peffers, Tuunanam, Rothenberger & Chatterjee 2008) in conjunction with the well-established Object-oriented Analysis and Design Methodology (OOADM) with an overlay of the qualitative case study research design.

Rationale for the hybrid methodology

This study is a proactive development research on Information Systems (IS) and adoption of the hybrid approach is based on the rationale contained in the discussion that follows. Some experts have concluded that IS phenomena posed serious problems to traditional research approaches in the development of scholarly knowledge about IS since the traditional research methodologies are incapable of explaining how individuals, groups, organizations, nations and society can harness ICT to serve humanity(Lee & Liebenau 1997). Thus, IS researchers employing these approaches cannot provide full and satisfactory accounts of the success, failure, effectiveness, efficiency, freedom, and subjugation that occur in computing environments.

Nunamaker, Chen & Purdin (1991) advocated the integration of system development into the research process, by proposing a multi-methodological approach that would include theory building, systems development, experimentation and observations. Information system design is deemed a class of research that would stand as an equal with traditional social science based theory building and testing (Walls, Widmeyer & Sawy 1992). The object-oriented approach decreases the "semantic gap" between the system and the real world even in complex environments, and enhances the construction of using terminology similar as that used by stakeholders in everyday business. Whereas the design science research approach agrees with the Simon's Sciences of the Artificial (Herbert 1981) that we produce and apply knowledge of tasks or situations in order to create effective artifacts as against the positivist/interpretive research. Hevner, March, & Purdin (1991) posited that the purpose of design science research is to achieve knowledge and understanding of a problem domain by building and application of a designed artifact.

Research design

This study used the case study design. The following approaches are employed in the design:

i. Identification of the needs/requirements: This phase followed a problem solving approach towards investigating the current system operated in the military health facility to discover problems as well as making pragmatic analysis to determine whether or not the problem/deficiencies of the current system is amenable to the proposed information system solution. The essence of the relevance cycle was to ensure that all vital details with respect to these activities (covered by the domain) and the existing level of computerization were obtained. Relevant data were collected from staff in various

departments. Computerized and non-computerized processes including the levels of information integration among the various departments were identified. The objective of the object-based analysis was to afford an easy comprehension of the system so as to reveal the challenges and problems that are expected to be resolved by the proposed system. The results provided by the object-based analysis were used as the input for modeling the proposed system

ii. Building the model: the basic operations involved modeling and instantiation of the model to match the requirements of the present scenario that elicited the design study. The model building phase is a component of the design cycle that iterates between the core activities of building and evaluating the design artifact and processes of the research. The modeling of the proposed system was done at four levels: the structural level using component and class (object) diagrams, which include static structure definitions of components, classes and objects. We employed the following modeling tools: Erwin data modeler (for data modeling and integration); Unified Modeling Language; and MySQL Server DBMS, an open source versatile database management system.

Analysis of the current system

Suffice it to say that every system is made up of integral components called subsystems. The subsystems may or may not be severable from the entire system. Usually, to understand how a system works (the behaviour); an understanding the various components or subsystems may be required. To this end, the major subsystems in the patient-care domain were studied in order to detect where challenges (amenable to computerization) really exist. To achieve the foregoing, for each identified subsystem, we specified the following:

1. Actors in the subsystem;
2. Business process model(what happens in the subsystem), using an activity diagrams;
3. Use cases (what the participants i.e. hospital staff, are doing in the subsystem or what they will be doing with the new subsystem);

The Patient registration subsystem

Generally, when a patient reports at the hospital, he/she is referred to the outpatient department where an appropriate registration is done. The patient receives an index card (registration card) which contains his/her registration number and on which data would recorded on. The index card number would be required to access the patient's file on

subsequent visit to the hospital. A patient's file is established bearing the patient's number (index card number) and name. Three groups of patients are recognized: regular patients, patients on referral, and critical care/emergency care patients respectively as shown in Figure 1. Every patient belonging to these classes may or may not be covered by health insurance. The registration process does not follow the same sequence for all patients. For instance, an emergency or critical care patient does not complete all the registration formalities needed for obtaining the index/hospital card prior to consultation owing to the criticality of his/her health condition. In many circumstances, the patient is usually rushed to the critical care department where preliminary treatment is commenced while the registration or documentation may be completed later on.

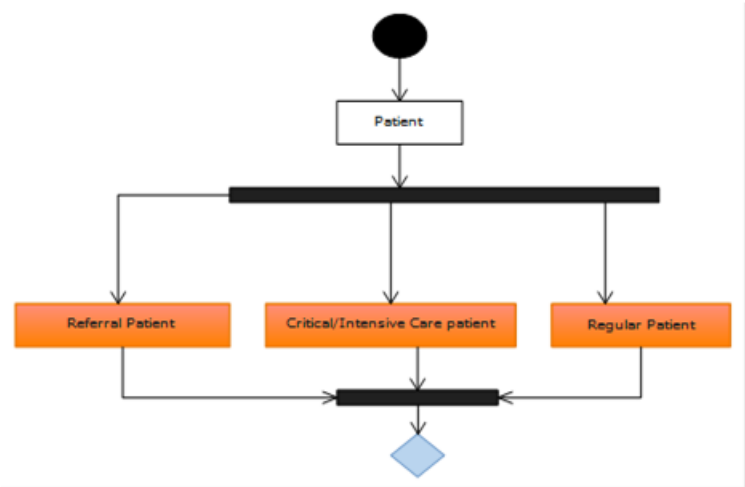

Figure 1: Classification of patients.

Actors

The actors in this subsystem are:

a. Patients

b. Records officers

c. Nurses

The activity diagram in Figure 2 is a reflection of the activities in this subsystem. The record officers are responsible for registering and issuing a patient with appropriate outpatient card also called an index or hospital card. A patient may present this card to the staff nurse who books the patient for consultation, that is, where the patient is a regular patient. The end product of this phase is the generation of a patient file and the issuance of a card containing the patient's basic details i.e. registration number, surname, first name, etc.

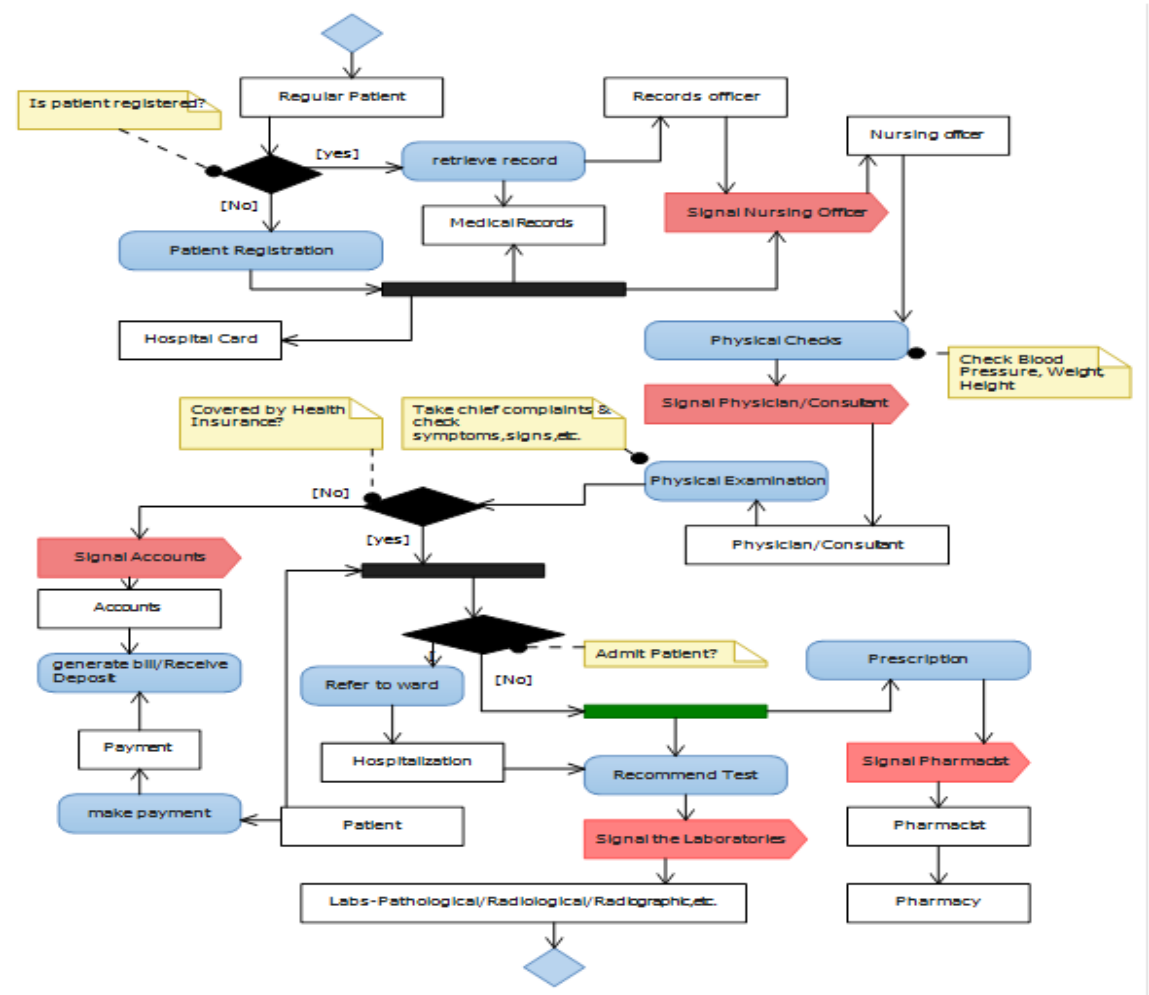

Figure 2: Activity diagram showing preliminary care of a regular patient.

The Physical examination subsystem

The physical examination process is applicable to every patient. It is the next task chain from where data may be generated. This phase involved the conduct of physical checks and measurements such as: blood pressure, weight, etc. by nurses as well as the routine physical examination of the patient for relevant signs by the consultants/physicians. At this point, the physician independently or with the assistance of other medical personnel (nurses, doctors, etc.) may plan to commence treatment or may subject the patient to further investigation through a medical laboratory. The physical examination process updates the patient file.

The actors in this subsystem are:

a. Patients

b. Physicians

c. Nurses

The Laboratory/Diagnostic subsystem

Like other subsystems, this component is very important in clinical care management as it provides relevant data needed to diagnose a medical condition. Laboratory investigation represents a host of activities ranging from pathological, biochemical, histological, radiological to radiographic investigations often requiring experts in various fields. However, the type of laboratory investigation depends on the result of physical examination. In some cases, no laboratory investigation may be recommended. The actors in this subsystem may include:

a. Patients
b. Nurses
c. Pathologists
d. Medical Laboratory Scientists
e. Radiographers
f. Radiologists

The output of this phase is a test result. The test result may come in various physical forms such as: a text paper document, graphics paper document, imaging on special surfaces, etc.

The Treatment/Prescription subsystem

This subsystem has the following actors:

a. Physicians
b. Surgeons
c. Nurses
d. Patients
e. Healthcare officers (Physiotherapists, Pharmacists, Psychologists, Optometrists, etc.)

The treatment subsystem is a complex component that involves a number of experts specializing in different areas. The main objective of this subsystem is to ensure that a patient recovers from his/her ailment. It is often a process that continues even after the patient has left the hospital. In many cases, the treatment process uses the input from the laboratory investigations. Treatment may be by chemotherapy (drugs), surgical therapy, radiotherapy, physiotherapy or a combination of two or more methods. The nature of treatment usually determines the actors that would be involved. Figure 3 is an activity diagram showing the progression of care from the laboratory investigation point to the diagnosis and subsequent treatment of a regular patient (outpatient). For an emergency patient, the treatment cycle may

follow a somewhat different pattern as shown in Figures 4 & 5 respectively. In this subsystem, physicians, consultants, or other allied health professionals may the results of laboratory investigation to diagnose and effect appropriate treatment. The treatment includes routine day-to-day monitoring where the patient is on admission. This phase of care generates more updates to the patient's file particularly in those circumstances where the patient in question is hospitalized.

The Billing/Discharge subsystem

The billing subsystem is always the tail part in the active care cycle. Here, the cost of care and materials expended on a given the patient during his/her visitation or hospitalization is calculated and the patient is made to pay this cost usually called the "hospital bill". In some cases, where an initial deposit was made by the patient prior to the commencement of treatment, this value is deducted from the total bill and the balance made known to the patient. The final bill for a patient is usually computed when the patient is ready to leave the hospital. The patient may be deemed ready to leave the hospital on three grounds: having received treatment as a regular patient (outpatient); having been on admission (inpatient) for a while and certified fit by an appropriate authority to be discharged; and if on referral to another healthcare facility. In any case, the hospital bill of the patient must be generated and the patient is made to pay the stated amount at the Accounts/Finance unit before leaving the hospital. Bills and payment made in regard to the bill also contribute to updates on the patient file.

Actors

The actors in this subsystem are:

a. Physicians
b. Nurses
c. Patients
d. Account officers

The Intelligence/Decision subsystem

The intelligence subsystem is also an important component of the healthcare facility but does not fully revolve around the patient undergoing treatment in the hospital. The intelligence component assists the management of the hospital in making informed decisions. This subsystem tracks the following: the average number of patients visiting the health facility vis

a vis the resources available to the facility; the number of patients satisfactorily treated as against those who were referred based on lack of resources; the trend in hospital visits; trend analysis on classes of health conditions common to the hospital; among others. This subsystem is often a problem due to the fact that it requires the use of appropriated computerized tools to handle.

Actors

The actors under this subsystem are: Consultants and Administrative officers.

Disease management and public health subsystem

Like the intelligence subsystem, the disease management and public health subsystem may not be a concern of the patient undergoing treatment in the hospital but that which assists in the tracking of healthcare concerns that follow unusual pattern. For instance, an increase in the number of patients having a particular health concern may be a signal to an epidemic. In a similar vein, the hospital also uses the subsystem in the detection, isolation and management of strange or unusual health conditions that are new in the facility. Tracking of such occurrences would help the hospital authorities to plan and implement appropriate actions to mitigate the challenges posed by these challenges.

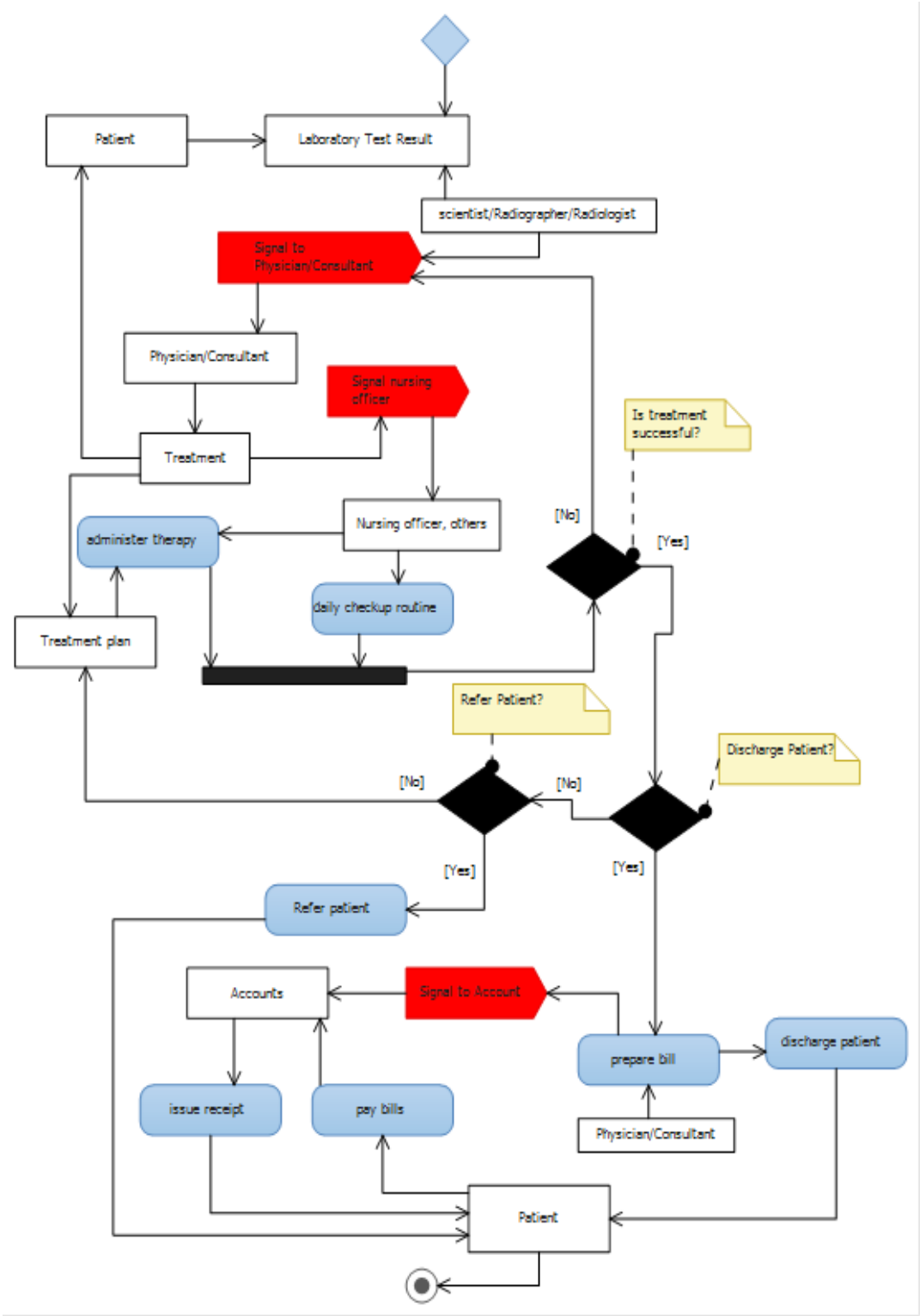

Figure 3: Activity diagram showing Laboratory investigation and Treatment cycles.

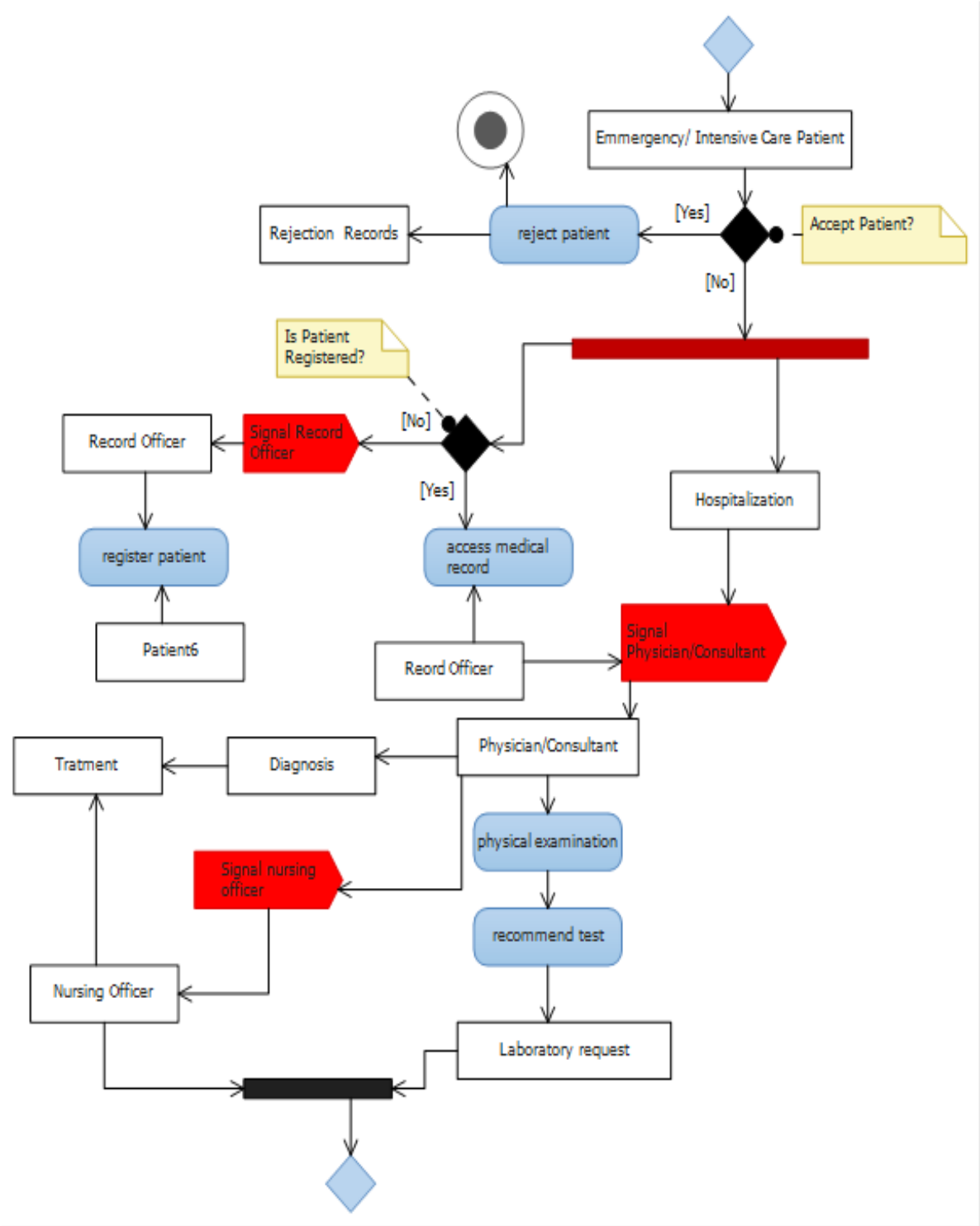

Figure 4: Flow of care for an emergency patient.

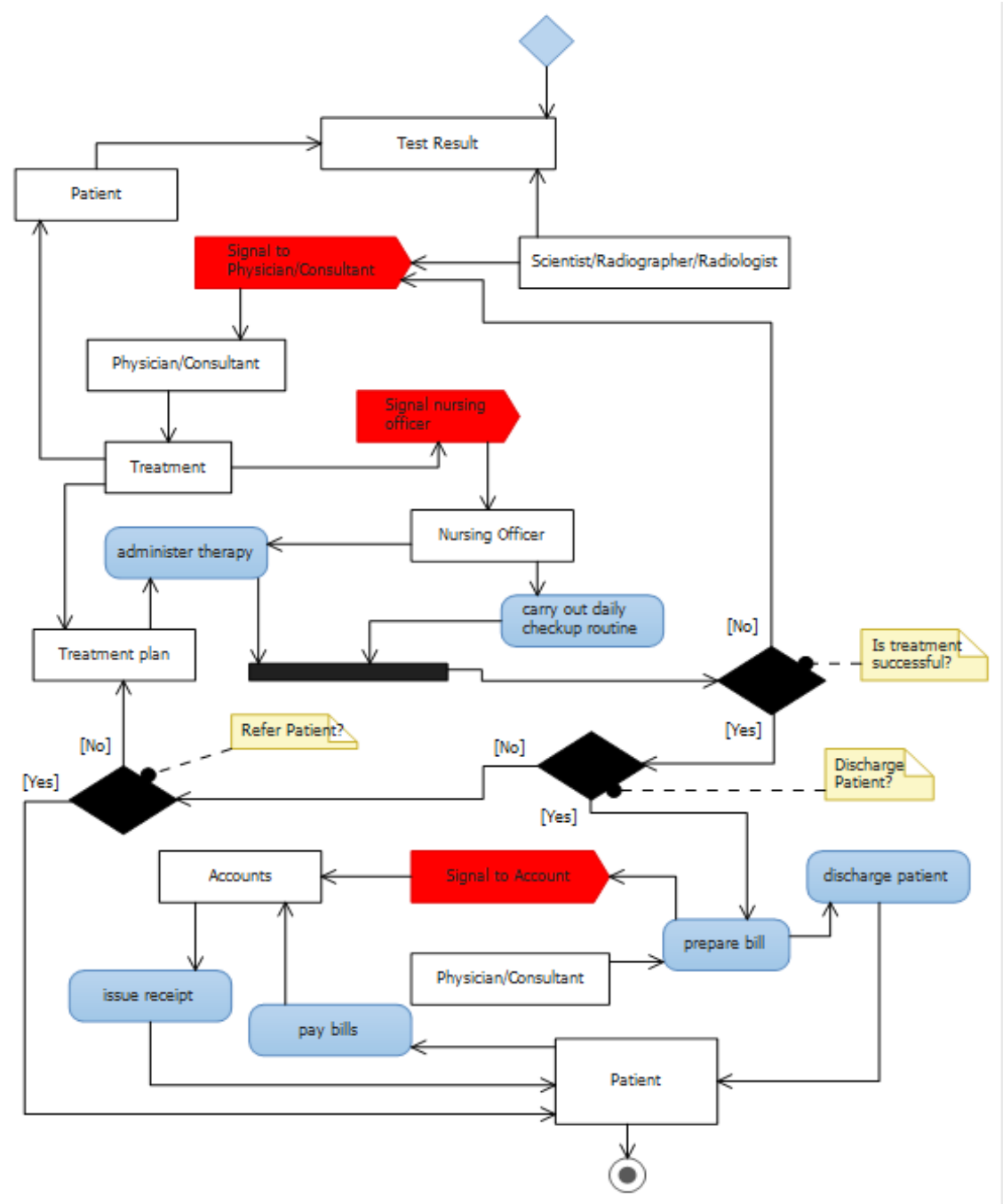

Figure 5: Activity diagram showing the tasks associated with an intensive care patient.

Problems in the Current system

It was observed that whereas the hospital has strived to achieve a lot in the area of quality health care service delivery to meet the modern goals of Accessibility, Availability and Affordability; it still suffered the following problems as it affect healthcare informatics;

a. Lack of a concrete clinical information processing model;

b. Lack of functional information technology infrastructure;

c. Lack of adequate system solution to capture, process, store and analyze data for management support;
d. Poor funding;
e. The health information managers are not adequately trained to meet up with modern day health information record management;
f. The hospital's health information system does not support easy access to health information;
g. Absence of standard information exchange network between the various departments and between the healthcare personnel and the public.

Analysis of the proposed system

Analysis is often important so as to ensure that the requirements of the proposed system are drawn through a careful examination of objects that would be tailored to solve the identified problems in the existing system. Thus, a careful and thorough analysis is sine qua non to the successful design and implementation of the proposed system. Analysis of the proposed system may be done at lower and higher levels respectively. In this study, we commenced at the lower level exploiting the behaviour of the current system with emphasis on the areas where the proposed system would tackle. At this level, we employed use case diagrams as tools for low-level system analysis.

Use case analysis

In object-based analysis, use cases are often used to depict the requirements analysis process. The functionalities defined by a use case are represented using the use case diagram. A use case diagram shows the relationships between the actors and use cases. When we say what an actor did (does), that's a use case. The associations between actors and use cases are represented with a solid line between them. The solid line shows that an actor is associated with the use case. Relationships may exist between different use cases. Two kinds of relationships have been identified. These are: 'Include', and 'Extend' relationships. The use case *include* is a directed relationship between two use cases which is often employed to show that behavior of the included use case is to be part of the behavior of the including or base use case. Unlike the *include* relationship, we use the use case *extend* to show a directed relationship which specifies an optional behavior that could be exhibited by base use case (extended use case) through the extending use case. We employed various use case diagrams to represent the activities that generate useful data in the clinical care cycle. The use cases are

represented in Figures 6 to 11 and analyzed using the use case analysis table. In the improved or proposed, the usual paper mechanisms are eliminated as relevant data are captured directly on the system while signals in the form of alerts are sent to those officers concerned.

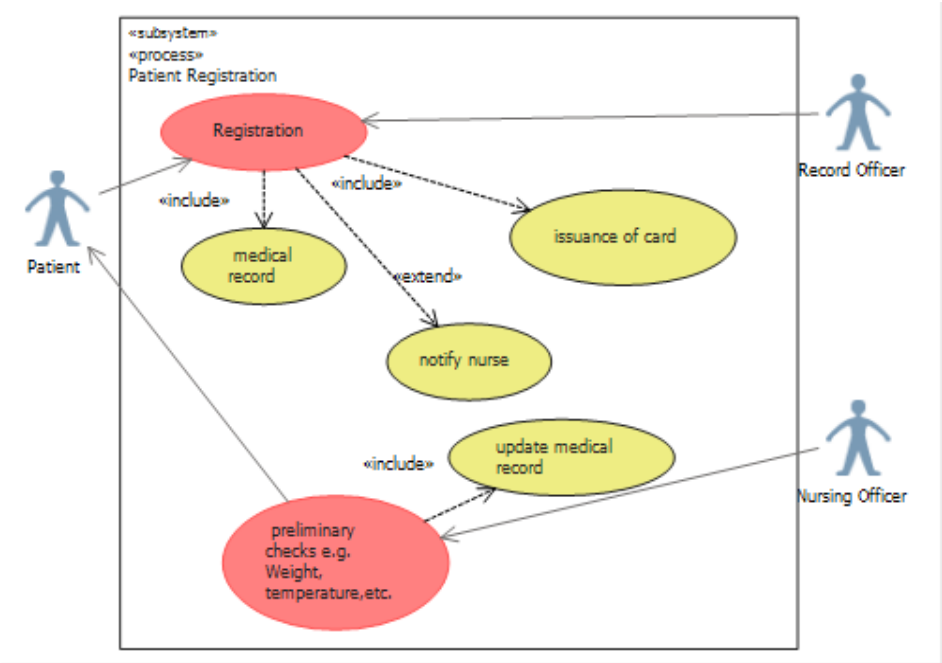

Figure 6: Patient registration use case diagram.

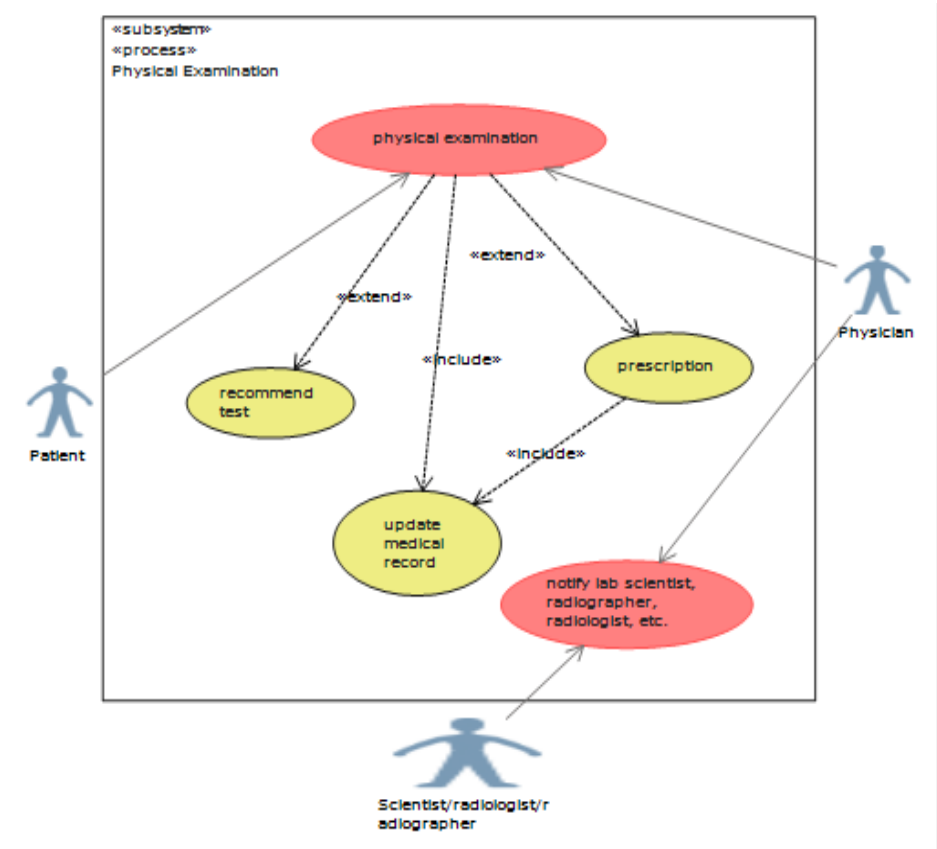

Figure 7: Physical examination subsystem.

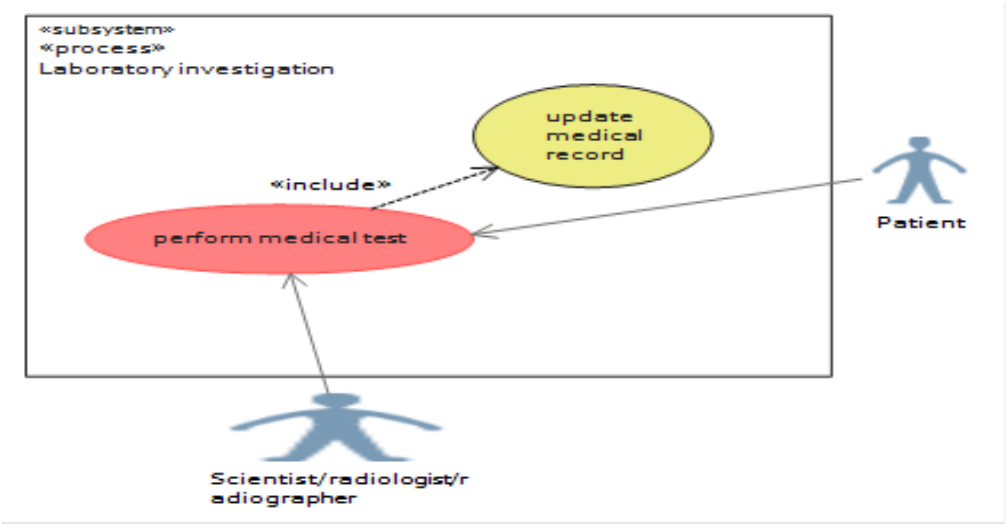

Figure 8: Laboratory investigation subsystem.

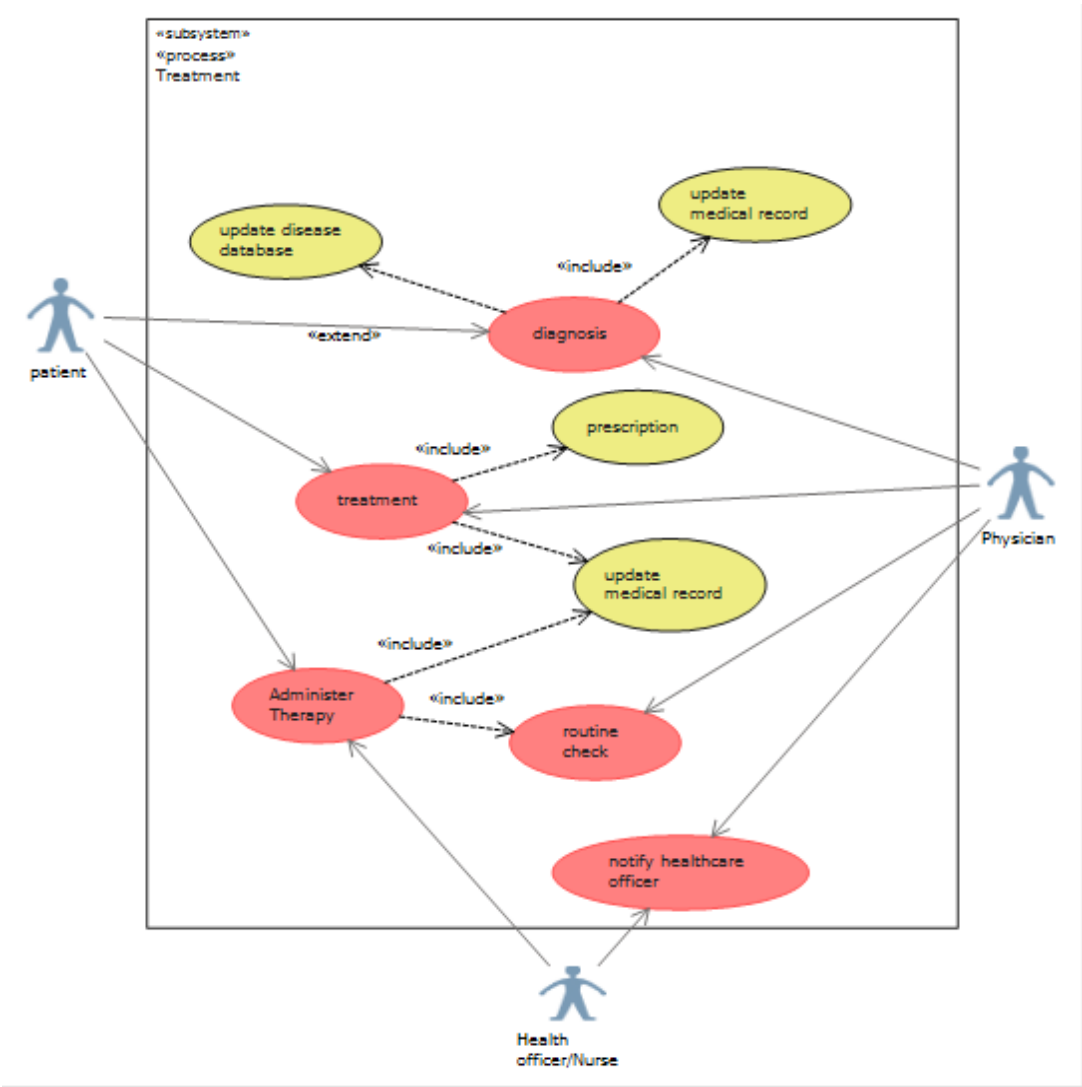

Figure 9: The treatment subsystem

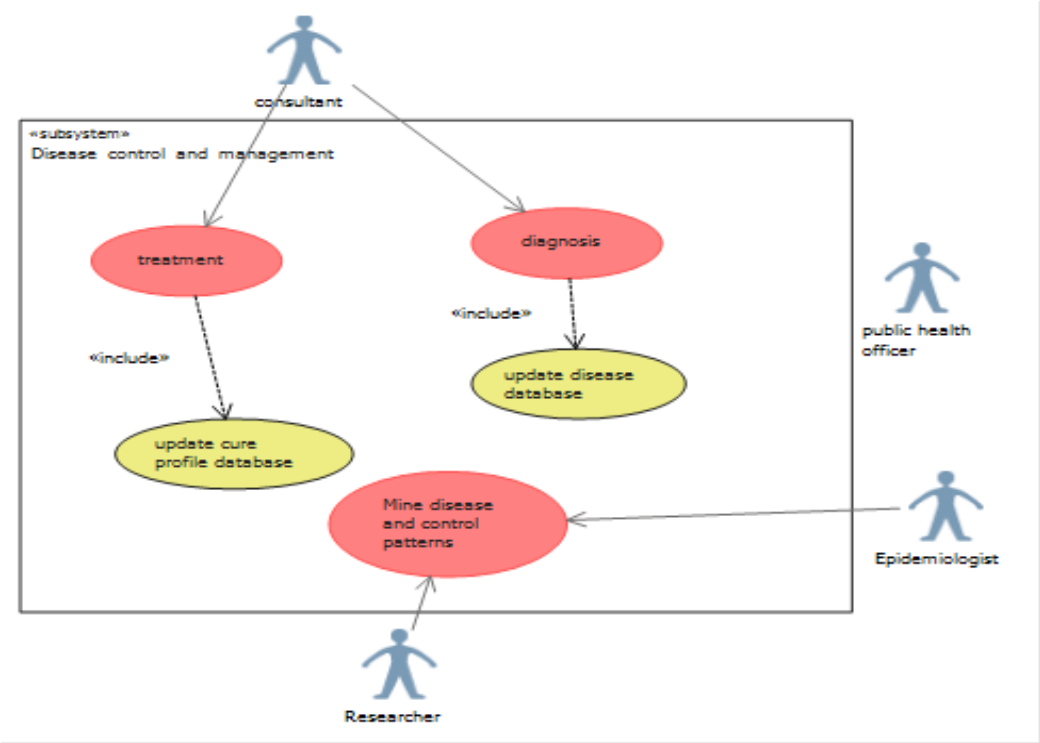

Figure 10: Disease control and management use case diagram.

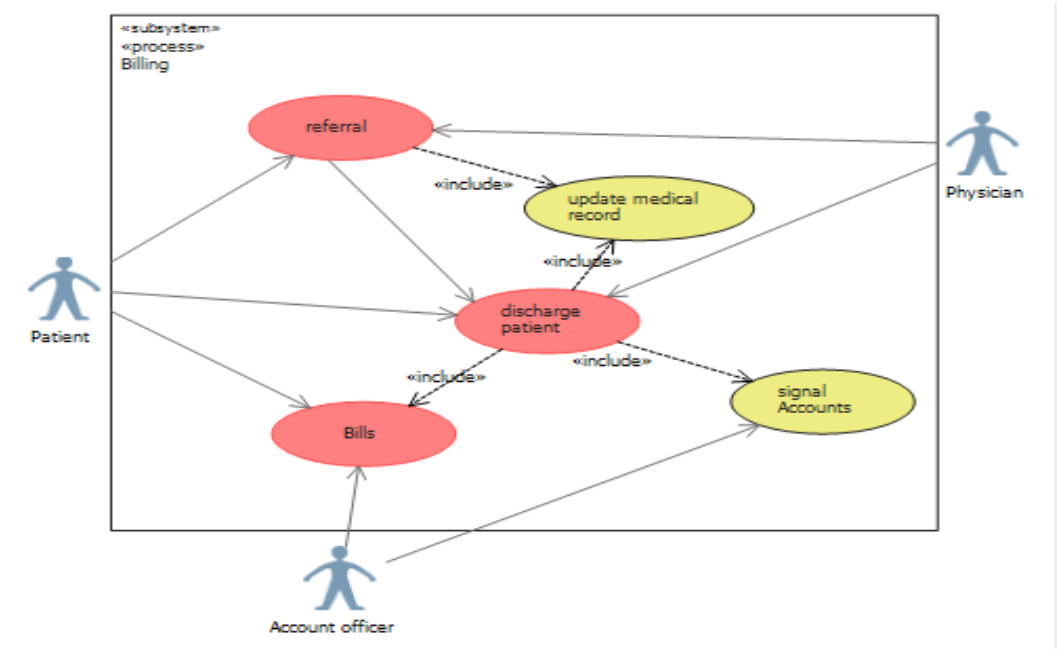

Figure 11: Discharge-Billing use case diagram.

To present the functionalities associated with the use cases, we employed the analysis use case tables in Tables II-VIII. The analysis use cases are presented using tables and references are made to the use case diagrams presented above. Table II presents the analysis use case for the patient registration subsystem.

Table II: The Analysis use case for Patient registration subsystem.

Use case name	**Registration of Patient**	
Description	This use case reflects the procedure for registering new patients	
Reference	**NCliniSoft Figure 6**	
Course of events	Action of Actor	Response from system
	1: The patient or proxy pays the prescribed fees for issuance of outpatient card	2. The patient's basic data are captured into the central database. 3. The system prints outpatient card
Alternate course	4. If the patient is an emergency patient the registration process may be deferred temporarily	
Pre-condition	Patient's ailment must fall within the domain of care of the hospital	
Post-condition	The records officer notifies the attendant Nurse for further actions	
Assumptions	None	

Table III: The Analysis use case for Physical examination subsystem.

Use case name	**Physical examination**	
Description	Procedure for conducting physical examination on patients	
Reference	**Figure 7: NCliniSoft**	
Course of events	Action of Actor	Inputs/Responses from system
	1: Nurse takes preliminary measurements such as weight, blood pressure, etc. of patient. Patient is sent to consultant/physician **2:** Physician/Consultant examines patient for vital signs and symptoms **3:** Consultant orders a laboratory investigation	**4:** Measurements and results of physical examination are captured into the central database. **5:** Laboratory orders are generated and alerts sent to the relevant laboratory personnel
Alternate course	**6:** Commence treatment/prescription if there is no immediate need for laboratory investigation	**7:** Prescription is created on system; System generates alert to the Pharmacist, Accounts respectively; Pharmacist dispenses drugs and updates patient's record
Pre-condition	The health insurance coverage of the patient must be checked to determine the range of care available to the patient	
Post-condition	The Consultant signals the laboratory specialist(s) or Pharmacist where prescription is given	
Assumptions	Patient is not under critical care	

Table IV: The Analysis use case for Treatment subsystem.

Use case name	**Treatment/Prescription**	
Description	This use case reflects the procedure for treating patients	
Reference	**Figure 8**	
Course of	Action of Actor	Inputs/Responses from system

events		
	2: Physician/Consultant and other care personnel examines lab results and effect diagnosis on patient in the consulting room or in the surgical theatre **4:** Consultant books patient for surgery at a scheduled date; **6:** Physician/Consultant and Nurses carry out surgical therapy; Move patient to the ward for monitoring and recovery **9:** Physician/Nurse reviews periodic recovery status of patient; Modify treatment regimen where necessary; Specify further investigation where relevant. Signal the appropriate personnel; Treatment cycle continues till patient is certified ok.	**1:** Results of laboratory investigation are displayed on the system **3:** Results of diagnosis is sent to the system **5:** Surgical treatment schedules are created for patient. Resources for surgery identified, assigned on the system. Messages sent to personnel **7:** State of patient after surgery is fed into the system **8:** Monitoring schedule for patient is created including routine therapy **10:** Therapeutic regimen success/failure recorded
Alternate course	**11:** Consultant/Physician prescribes appropriate therapy; Signal pharmacist and Accounts unit; Pharmacist dispenses the prescription to the patient; Accounts is informed of the patient's bill.	**12:** Prescription is created on system; System generates alert to the Pharmacist, Accounts respectively; Pharmacist dispenses drugs and updates patient's record
Pre-condition	The health insurance coverage of the patient must be checked to determine the range of care available to the patient	
Post-condition	The Consultant signals nurses for preparation of bed in the appropriate ward for hospitalization where patient is admitted; Routine checks and treatment continues till patient is certified ok.	
Assumptions	Patient's condition falls within the hospital's care domain	

Table V: The Analysis use case for Discharge/Billing subsystem.

Use case name	**Discharge/Billing**	
Description	This use case reflects the tasks associated with discharge and billing	
Reference	**NCliniSoft** **Figure 9**	
Course of events	Action of Actor	Inputs/Responses from system
	2: Physician/Consultant certifies health of patient where there is marked therapeutic success; updates patient's bill; discharges patient; signals Accounts and Pharmacy respectively **4:** Patient pays bills;	**1:** System displays details of patient including resources consumed, health status, etc. **3:** Therapeutic regimen success/failure record updates; System generates Patient's bill; Patient's treatment file is updated

	5: Account officer receives and confirms payment from patient; **6:** Patient picks up prescribed drugs from Pharmacist(where necessary)	and closed; Alerts are generated for Accounts & Pharmacy units respectively **7:** Prescription and Accounts records of patient are updated and finalized.
Alternate course	**8:** Physician/Consultant places patient on referral(where facility cannot continue with treatment);	**9:** Referral record is updated; Bill is paid and financial record of patient is updated; **10**: Treatment case records update with therapeutic failure
Pre-condition	The health insurance coverage of the patient must be checked to determine the range of care available to the patient	
Post-condition	The Consultant/Physician signals Accounts unit and Pharmacist respectively; Patient picks his/her maintenance medications and quits the facility	
Assumptions	None	

Table VI: The Analysis use case for Disease control and management subsystem.

Use case name	**Disease control and Intelligence**	
Description	This use case reflects the tasks associated with intelligence gathering and research	
Reference	NCliniSoft Figure 10	
Course of events	Action of Actor	Inputs/Responses from system
	2: Medical researcher/Epidemiologist mines disease patterns and trends; makes forecasts as to resources needed to manage the spread of diseases	**1:** System displays disease frequencies and histories. **2:** System presents Therapeutic cure profiles for selected diseases
Alternate course	None	
Pre-condition	Consolidation of therapeutic profiles and disease history databases	
Post-condition	Researcher notifies the appropriate authorities on findings	
Assumptions	None	

Table VII: The Analysis use case for Laboratory investigation subsystem.

Use case name	**Laboratory investigation**	
Description	This use case reflects the tasks associated with laboratory investigation	

Reference	**NCliniSoft** **Figure 8**	
Course of events	Action of Actor	Inputs/Responses from system
	2: Laboratory personnel performs test on patient or with samples where necessary	**1:** System displays laboratory requests from Physician/Consultants **3:** Results of laboratory investigations are captured on the system; Alerts are generated.
Alternate course	**4:** Patient is referred to external service facility for the conduct of tests	**5:** Updates are made to the laboratory requests regarding use of external facilities; **6:** Patient returns results to relevant department for system conversion; alerts are generated.
Pre-condition	Physical examination completed	
Post-condition	Alerts are generated to signal Consultants/Physicians	
Assumptions	None	

Model of the proposed system

The proposed system is code-named NCliniSoft though subject to change on adoption by the relevant military health establishments in Nigeria**.** It is a network-ready program with a powerful backend and a decision-support component. The proposed model is a user-friendly system that could be adapted for mobile devices such as smartphones, allowing easy access to data, documents, electronic archival and data analysis, irrespective of location; offer extensive storage of data and documents in various formats. The model is intended to support all the subsystems discussed above including data mining, analysis and predictions. The model is designed for flexibility, maintainability and extensibility. Each user of the system would be granted relevant privileges based on defined roles. All patient care actions would be routed to the central database; histories such as resources, therapeutic cure/failure profiles, disease histories, etc. would be extracted, transformed and loaded periodically to the data mart.

The high-level model of the proposed system is presented in Figure 12 using the component model diagram. It is composed of four interconnected subsystems: Front end, Operational database, Extract-Transform-Load (ETL) component, and the Data mart.

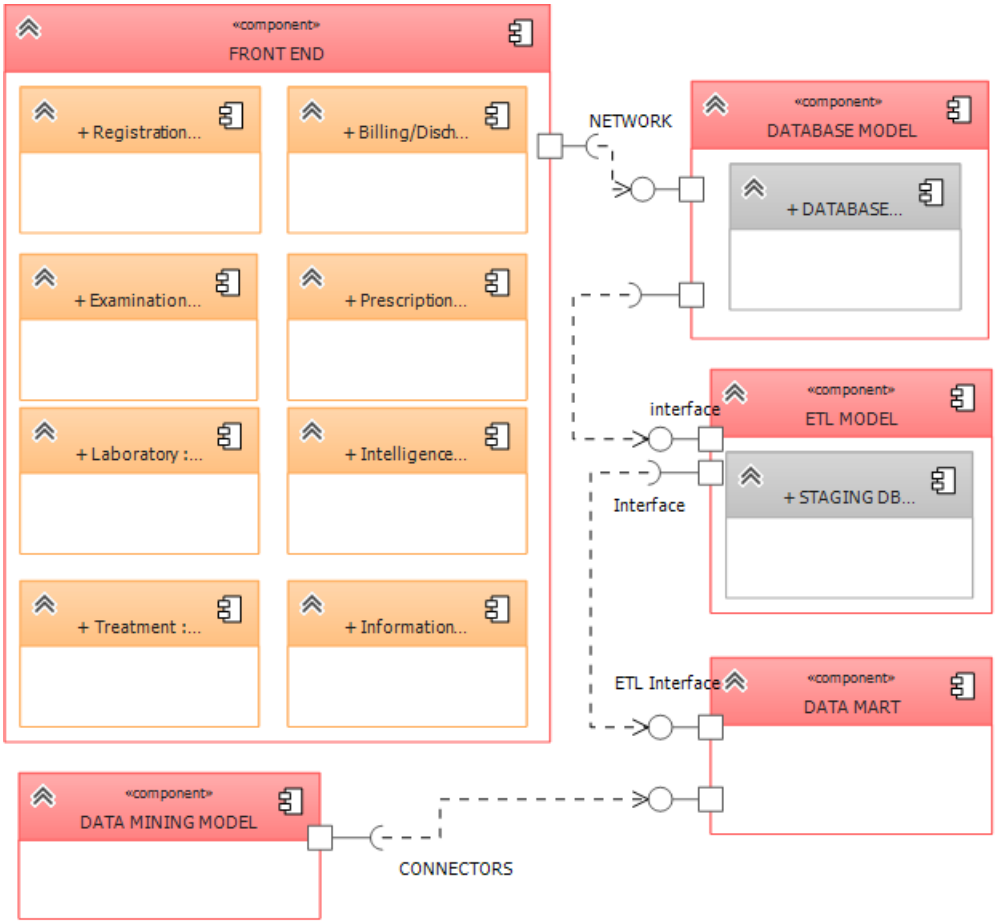

Figure 12: High level model of NCliniSoft system.

DISCUSSION

Healthcare systems are similar irrespective of geographical locations. The secondary/tertiary healthcare system plays significant role in the management of healthcare, and Nigeria cannot be different. Irrespective of the provision in the constitution, effective healthcare delivery has been a dream. This gave rise to the development of this model. Comparing the proposed model with the existing system, various significant improvements would be noticed that enhances adequate healthcare management and improve research. The comparison between NClinisoft and current systems is illustrated in Table VII.

Table VII: Comparison of NClinisoft with Existing System.

S/N	Description	Existing System	NCliniSoft
1.	System Architecture	Department/Units	Network based Sub-system
2.	User Interface	Manual User Interface	Graphic user interface
3.	Information Collection	Manual	Electronic based
4.	Information Storage	Physical Filling	Database Storage system
5.	Information	Manual Look up	Database Query

	Retrieval		
6.	Collaboration between staff	Physical delivery of record	Instantly via user login system
7.	Decision Support	Based on practitioners experience	Clinical decision support system
8.	Access and Security	Physical security which can be compromised	Access control techniques
9.	Research	Little or no research as information is limited	Adequate information for research as data can be retrieved from the data mart
10.	System modification	Difficult	Expansion and modification is possible.

In a real world deployment of a system such as NCliniSoft, The participating parties are carried along in the design, development and implementation to get a significant result from the system. A prototype system of the model can be used as a pilot study in any chosen hospital in Nigeria to validate the model. The training of the users is necessary as they would be involved in the management of information in the system and other activities in the healthcare system, which if not properly handled will reduce efficiency of healthcare and decision making.

In addition to improving healthcare, the institutions will benefit from the system in terms of cost, time management. Diagnosis and patient care would be improved as there are evidences that can match new patients and hence enhance quick decisions. Integrating the decision support system and Data mart will allow researchers carry out evidence based research for improvement in the health care institutions in Nigeria.

Limitation and Future work

The field of health informatics is still evolving, consequently, many health care providers and practitioners are yet to know the potentials of informatics-based medical practice. Inasmuch as many officers at the hospitals are already acquainted with the changes ICT is making in other fields, a significant number of trained health personnel still shy away from revealing certain operational deficiencies in the guise of not in the official position to disclose such information considered as sensitive. In addition are: lack of a concrete clinical information processing model; adequate system solution to capture, process, store and analyze data for management support; and absence of standard information exchange network between the various departments and between the healthcare personnel and the public. In the development of the prototype, the inherent limitations should be taken care of using the appropriate tools

as indicated in the method and materials section of this work. Development and implementation of a system based on the model would be a future work.

CONCLUSION

Many models have been developed and implemented in the healthcare sector. Most of these systems are custom-built and cost of implementation very high in developing countries. This model is developed based on peculiarities of a developing country (Nigeria) and for adequate management of care and research in the healthcare sector.

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