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A Model-Driven Optical Clinic Management Systems: Systematic Software Engineering Approach

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Abstract

INTRODUCTION: eHealth systems in a modern hospital and clinic require stringent measures to coordinate the operations of doctors, nurses, pharmacies for improved health care delivery.
OBJECTIVES: The primary objective is to perform a comparative analysis to devise a novel approach to address the needs of a hospital information management system. This has triggered an urgent response to develop Optical Clinic Management System (OCMS) to address the limitation of the existing system. This intervention would promote the good health and well-being of humankind to meet the Sustainable Development Goals 3 (SDGs 3).
METHODS: The study proposed a Design Science Research Methodology (DSRM) approach in Software Engineering as a catalyst to design OCMS to capture patients' up-to-date records for medical diagnosis. The system is to assist Clinicians to prescribe medications based on a patient's medical history by clicking a computer button.
RESULTS: The limitations discovered during systems analysis and design of the existing systems were addressed during system evaluation and testing. It was observed that the proposed optical clinic management systems received a 98% acceptance for the implementation.
CONCLUSION: This study explores the problem facing clinic and hospital administration and established major factors affecting the existing systems. It was discovered that the paper-based management systems used to keep patients' medical records were found to be unreliable and therefore unsafe to be used as the basis to prescribe medication for patients, hence the need for this comprehensive system to address the problem for effective health care delivery. The situation in the existing system incidentally led to misplaced and unstructured handling of patient clinical records that may inadvertently make the clinicians administer medications with no reference to the patient's previous diagnosis due to the lost file. Hence, the aftermath of the Covid-19 pandemic and its global destruction of human lives should motivate African leaders to invest adequate resources in the development of information technology applications for robust health information systems to improve health care delivery in Africa.

Keywords: Healthcare management, Healthcare Technology, Social challenges, Patients' needs, Telemedicine.

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1. Introduction

Healthcare organizations across Africa and in other Continents have made a transition in medical records keeping from the manual records management system to an electronic management system (EMS). Ghana is making a substantial effort to transition all the health facilities with EMS to experience the full benefits of these applications in our health institutions. This application is moving at a slow pace in certain facilities to meet the urgent needs of hospital administration. About two decades ago, some well-established hospitals such as Korle-Bu Teaching Hospital, 37 Military Hospital, private Hospitals, and others have made unprecedented transitions for using electronic management systems to support efficient eHealth applications in hospitals.

The lack of this electronic records management system in certain health facilities affected efficient health care delivery in

terms of proper up-to-date record keeping of patients to keep pace with previous medical records before diagnosis and medication are prescribed.

This situation has made many doctors inadvertently give false diagnoses and medications without knowing the medical history of the patients. This is quite common in most hospitals due to a lack of electronic management systems. This situation made them resort to paper records management systems which is difficult to keep up-to-date records of patients and for that matter clinicians find it extremely difficult to keep track of patient records in terms of medication and diagnosis when they move from one region to another seeking medical care.

This is due to the use of patient folders by multiple users without reconciling this information in a situation where the patient moves between multiple regions. These challenges result in complications where most clinicians do not know the history of their patients and therefore give false diagnoses and wrong medications to patients without knowing the medical history of each patient. This can eventually lead to the untimely death of the patients.

Due to this phenomenon, Optical Clinic Management System (OCMS) becomes inevitable in an efficient Optical Clinic management of patients to manage the Optician's daily activities and to keep track of basic medical records where each patient seeks medical assistance. The successful implementation of the electronic management system would address the challenges with paper-based record keeping. This eHealth implementation would significantly improve healthcare delivery thereby reducing the complications in paper-based records keeping and a significant reduction in patient waiting time.

This study seeks to design an electronic management system to automate the paper-based management system to improve healthcare delivery. The Optical Clinic Management System provides the benefits of advanced administration & control, excellent patient care, timely cost control, and improved profitability. The types of modules used in the Optical Clinic Management System to meet eHealth standards are indicated below:

- Patient management
- Clinicians' management
- Appointment scheduling
- Pharmacy management
- Finance Management

The huge influx of patients visiting the clinic makes the process of using paper-based records keeping extremely difficult. Many research papers indicate the need to improve the paper-based management system. However, some of these problems remain and require intensive research to mitigate the challenges and this is the direction of the study. The recent development of computerized hospital information services and management platforms has seen unprecedented functionalities and can address complex tasks surrounding clinical healthcare delivery [1, 2].

According to [3, 4] paper files consume a lot of office space. This results in slow recording, processing, and retrieval of patient details. Accessing and sharing information from different departments is a daunting task and difficult due to poor information management. The study on clinic management is aimed at improving these problems faced by the patients during a check-up and other medical formalities.

Below is the pictorial representation of the situation in the record room.

Figure 1. Sample patient files in a records room

1.1 General Objective

To develop an efficient Optical Clinic Management System using the proposed Design Science Research Methodology (DSRM) to develop OCMS to replace the paper-based system.

Specific Objectives

- To generate patient bills and health records electronically
- To register patients and give unique patient numbers
- To receive cash payments and issue system receipts in a real-time
- To implement a system alert concerning the stock level of a drug
- To access patient information by a click of a button

1.2. Organisation

The session discusses and outlined the following:
Session 1: Presented the research problem that led to the formulation of system design and development using a DSRM.
Session 2: Took a critical look at existing literature on hospital management systems, best practices related to health care delivery were taken into consideration to develop an alternative methodology to ensure a new systems approach.
Session 3: Performed a comparative analysis on Agile, Waterfall methodologies, and the proposed Design Science Research Methodology (DSRM) for the ultimate selection of DSRM.
Session 4: Use a software problem-solving technique to formulate a new methodology based on a DSRM. This methodology led to the selection of appropriate tools to design and implement the proposed system. **Session 5:** Outlined the proposed system implementation with all the interfaces, and functions were demonstrated systematically and concisely to address the individual specifications to report on some major findings.
Finally, **session 6:** Conclude the proposed study and outlined the future direction of the study.

2. Problems and Background

This session takes a look at existing systems to analyze and formulate concepts for the electronics hospital management systems. This serves as the basis for assessing the requirements for the proposed system design.
The rise in data collections in an institution has paved way for a new class of systems known as Management Information Systems. This class of systems is primarily designed to deal with large sets of data to aid in decision-making in an organization. Therefore, it is of great importance to study how this system is used in a hospital setting where patient data keeps increasing exponentially. A name given to this class of application is the Hospital Information System (HIS).

2.1. Hospital Information System (HIS)

According to [5, 6], HIS is an integrated information system to improve patient care by increasing the users' knowledge and reducing uncertainty allowing rational decisions to be made from the information provided. The author [7, 8], defined the hospital information system as the information processing and information storage subsystem of a hospital. HIS are made up of varied integrated applications ready to capture data in specific sections of the hospital [8, 9]. It handles the workflow on daily medical services and also assists in managing financial, administrative, and clinical data. HIS is a pre-programmed system designed to provide the needed information and knowledge to the right people, at the right place, at the right time, and using the right standard practices.

2.2. Hospital Information System (HIS): The Past, and Present

In the 1960s, the study, and implementation of information record systems for health information management received a widespread impact in many countries. As a result, effective health care management has become a major concern for the well-being of mankind in general. Due to the urgent need for effective hospital administration, the first hospital information management system was developed from the 1960s to the 1970s. According to [10, 11], this hospital system was implemented in El Camino Hospital in California in 1972 to address the health needs of the patient. This system could only operate with these functionalities (to provide request inputs and the ability to provide report services). The system could not provide emergency and outpatient services due to limited computing power at that time. The second wave of HIS happened in the mid-1970s with a financial implementation functionality of the existing Hospital Management Systems.

After this era, came the introduction of database technologies in the early 1980s [12, 13]. This system focused mainly on patient care planning, laboratory, and pharmacy issues, and how to store and retrieve data from the systems. Third-party application integration would not happen until the end of the 1980s. This era is known as the fourth generation of HIS. In the 1990s, the prices of computers had begun to decrease and the processing power of computers rise exponentially [14, 15]. Due to the improved computer functionalities, the investment in HIS had also increased significantly, and this prompted many health institutions to adopt the use of HIS. The Institute of Medicine published a report in 1991 on a "Computer-Based Patient Records: As an Essential Technologies in Health Care" [16]. This report outlines the weaknesses of the paper-based systems and encouraged the use of electronic patient records systems in hospitals. Besides, the report stressed the importance of roles doctors play in the system and the need to make the system patient-oriented [17, 18]. Currently, the safety reduction of patient medical errors has seen an unprecedented increase in healthcare quality delivery and this intervention becomes the priority in HIS design approaches. The current advances in technology have made HIS, more relevant than before in the healthcare industry [16]. In recent times, electronic management systems are among the most basic applications in the health sector and this technology is available to all hospitals and clinics to be implemented in their respective hospitals.

2.3. Hospital Information System (HIS): Purpose, Functions, and Benefits

The purposes of hospital information systems have been documented [16], to ensure that all the:

- Basic information about the patient's CV should be recorded instantly into a computer for easy accessibility upon request.
- Time used for searching archiving systems before the diagnosis of the disease is fast-track to ensure reliable and prompt service delivery on time.
- Hospital management information systems should be made easily accessible to the users of the systems.
- Incomes generated through billing are supported by official document preparation reliably without any financial complication.
- Financial transactions and material distribution are done using a computer for easy record keeping.
- Medical research is supported by high-quality communication by exchanging information between different hospitals. Proactive and curative health services are easily managed and integrated into each hospital.
- The financial transaction subsystem should be established in a cost-effective manner.
- The output of each employee and medical device is managed to meet the highest standard of the hospital.

The functions of the hospital management information are briefly summarized [16] below:

- Each hospital should constantly keep and record files in the hospital by staff using the system.
- Ability to receive information, and make certain changes by the system administrator when necessary.

- Ability to draw study analysis reports of each center of the hospital, produce computer reports, and analyze them to make administrative decisions.
- Ability to produce information about labor costs, quality control, personnel productivity to make management decisions on them.
- Ability to provide enhanced information support on the effects of diseases, drugs, diagnostics, and treatments in real-time.
- Ability to appraise each staff to ascertain special talents, and document situations for staff development and promotion.
- Ability to get prompt information about patient treatment quality, performance, and cost for management decisions.
- Ability to use the Patient Management Information Systems regularly in the right context and standard.

The hospital information management systems' benefits are outlined in [16] as follows:

- To reduce all the problems in the paper-based system through effective use of the system.
- To ensure that all statistical results are obtained according to different criteria sets by the hospital.
- To ensure that all leakages are prevented by input, control, and make a regular follow-up on all kinds of materials in the hospital.
- To ensure that all operations and relevant images are saved, and recorded in the digital environment to avoid any misrepresentation.
- To ensure that all information is stored in an electronic environment through digital archiving.
- To ensure that all the performance appraisal is constantly recorded about each staff of the hospital.
- To ensure the continuity of patient treatment and patient satisfaction as a standard benchmark.
- To support personnel management, logistics operations, case costs, and supply chain management of the hospital.

2.4. Hospital Information System (HIS): Review of Related Work

A careful study of similar work done for hospital administration indicates that governments of several nations have adopted several interventions and mechanisms to promote and develop a comprehensive basic national primary care program**.** This is often proliferated due to a lack of specialized health care facilities, and expertise to run the few that are available. According to [18, 19], the hospital system is complex among all of the administrative organizations. The main objective of a hospital is to provide adequate critical health services and treatment to individuals in a timely fashion. Aside, the primary objective, the hospital also records information about the patient, generate bills, record information about diagnosis given to patients, keeps Immunization record of a patient, keeps accurate data on various diseases, and make medications readily available**.**

These tasks are handled manually in certain hospitals today, and take up huge rooms to facilitate storage or records. The author in [20] identified one major challenge facing the existing system known as the paper-based record system lacks operational efficiency since hours are used to perform different processes. According to [20, 21] the shortcomings of the paper-based system, and devised alternative methodology using an RFID (i.e. Radio Frequency ID as well as wireless sensor-based to validate location and information management systems to facilitate time-tracking asset and human resources management on daily basis using a pre-defined procedure in the hospital. The author in [22] also proposed another method by using a web-based real-time system to improve medical research and data analysis. Furthermore, [23] stated that health care service management in China has adopted Hospital Service Management System (HSMS) to align its core services to improve quality health care delivery in a cost-effective manner. The interventions from previous systems point to the fact that the information storage and retrieval of the patient are very crucial for the improvement of the hospital administration capability in decision-making for the overall efficiency. Hospital administration has used a variety of methodologies to ensure that reliable and accurate systems are deployed [24, 25].

In [26] stressed the importance of an automated system towards achieving efficiency. The researchers used India as a case study, where the population keeps increasing steadily, which might pose a problem to hospitals still using the traditional system of information organization and storage. The increased population comes with the increased use of amenities, hence all institutions are advised to devise better ways of handling the increased need and expectations of the populace. It stressed how the current system would require a lot of paperwork, manpower, and file cabinets to maintain records. The current system would also require a lot of room space to house the file cabinets with patient information.

The old system is time-consuming when it comes to information retrieval, organization, and filing. It also has poor security, because access to the information cannot be well monitored. According to [27, 28], the new system was proposed to improve on the performance with regards to the hospital management, efficiency in terms of how it manages, and coordinates every information regarding the patient, and control in terms of who can access patient information.

A careful review of the article revealed that relevant data was difficult to collect due to some difficulties in meeting with top officials of the hospitals visited. Most of the information contained in the work was modified because the researcher claimed there was some form of bias from the people interviewed. Hence, most of the analyses and interpretations, made for the report, were based on secondary data obtained. Therefore, the data may have contained inherent mistakes and errors. The tasks specified were not well defined because nothing was mentioned regarding validations in the study. Even though a maximum effort was given to check the software with different validation tests. This demonstrates the findings or results reported in the article might be flawed, due to poor data collection. The article also did not state the methodology used in the collection of data. Therefore, it is very imperative to use a well define methodologies in HIS to avoid any research gaps.

According to [29], the need for hospital information systems is constantly in high demand to keep pace with the increasing population to help doctors deliver essential services to the public

with precision, and speed. This study focused on feasibility studies, and a requirement gathering methodology to assess and identify the essential components of the Health Management Systems (HMS) to meet the need for health facilities across the globe. The methodologies evaluated for the identification of the key performance indicators of the HMS have been regarded as a benchmark perspective. The researcher reported that the study was based on qualitative, and descriptive, and most of the data were based on secondary sources of survey data. This approach adopted in the study area was very broad and failed to address the research design concepts outlined. To arrive at a comprehensive conclusion, it is very important to look at the bigger picture of hospital administration, and a critical look at the existing information system based on survey data, and specific successful case studies of HIS**.** This effort would give a better result by finding the answers to the research question framed for alternative methodology**.** This study is about the factors that are responsible for the successful implementation of HMS. These factors include the commitment of the administration to implement clear targets. The article reported the success factors of HMS, tend to vary depending upon leadership support, training, technology, and adopt user-friendliness. The article stresses that no matter how efficient the HMS proves to be, it would fail to accomplish the hospital's objective if poorly implemented. Hence, the implementation plays a very crucial role in the success rate of HMS. Moreover, careful planning and implementation strategies should be adopted by the Administration. A good change policy should be adopted, for the staff to be trained on how to effectively use the new system. The study also focused on the key components of HMS, and factors that may affect its success rate. It states that designing an efficient HMS is highly dependent on the implementation strategy adopted. However, the study failed to put into consideration the attitude of the users of the system.

Furthermore, [30, 31] maintains that the secret to quality health care relies on efficient management. To achieve this, a reliable means of handling and organizing patient information must be adopted. The study further stated that an electronic means of handling patient-related information would make it easier for hospitals to provide better services for their patients. To handle information about patients, the paper proposed the development of database management software which would be very beneficial to the hospital. The article stresses that if patients realize that their information is well taken care of, it makes them feel very important. Also, well-kept records usually reflect the level of care given to a patient by the physician. It also stresses that an electronic information system corrects a lot of limitations encountered in a manual system such as lack of prompt updating of information, lack of immediate information storage, and lack of immediate retrievals of stored information.

These limitations can be very problematic, especially when there is an emergency like childbirth where there may not be enough time to search through files before attending to the patient. In some cases, patients are allowed to receive treatment based on recognition, but this can be detrimental to the hospital. The authors in [29, 31], addressed a lot of problems faced by hospitals and also suggests the proposed system would also be used to protect organizations, handwriting errors, overstock problems, conflict of scheduling personnel, and official documentation errors like tax preparation errors. This paper does not put into consideration the fact that personnel attitude plays an important role in achieving patient satisfaction. No matter how efficient the information system of a hospital might be, if the doctors, nurses, or lab attendants have a lazy attitude towards the patients, customer satisfaction cannot be achieved. Good organization of information is important to the success of any organization, including hospitals, but poor attitude by members of staff would endanger whatever progress has been made towards that effort. Hence, a study should be conducted to identify ways in which customer report services rendered would be integrated with the information system, for effective management of feedback from the patient in real-time without any human manipulation.

The author in [32], advised hospitals to provide efficient, and satisfactory services to their customers. A Hospital Service Management System (HSMS) should be implemented to accommodate some of the limitations of a typical Hospital Information System (HIS). The study further explains that HIS, is designed to improve the quality of healthcare performance without ways to measure the quality of those services. This study [33], explains that hospitals would have to use HMS to efficiently manage the large volume of data generated daily. The paper also identified stakeholder participation as a major factor for the improvement of the hospital information systems (HIS) to elicit a comprehensive requirement to develop a robust system to address all the challenges encountered in the existing systems. This study was aimed at investigating the varying degree of stakeholder participation at different stages of the development to envisage any factors that may affect the systems. The study further showed that user participation at different stages of development of HIS was low and suggested that managers provide health care managers to devise a new methodology to attract wider stakeholder participation at system analysis and design stages of the systems to identify and ensure that all the relevant requirement are fully identified and to continue to involve the stakeholders until the system is fully developed. The study also, suggests that without involving the expected users of the system in the development stage, the system would fail in meeting the required expectations and needs of the user. Hence, user participation is essential to the success of the system. The study also proposed a solution to enhance users' participation. It was suggested that users' participation can be enhanced through effective assessment of the users and the hospital facility for the development of HIS. Furthermore, establishing an appropriate communication standard would attract the full support of all the stakeholders (i.e clinical, managerial, and information technology) needed to develop a robust hospital information system for healthcare providers. As soon as the proposed systems are developed the developer needs to select appropriate leadership, training, and to equip them with the necessary skills for health providers to understand the benefit of the system.

According to [34, 35], high costs involved in the planning and design phase of enterprise systems often lead to the non-implementation of those systems due to unmanageable, and unknown factors. These factors include subject area expertise, and lack of knowledge on different Hospital enterprise functions :

- Patient admission
- Patient Treatment planning
- Order Entry
- Execution of diagnostic and treatment procedures

- Administrative documentation
- Billing
- Clinical documentation
- Discharge
- Referral to specialized medical institutions, lack of knowledge /experience on the entity's types involved (example: patient, Clinical finding).

This study aims at reducing the cost involved in studying, and analyzing the current states to identify the necessary gaps to propose additional requirements that will significantly reduce the reference data model that will serve as a generic starting point for any new HIS development projects.

According to [36], the opinion that the environment in which a hospital is situated is an important factor to be considered to fully understand and identify the activities, and decision-making process that would be required of the hospital management. This study identified some of the challenges associated with the environment that need to be worked on to ensure customer satisfaction**.** The paper highlights Environment Shaping Factors (ESF) that should be considered, thus contributing to the planning, design, and development aspects of any Hospital Management System.

The author breaks down the environmental factors that can affect the development of HMS into external and internal factors. The external factors include public law, policymakers, funders, medical suppliers such as pharmaceutical companies, the scientific community, the software development community. While the internal factors to be considered are the skills and experience of staff, internal business strategies such as competition, and subsidization factors such as morale and culture, and equipment availability. Thus, the DSRM research becomes a suitable methodology for this paper due to the numerous limitation identified in the literature.

3. Software Framework: Agile, Waterfall and Design Science Research Methodology

3.1. Introduction

Software development methodologies have seen unprecedented and rapidly changing market conditions, as a catalyst to develop new technologies to meet the multidisciplinary business-specific requirement to specific project domains. Different types of projects require specific procedural models to accomplish each task. What are procedural models? – It specifies the methods and tools required in the project phases or processes based on different methodologies are discussed.

3.2. Waterfall Methodology

A classical waterfall method follows a plan-driven process for gathering the required information to ensure proper planning and execution of the desired results which is then communicated clearly by the client at the initial stage of the project initiation [37, 38] in a goal and plan-oriented manner from the beginning to the end of the project completion with specific work packages, responsibility, and deadlines. This method focuses on implementing the initial plan exactly as stated as the bases to provide stability, structure, and predictability of resources and documentation planning [38, 39]

The waterfall model is a sequential design process in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of Conception, Initiation, Analysis, Design, Construction, Testing, Production/Implementation, and Maintenance.

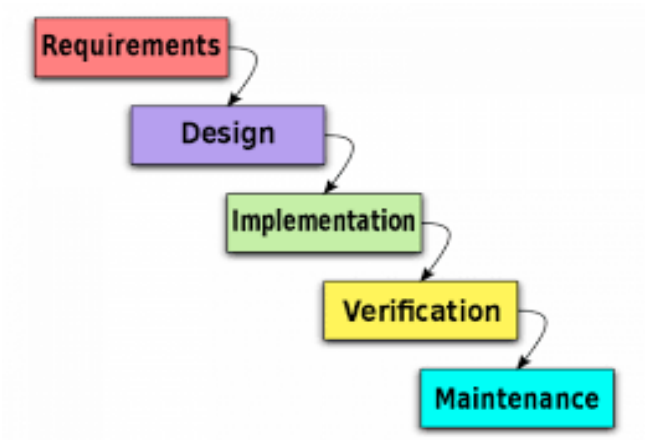

Figure 2. Waterfall Model

- **Requirement gathering and analysis:** This allows all the possible requirements needed to develop the system and is captured in this phase and documented in a requirement specification document.
- **System design:** This is the requirement specifications at the beginning of the first phase where the system is designed by specifying the hardware and system requirements for the overall system architecture.
- **Implementation:** It allows inputs from the system design stage, and subsequently developed small programs called units, which are then integrated into the next phase. Each unit is developed and tested for its functionality, during Unit Testing.
- **Integration and testing:** It combines all the units developed at the implementation phase which is then integrated into a system after testing each post-integration to ensure that the entire system is tested for any faults and failures for possible amendment.
- **Deployment of the system:** It ensures that the functional and non-functional testing is done and the product is deployed into the stakeholder environment or released into the market for implementation.
- **Maintenance:** It addresses some of the issues that may come up in the client or stakeholder environment. Maintenance is done to deliver any changes in the stakeholder environment.

The main objective is to design a comprehensive OCMS to ensure efficient and effective patient information management by the click of a button. To ensure a holistic architecture to coordinate the information of the patient, doctors, nurses, pharmacies, and health care administrators and to meet these stringent requirements a DSRM is proposed to achieve these objectives, with the following functionalities:

- Provision to enable the systems to manage patient information.
- To establish a link between the clinicians and patients for information sharing.
- To automate and integrate health care operations in the hospital
- To coordinate clinical information and make it readily accessible to the users.
- Provision of clinical decision systems to facilitate effective service delivery in real-time
- To store all relevant transactions within the health information systems for easy accessibility to users.

In the proposed software architecture, the above functionalities have been implemented in the Hospital Information Systems.

3.3. Agile Methodology

An Agile method, for instance, follows an iterative test-driven process [39, 40]. This method on Scrum and Kanban do not focus on advanced planning and execution processes [41], instead, the project team develops step-by-step processes with clear coordination with customers to deliver interim results in a cycle [39, 40, 42]. The main reason for adopting DSRM is that the customer or user specifies incomplete requirements at the project initiation phase which may not lead to the desired requirements where Agile methods are used. The flexibility in DSRM method allows room for change requests which is more important than rigid adherence to the initial plan. This allows the expected results are finalized during the project implementation [39, 40]. It is worthy of note that the project processes in an Agile method are not linear in successive phases as required in the classical waterfall process. Rather, a series of iterations may be used to achieve the desired result in a test-driven manner thereby allowing flexibility in the project management team to incorporate changes made in a customer requirement to achieve the overall goals[40, 43].

4. Design Science Research Methodology (DSRM)

Researchers, as well as practitioners, find certain degrees of limitations for the implementation of new applications. The growing concern is the importance of the technological literacy of eHealth applications and this limitation hinders the development of eHealth solutions that would break certain limitations based on patient communication, cost, collaboration, and the overall participation within the health environment. This limitation of literacy is a barrier and the technological capacity exists for the provision of patient care, but what is lacking now is the appropriate design of new eHealth services, hence the need to use a DSRM approach for this paper.

Although, several methods of design exist to implement eHealth solutions to support a comprehensive eHealth application. The majority of the developers, implement an eHealth innovation to meet the needs of the user/stakeholders. To achieve this demand, developers have adopted a known method such as Agile, which allows a short development cycle based on prompt stakeholders/user feedback. This follows a new eHealth solution through innovation based on disruptive models. This method focuses more on finding the right business model instead of developing the solution. However, the ability to adopt a unified framework to examine these innovations is yet to be validated. Nevertheless, the major challenge is how to find the right methodology to help implement eHealth services, backed by appropriate technologies becomes a major challenge that affects the final output of the systems. To avoid some of these technical barriers to eHealth application, this paper proposed DSRM as an alternative methodology to implement a novel application. Using DSRM to design a new system to store, retrieve, and analyze electronic medical record data, the output is an artifact. Design Science (DS) artifacts must satisfy two important characteristics such as purposefulness and novelty: The artifact should solve a very important problem (i.e. purposefulness); innovatively (i.e. novelty).

The main focus of DSRM is to design an artifact to address a specific challenge in an organization. DSRM is open to a variety of stages which is less concerned about design rigor as well as formal evaluation stages of the artifact. Unlike other alternative models based on a user-centered design, DSRM research advances from a series of cycles/stages to ensure the specific problem is identified and ensure that the user's needs are evaluated scientifically and addressed. These requirements based on the user's needs are then used to design the new artifact, with the possibility to make changes during the implementation; which is further evaluated before starting a new cycle again. The main direction of this study is to use DSRM as an alternative methodology but not for the development of the technical applications only but the systematics design, development, evaluation, and implementation of the overall artifact.

Moreover, DSRM refers to the development and the performance of a design artifact that consists of an explicit development and the improvement of the functional performance involving the artifact to enhance overall system performance. DSRM research is suitable to a group of artifacts that involves the development of algorithms, computer interfaces, and design methodologies that consists of a process, models, build and experimental and languages [44]. This application is widely used in Computer Science and Engineering disciplines and this is not limited to these domains only, but can be found in many other disciplines as well.

The primary goal of a DSRM, is to create knowledge for the research community to empower professionals and practitioners to develop and design novel solutions to address societal needs. In [44, 45], outlined a set of guidelines for the DSRM to guide a variety of disciplines to follow system development cycles in general. DSRM requires the creation of an innovative, purposeful artifact for a special problem domain. To ensure a novel research contribution, the artifact should either solve a problem that has not yet been solved or be used to provide a more effective solution in a specific research community. In these cases, the guidelines for the construction, and evaluation of the artifact should be done rigorously, and the results of the research presented are both technology-oriented and management-oriented in a particular research community. To ensure good design principles, 7 guidelines for DSRM has been proposed in [46], and explicitly explained below:

- **Design as an artifact:** DSRM should produce a good artifact in the form of a construct, a model, a method, or an instantiation.
- **Problem relevance:** DSRM develops technology-based solutions to important and relevant business problems within a specific research community.
- **Design evaluation:** The overall utility, quality, and efficacy of the design artifact should be rigorously demonstrated through a well-executed evaluation method that is generally accepted.
- **Research contributions:** DSRM should provide clear, viable, and verifiable contributions with a specific focus on the design artifact, design foundations, and design methodologies.
- **Research rigor:** DSRM relies heavily on rigorous methods for the construction and evaluation of the design artifact.
- **Design as a search process:** The search for an effective artifact requires utilizing all the available approaches to reach the desired results while satisfying laws or ethics in the problem domain.
- **Communication of research:** DSRM should be presented effectively both to technology-oriented as well as management-oriented communities.

DSRM research is becoming an emerging concern to research communities due to its continuous improvement cycles to accomplish the artifact at a faster rate. DSRM strives to be realistic, and relevant to researchers in this 21 century. However, only a few researchers have experience in DSRM on how to utilize meaningfully the theoretical knowledge produced by DSRM research in solving real-world problems practically. This potential gap between the theoretical approach as well as the practical issues faced in practice, and its challenge refers to as the design theory indeterminacy [47]. How to formulate DSRM research in practice is specifically carried out in this paper with simplicity to help practitioners and developers to use this alternative approach in system development.

Stage 1 – Problem identification and motivation

As usually done in any research endeavor, where the first stage is used to elicit requirements on the problem to be addressed. In this eHealth system, the initial research question was ‘ how could the Optical Clinic Management System concepts be applied to remote systems to create a holistic and robust system?’ To start with the requirement gathering process, the exact parameters for the new system at hand need to be defined. In doing so, we need to examine different methods on how similar projects were carried out based on literature.

The first step is to perform a literature review [48] to ascertain the state-of-the-art on the Clinical Management Systems services being provided, how these services were using technology, what was the experience for using a remote system to support health delivery, etc. The reviewed literature focused on the previous systems, the technology used, and its associated challenges to find the required gap for the proposed system. The observational study supported by the literature review alongside the real-world data taken directly from the exact environment where the activities of the DSRM would be implemented. With this information at hand, it would help the researcher to collect data on the state of the problems and the current solutions if any, and their efficacy (i.e. strength and weaknesses). In DSRM, the final outputs of this activity would be a valuable asset for different stakeholders as follows: For the professional, the scenario demonstration provided adequate information about the action that should be taken to pave way for the development of new roles required for the Optical Clinic Management System in this 21st century; for the participated health professional in the observational study, provide enough information on the workflows, work practices, and services’ cost; for the researcher, it requires a deep understanding of the application domain along with the development and the implementation problems. DSRM cycle, allow the final output of this stage to inform the design solution in stage 3, coupled with the required method to follow in the next stage

Stage 2 – Formulating the objectives of the study

This step is where a researcher starts to define the exact solution required in the new artifact to address the problem identified in stage 1. DSRM solution should be done both quantitatively and qualitatively where the quantitative define to what extent the solution should be better than the current process, while the qualitative define how the new artifact should be better to support the problem identified in the first stage. To address the problem gathered at stage 1, the researcher starts to interact with the stakeholders/end-users of the possible solution. To support the researcher to address these objectives, it is very important to listen to the end-users (both patient and health professionals) about their choices and opinions attentively and holistically.

The methods of choice regarding the Optical Clinic Management System (OCMS) were identified to be a focus group with professionals and a survey with potential users. In [49] outlined guidelines permitted to collect information on the user expectations regarding features to include in the final artifact that may not be previously identified coupled with the explanation of the evaluation method. The processes at stage 1, guide what parameters are relevant to the implementation of the OCMS.

In this stage, a set of steps is required to evaluate and examine the usability, quality, and efficacy of the artifact in the final stages of the cycle which will be one of the most important outputs. Also, important findings from the end-users will inform the exact stage that should be done in subsequent stages.

Stage 3 – Design and development

This stage places concrete emphasis on the interdisciplinary nature of the DSRM cycles. It provides effective interaction among different players in the DSRM cycle to accomplish the desired tasks. It involves the start of the internal design cycle, [50, 51] supported by methodologies identified from previous applications. In [52], the activity started with a modeling stage augmented with Service Experience Blueprint [53], which permits the design of the architecture of the OCMS based on the eHealth service [49, 54]. The main output of this stage is the design of the physical artifact for demonstration by the end-users in a real-world setting. To achieve this, the design and development of the OCMS. The process breaks the project into several stages involving continuous improvement and collaboration between the team and stakeholders/users. It collects feedback concurrently in a continuous manner from end-

users/stakeholders so that new features/components are implemented while the system is developed to meet its maximum value. The prototype of the artifact has been designed and built in a continuous cycle until it reached a certain stage, and is ready for the demonstration at stage 4. The third stage works well with stages 4 and 5, within the design cycle to allow the outputs of the next activities to inform the re-design of the artifact, in a perpetual cycle of continuous improvement. Therefore, no "final" output of this process is developed once, but only "versions" that can be further tested and evaluated are permitted.

Stage 4 – Demonstration

This stage allows the artifact to be tested, through to stage 5 and stage 6 of the design process. The main purpose of this process is to collect data that indicates a clear direction for evaluating the utility, usability, and overall purpose of the artifact. Usually, the acceptable methods are the ones that a health service researcher is familiar with. For instance, case studies to case-control studies, randomized control trials, or any other alternative research methods to gather the required information to enhance thorough evaluation of the artifact [55]. To assess the usability of the artifact, a sample of clinicians and patients were selected to perform and assess the functionalities of the artifact against the user requirement through the evaluation stage to ascertain compliance.

Stage 5 – Evaluation

The fifth stage compares the objectives of the artifact's demonstration at stage 4 to the actual observed results to ascertain whether the artifact addresses all the problems that originated from the cycle. The core output required is centered on the evaluation of the artifact, measured against the overall impact on the indicators identified in stage 2 and its effect in stage 4. The proposed Optical Clinic Management System is the main health outcomes assessed alongside the impact the actors such as Ophthalmic nurse, Optician, patient, Pharmacist the artifact had on medication adherence against other relevant outcomes like patient satisfaction, utility, and intention of the user to accept and proceed with its use have been assessed. In [56], the artifact usability considered were time to perform an activity with regards to the number of clicks needed to access certain information were determined as a catalyst to identify major bottlenecks.

It is worthy of note that the DSRM provides a continuous improvement cycle in the lifetime of the artifact. After the evaluation is completed the artifact may return to stage 3 for further inputs or have other functionalities added before allowing for a new demonstration at stage 4 to pave way for evaluation at stage 5, or otherwise proceed to communication at stage 6 if the artifact meets all the objectives at stage 4. However, any other serious outcomes identified may be allowed for further improvements in subsequent projects for a new DSRM cycle for future projects.

Moreover, stage 5, should also yield the desired results as a catalyst to contribute to the current state of knowledge, for the Design Science theoretical bases and for the specific scientific field where the artifact is intended for implementation.

By so doing, researchers and practitioners can provide these three types of outcomes expected from a completed DSRM cycle such as:

- Enhanced practice and utility for the artifacts' end-users
- Good design principles that contribute to the literature in a specific domain
- Prototypes from good research and design teams, contribute to the development of specific artifacts.

Stage 6 – Communication

The sixth stage allows the need to communicate the overall results to the intended research community. According to [57], the main aim at stage 6 is to communicate the problem and its importance about the artifact's utility as well as the novelty, the rigor of its design with its effectiveness to researchers and other relevant audience such as practitioners. It is very important to communicate the results through (journal papers, conference papers) or through planned workshops and seminars with potential end-users and other stakeholders. This is why this paper on 'A Model-Driven Optical Clinic Management Systems: Systematic Software Engineering Approach' is accepted for publication to allow researchers to know the importance of the Design Science Research Methodology in healthcare application development. The DSRM diagram is shown below with the stages.

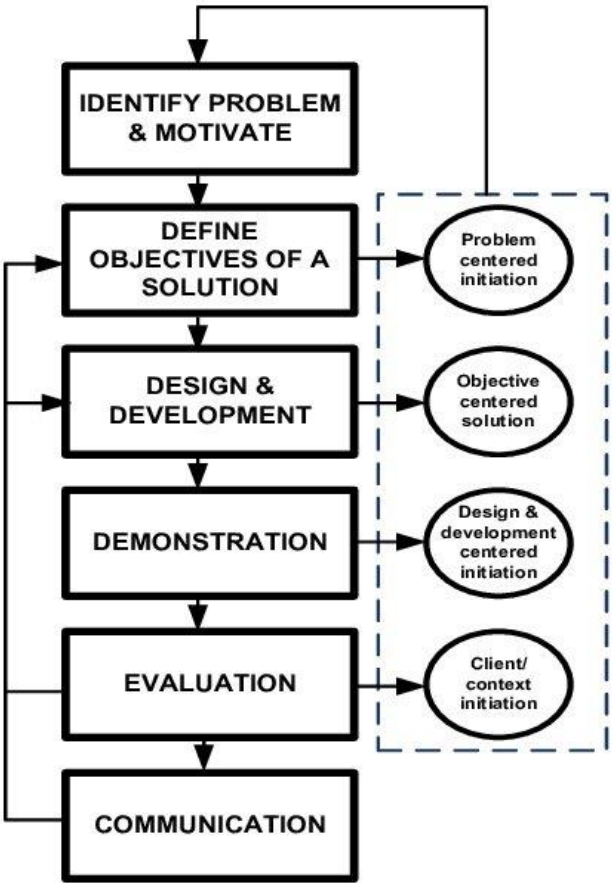

Figure 3. DSRM Model

4.1. Software Architecture for the proposed systems

The software architecture has been designed to facilitate and coordinate effective transactions between patients and care providers (i.e. Clinicians) to provide health care delivery.

The Clinical Information System Architecture consists of the following components:

- Data storage
- Data retrieval and display
- Patient care planning
- Clinical documentation support
- Quality control
- Clinical data entry capabilities

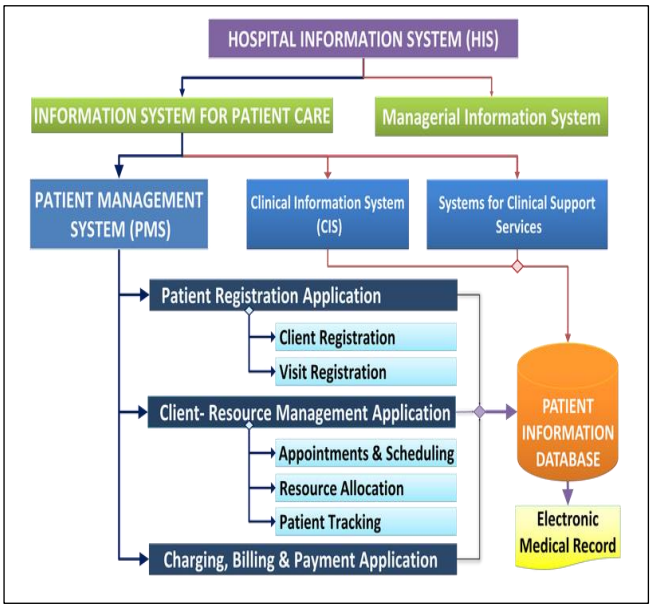

Figure 4. Patient Management Systems Architecture

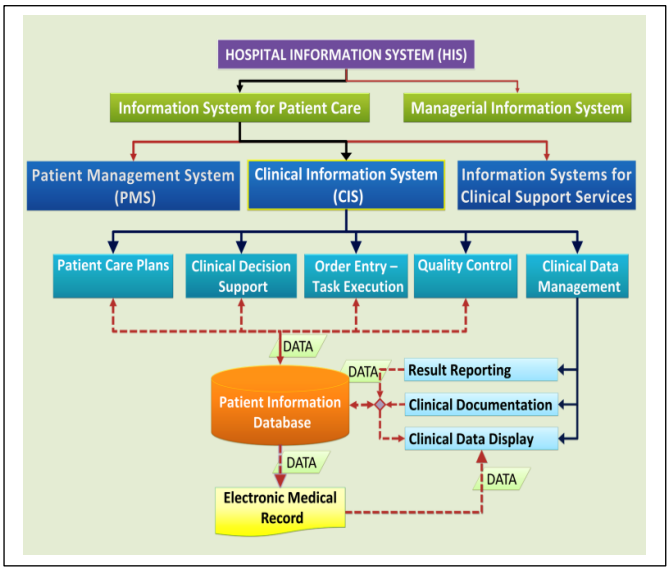

Figure 5. Information Systems Design

4.2 Software Functionalities

The software functionalities have been defined using the Unified Modeling Language (UML). UML refers to a well-defined standardized that supports researchers/developers to specify, visualize, construct, and document artifacts of a software system. UML models the artifacts to be scalable, secure, and robust during software execution. UML is an important element in object-oriented software development processes.

Use Case

This diagram depicts the functions of all the actors (i.e. Users of the Health Information Systems). The actors are used in the system to analyze, identify, clarify, and organize system requirements based on the role of each actor in the system.

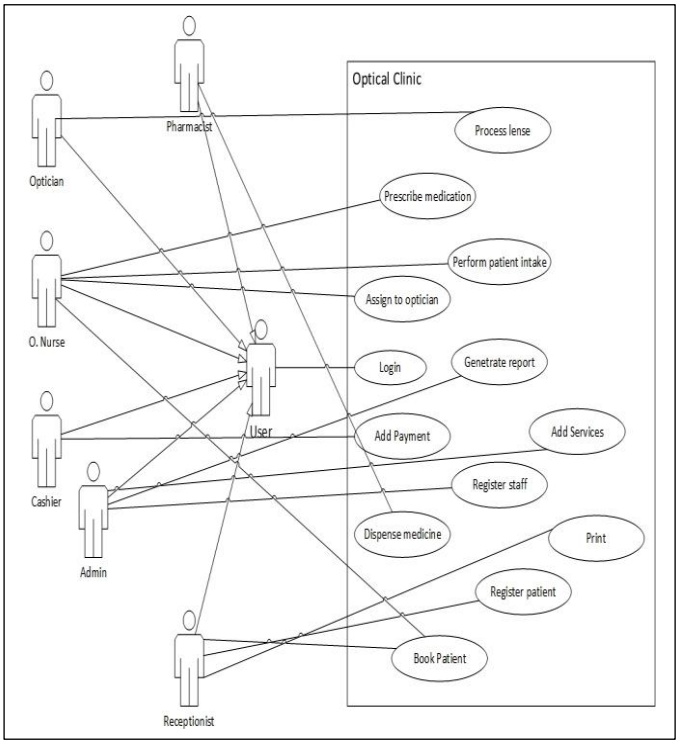

Figure 6. Use Case Diagram

Sequence Diagram

It describes the manner and the order in which the object interacts with the system. It helps to understand the requirements of the system to achieve the overall functions of the proposed systems. The sequence diagrams below are expected to:

- Interpret the use case behavior of the system
- Show the interaction of the object in the system
- Show the functionalities of the system

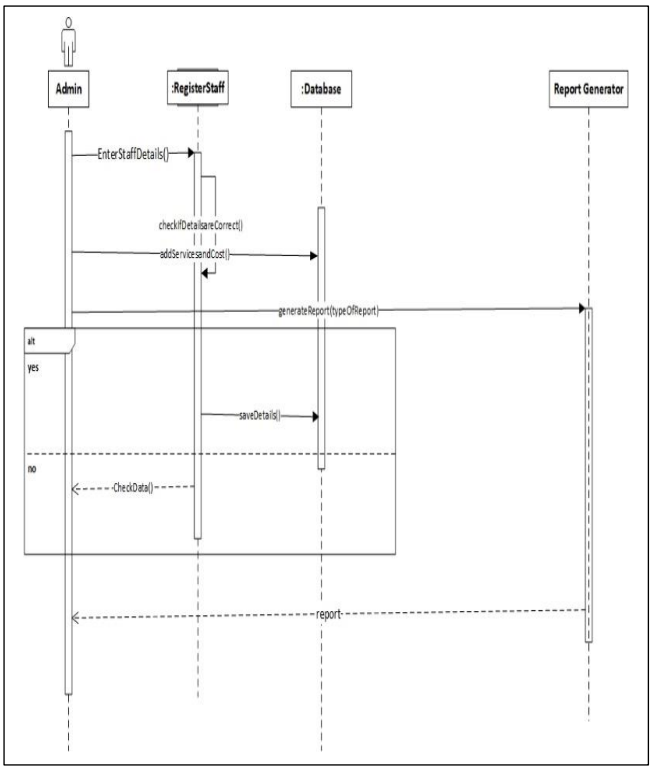

Figure 7. Administrator Sequence Diagram

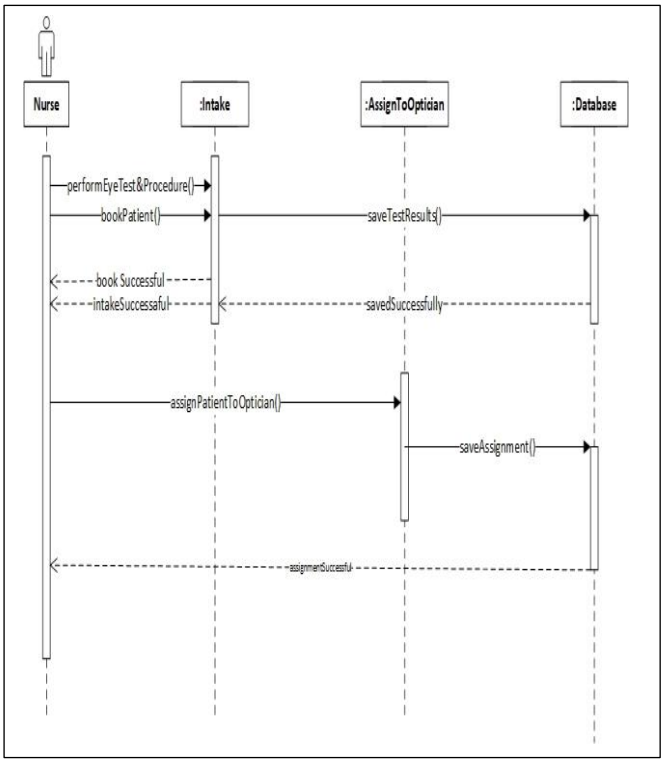

Figure 9. Nurse Sequence Diagram

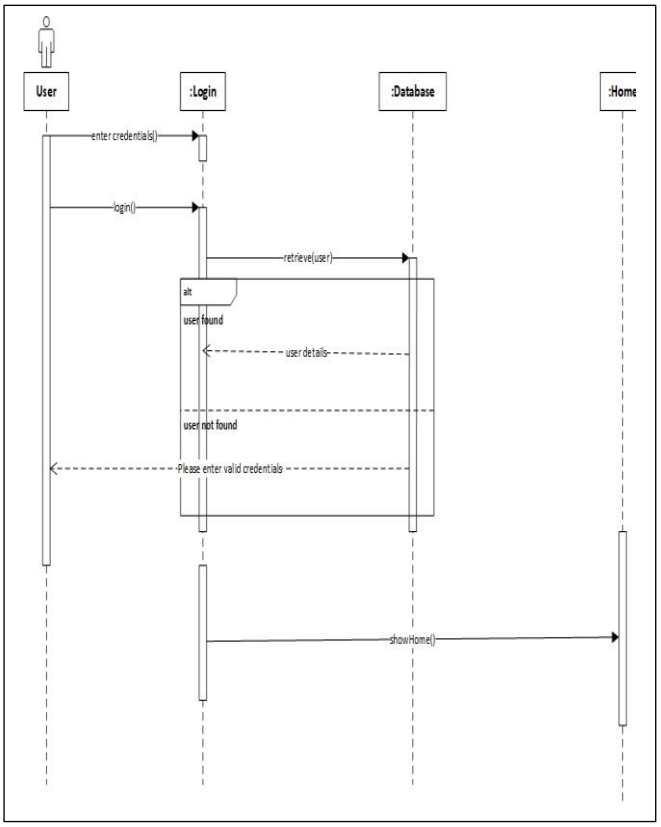

Figure 8. Login Sequence Diagram

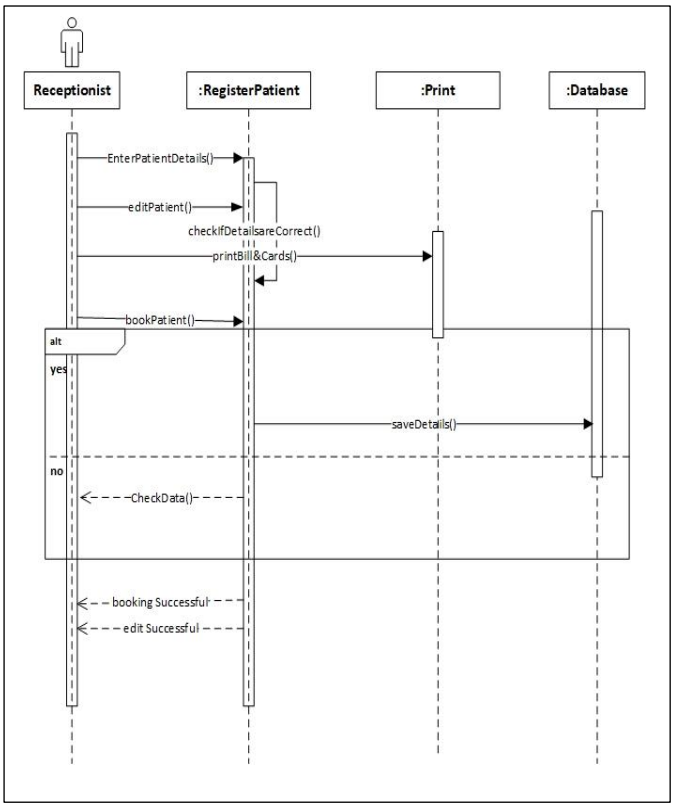

Figure 10. Receptionist Sequence Diagram

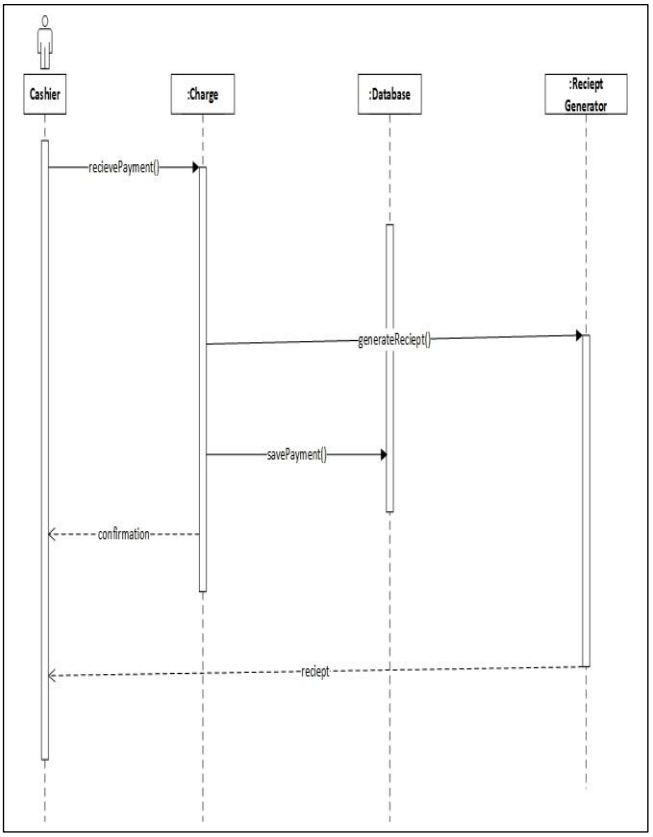

Figure 11. Cashier Sequence Diagram

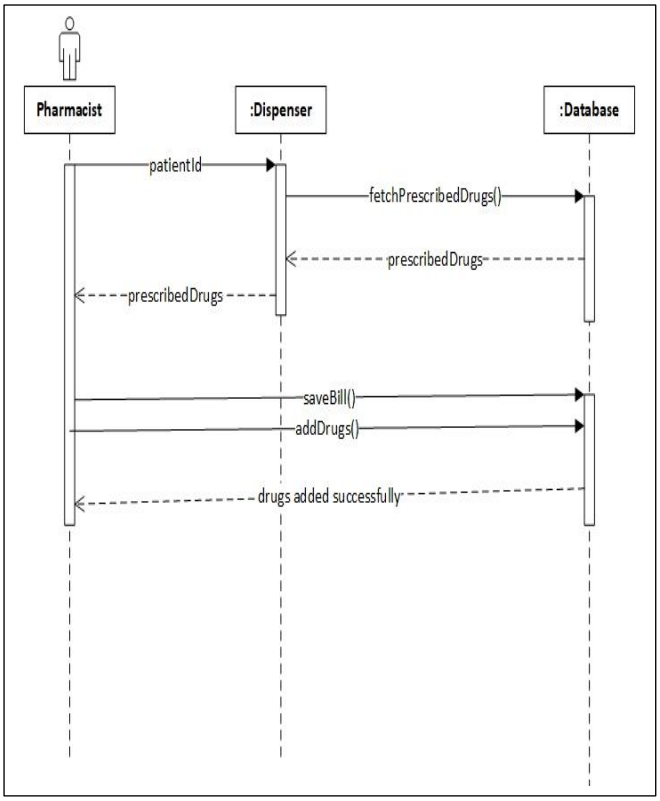

Figure 12. Pharmacist Sequence Diagram

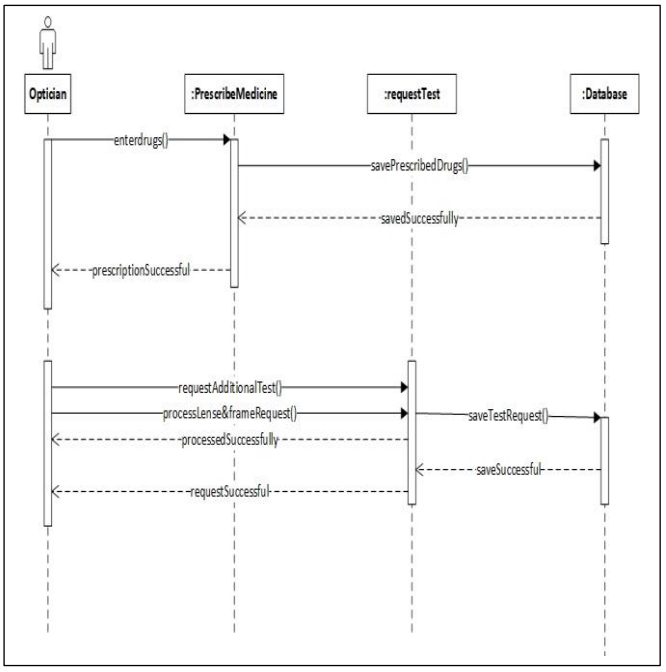

Figure 13. Optician Sequence Diagram

Data-Flow Diagram

A data flow diagram (DFD) illustrates how data is processed by the system about the interaction between the inputs and outputs. DFD focuses on the flow of information, regarding the source of the data, destination, and where it is finally stored. The main components of a DFD are:

- It changes the incoming data into an outgoing data flow
- Database stores are repositories of data in the system.
- It Labels the arrows with the name of the data flow movements.
- External entities are objects outside the system, in which the system communicates.
- External entities are sources and destinations of the system's inputs and outputs.

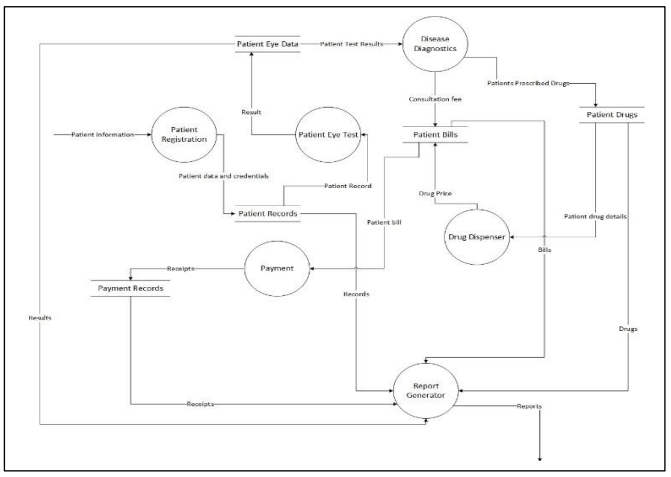

Figure 14. Data Flow Diagram

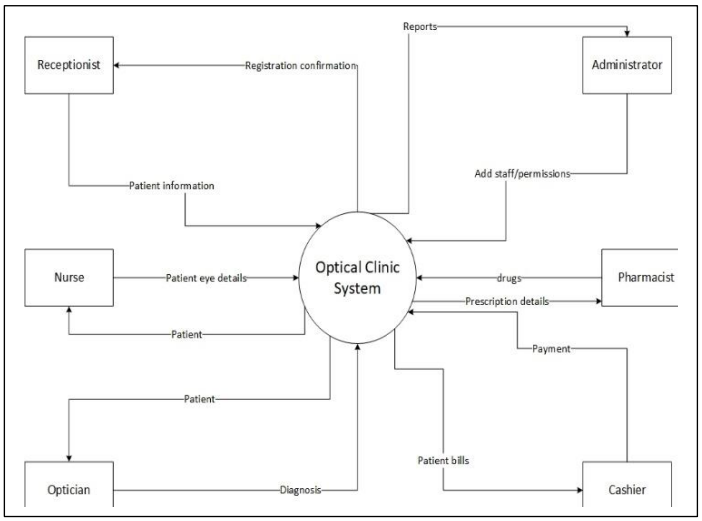

Figure 15. Context Diagram

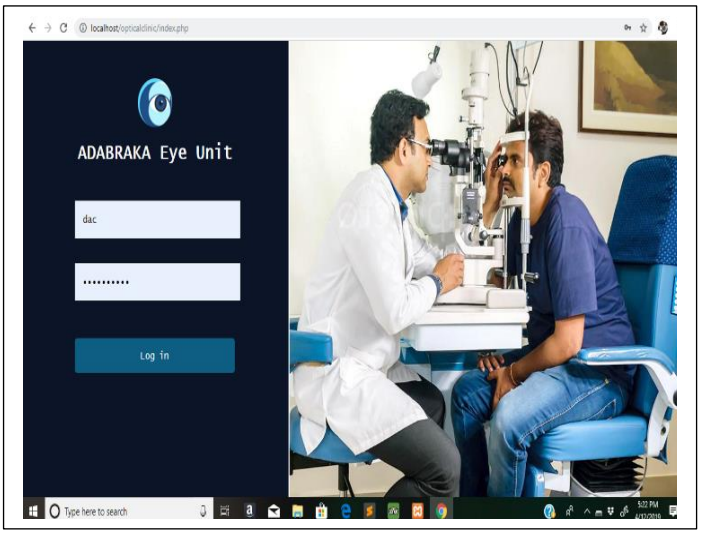

Figure 16. Login Interface

5. System Implementation

The Health Information Systems (HIS) was designed for a Polyclinic (i.e. Eye Clinic). The system is made up of components and interfaces. These interfaces demonstrate the functions of the HIS system. The following interfaces have been integrated into the DSRM artifact but for demonstration, only a few of the interfaces would be shown below to support the overall research approach for a better understanding of the research community and beyond.

- Login Interface
- Admin Home Interface
- Register Staff Interface
- Staff List and Permissions Interface
- Add New Service Interface
- Reception Search Interface
- Booking of Patient Appointment Interface
- Amendment of Personal Information Interface
- Assign New Patient Interface

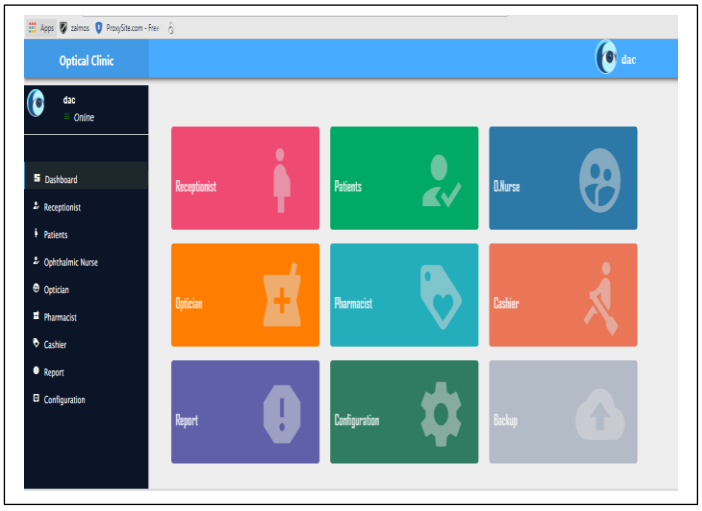

Figure 17. Admin Home Interface

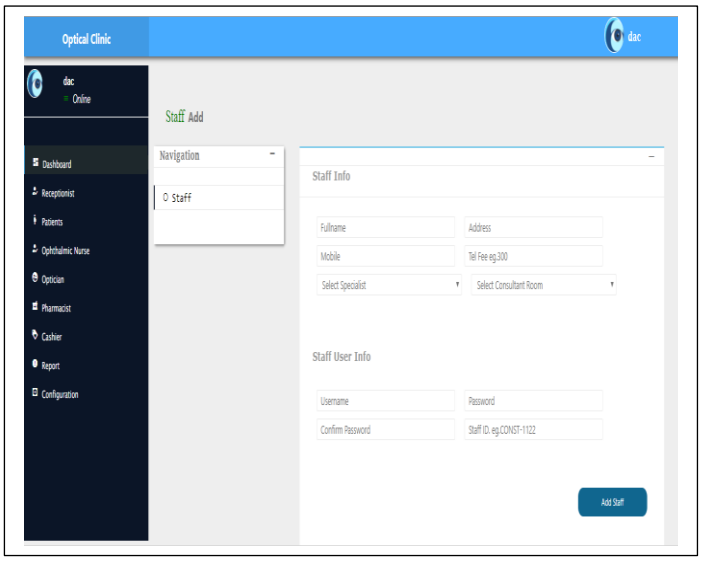

Figure 18. Staff Interface

5.1 System Implementation Interfaces

The systems interfaces explain the features and how each appears in the software functionalities. The interfaces consist of the following: Login, Admin Home, Register Staff, Staff List, and Permissions, Add New Service, Reception Search, Booking of Patient Appointment, Amendment of Personal Information, Assign New Patient, Patient Medical Records, Receptionist View Appointment, Patient Bill, Receptionist Patient Registration, Pharmacist, Pharmacist Patient List, Patient Prescription, Nurse-Patient Review, Patient Basic Review, Optician Patient List, Optician Patient Detail, Cashier Main, Cashier Search, Process Payment, and Patient Report.

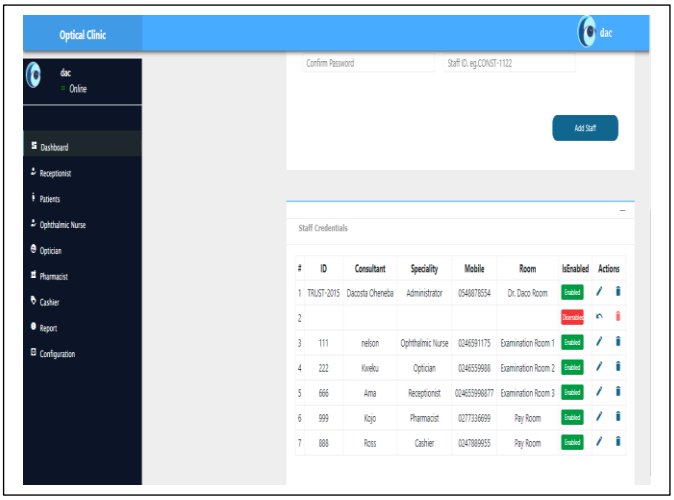

Figure 19. Staff Access Control Interface

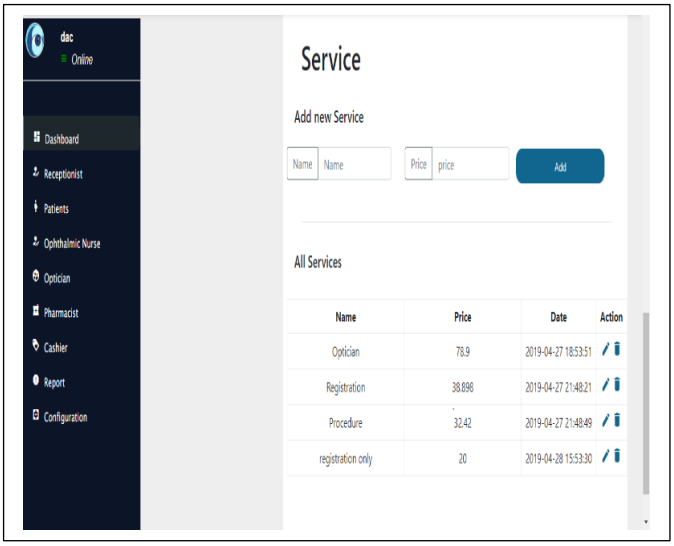

Figure 20. Add New Service Interface

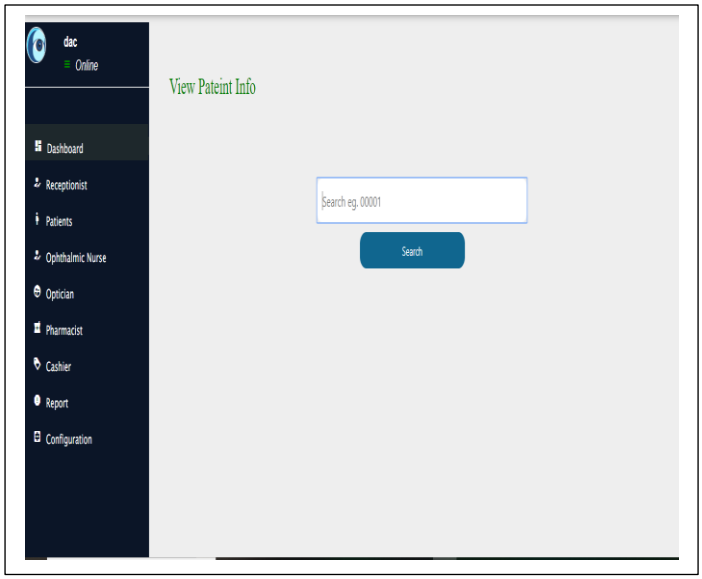

Figure 21. Receptionist Search Interface

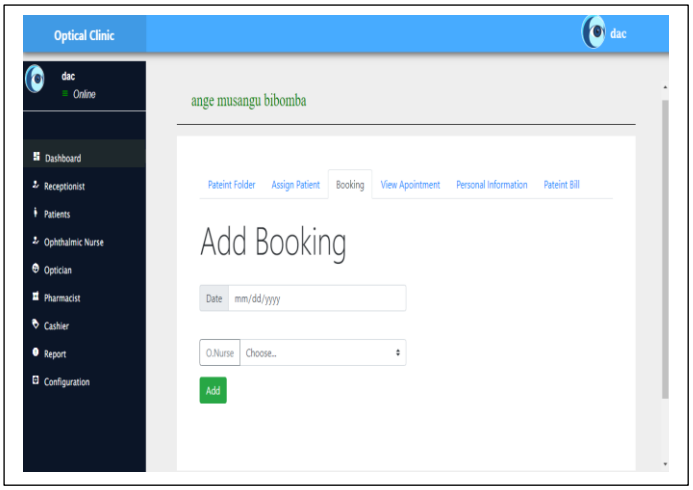

Figure 22. Appointment Interface

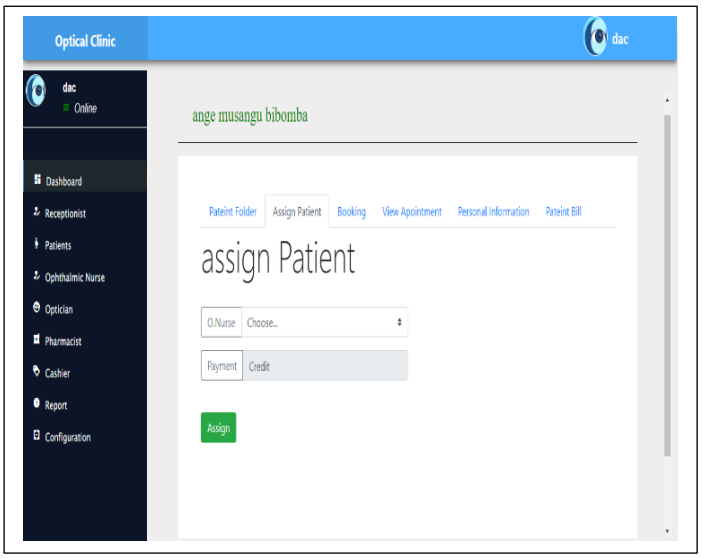

Figure 23. Assign New Patient Interface

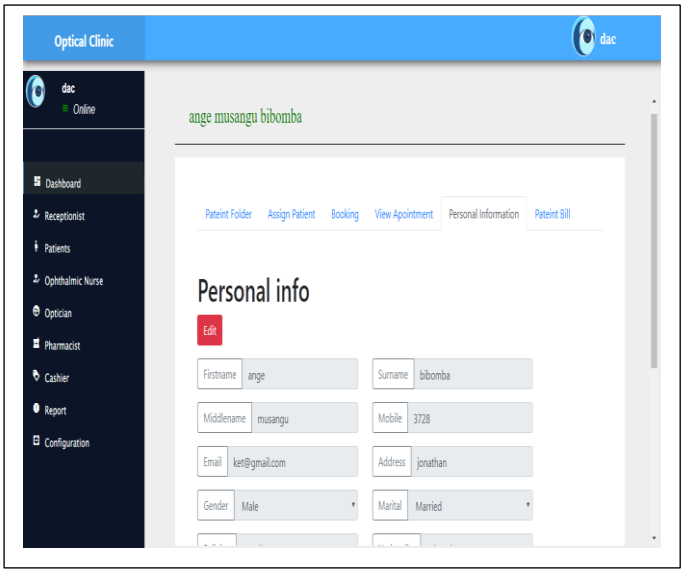

Figure 24. Amendment of Patient Information Interface

6. System Evaluation and Testing

System evaluation and testing have been performed to determine the accuracy and the correctness of the system. User acceptance has been done to test the system against user requirements. The system performance has received a 98 acceptance by the user. The response of the user has been outlined in the table below.

Table 1. Performance Evaluation Criterion

	The Evaluation Criterion		
Criterion	Strongly Agree (8-10)	Agree (5-7)	Disagree (1-3)
System Accuracy	√		
Ease of use	√		
System Validation	√		
Transparency		√	
Convenience	√		
Authentication	√		
Reliability	√		
Non-coercibility	√		
Integrity	√		
Certifiability	√		
Cost-effectiveness		√	
Uniqueness	√		
Auditability	√		
Secrecy	√		

After using the DSRM to implement the optical clinic management systems (OCMS), a software test plan (STP) has been developed to evaluate its objectives. The scope and the methodology need to be evaluated to ensure the system features meet full compliance after the comprehensive testing. To achieve this goal, we need to:

- Perform software testing to ensure that all the codes conform to all the requirements and documentation
- Provide a framework for unit and system testing.
- Allow the users of the systems to make an input to modify, when necessary until the system is accepted by the user for the full implementation.

A unit testing has been carried out on each software feature to ensure that all the individual components functions according to the specifications. Integration testing has been done to put all the individual components into a functional unit to ensure that each component works together to achieve system compliance toward the full implementation of the optical clinic management systems. The result from the software test plan has been remarkable when the system interfaces were subjected to rigorous tests according to the design specifications for implementation. The acceptance testing was given 98% when the system was deployed for full implementation

6.1. Discussion

The study explores the problem facing the clinic and the hospital administration and established major factors affecting safe and reliable health care delivery with a particular focus on the Eye clinics. It was discovered that the paper-based systems used to keep patients' medical diagnoses were found to be unreliable and therefore unsafe to be used as the basis to prescribe medication for patients. These paper folders used to keep patients' records were not usually available for the clinician to determine the patient medical history as the basis to suggest further diagnoses before medication. This made healthcare delivery unsafe for the patient and therefore call for a different methodology to change the existing system for the better. Further investigation was made to ascertain various systems used alongside their methodologies for health administration in different countries. This suggests a good number of computerized health information systems have been designed to be implemented in some countries. Some of these systems were problematic and unsuitable for use in the hospital. These systems were further improved and piloted with several modifications using different methodologies as a yardstick to make the hospital information systems safe and unreliable for use in hospital administration. Major advances in the development of health information systems were implemented in France, America, the United Kingdom, Switzerland, Japan, and other countries in Africa and beyond.

Most of the related work was confronted with the methodologies used for its implementation and this required an alternative methodology to implement the proposed system and thus, the need to use DSRM in this study with major modifications to improve future health information systems. The DSRM has been used to implement the proposed study. Hence, the research findings in this study coupled with the aftermath of the COVID-19 should guide African leaders to invest heavily in information technology applications to develop a robust health information system to improve health care delivery in Africa.

DSRM Implementation Studies

DSRM can be seen as a valid alternative methodology to design new applications from the design stages until the cycle of implementation is achieved. The DSRM stages provide a framework for a continuous improvement cycle which provides a roadmap for developers to implement projects rapidly. This technique allows developers to interacts with the environment in the project is intended to be used. DSRM provides adequate activities that inform specific cycles with rigor for the design

artifact for implementation. Developers using DSRM should provide adequate processes for the implementation of health service applications. The inherent rigor behind the DSRM cycle serves as a catalyst for sustainability; implementation and development to support new solutions in any field of healthcare applications. It should be noted that DSRM is not the only solution to implement projects but an alternative option that researchers and practitioners should consider besides other methodologies whenever they face pertinent challenges that need to be solved with flexibility and rigor in the design cycles that ensure a continuous revision until the artifact meets the users need.

DSRM as an alternative approach to research

Work done in this paper with DSRM offers theoretical DS research as a comprehensive methodology when looking for more practical step-by-step development of an artifact in a continuous cycle until the application is fully implemented. In [54], Several approaches were proposed in the context of an experience-based co-design [58], as well as the combined methods of health service participatory action research supported with action design research. Authors [59, 60], methodologies were based on a user-centered approach that allows effective coordination and continuous use of the cycle of a new service. DSRM is considered similar to experience-based design (EBD) with the engagement offered between developers, practitioners, professionals, and end-user of a service. This process provides the likelihood for continuous improvement while cementing the motivation to keep using the final artifact. Moreover, DSRM start with the first step prior to identifying a particular problem before bringing patients' expertise to the team. The design principles then followed by EBD where functionality means- how well does a artefact do its job; Engineering means-how safe, reliable and well-engineered it is; Aesthetics of experience mens -how does the whole interaction with the artifact/ service feel for the user and the EBD approach are all part of a DSRM process are common to any design methodology. However, immediately after the design or re-design is accomplished the use of DSRM means that the cycle of the design and redesign continues through the service in a continuous quality improvement cycle. Another significant difference between EBD and DSRM is the manner patients, professionals and developers interact. In EBD for example, instead of the group working together, they sometimes work separately on an issue before sitting together in smaller codesign teams. This approach eliminates certain information or some problem might be over-emphasized. Therefore, to aggregate patients' experience in a new design of a new artifact, the DSRM is very essential to provide a structured cycle of improvement which would eventually allow redesigning of an artifact before and during its implementation

6.2. Conclusion and Future work

The novelty of this paper provides a design framework of the Design Science Research Methodology and its comprehensive applications in health systems implementation with a specific focus on the eHealth community. Thus, DSRM outlines a logical and systematic methodology to formulate the process needed for developing new solutions in any health service community and what researchers and developers should consider as a valid alternative methodology with simplistic and rapid application development. The primary advantage of DSRM compared to other user-centered methodologies is that it offers a continuous improvement cycle within the lifetime of the application development in practice and health service research. Looking at the multidisciplinary nature of the healthcare industry in general, the coordination of relevant information from the stakeholders for developing health service solutions is a daunting and complex task to perform. To mitigate these complexities, DSRM provides guidelines to facilitate continuous information gathering from the relevant stakeholders from the external environment to strongly collaborate and reinforce the multidisciplinary methodology when developing applications in an integrated healthcare environment. The eHealth application for the proposed Optical Clinic Management Systems is a valid alternative methodology that should be considered when brainstorming innovative ways to design any eHealth application as well as study its implementation and sustainability of the healthcare industries with their expertise and experience in patient management is a critical and valuable partner for any researchers interested in developing and implementing applications supported by an interdisciplinary team of healthcare professionals.

The proposed DSRM has been used to implement efficient health care delivery in terms of proper up-to-date record keeping of patients to keep pace with previous medical records before diagnosis and medication is prescribed. This OCMS has eliminated the major challenges from paper-based record keeping to computer-based record-keeping to avoid doctors' inadvertent false diagnoses and medications without knowing the medical history of the patients due to misplaced folders/no medical history to inform doctors decisions.

DSRM for future research, in an eHealth setting (i.e. Optical Management System)**,** should consider the necessity to ensure sustainability in the continuous process to prioritize the core values of patient needs in a continuous manner.

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