International Journal of Scientific & Engineering Research
ISSN 2229-5518

MASTER THESIS

Monitoring Child Immunization System in Ethiopia Through Android Application

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In partial fulfilment for the degree of Master of Science in Information Technology

Advisor

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September 2016

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DECLARATION

I, the undersigned, declare that the thesis comprises my own work. Incompliance with internationally accepted practices, I have dually acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the university and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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International Journal of Scientific & Engineering Research
ISSN 2229-5518

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Abstract

This paper provides a new system model for delivering routine vaccination service in Ethiopia by incorporating the entire supporting infrastructure from vaccination suppliers to vaccination receivers. The model introduces ways of improving access, service quality, improving decision making for the administrative staff as well as CHWs' motivation to complete children's vaccination schedule. A system model design is provided together with graphical user interfaces for all agents in the new system. Vaccination service is not easily available and too often not reliable due to rural health facilities being far away and in poor condition with few health workers, and because of an unreliable vaccine supply system. So a geographically more centralized outreach program in direct connection to district vaccine stores could circumvent unreliable vaccine distribution channels and strengthen vaccine availability and quality. Community Health Workers, coordinated with help of ICT, can be used to encourage families to complete vaccination and inform them on upcoming vaccination outreach sessions. Qualitative analysis technique, with methods including structured, semi-structured, observations and literature studies was chosen to analyze and evaluate the current Ethiopian vaccination system. A DSRM in Design science was used to develop the proposed framework and ISO9241-110 usability metrics was used to evaluate the GUI of web based android mobile application.

Keywords: Vaccination service delivery model, immunization, ICT, CHW, DSRM, DVS, VTC, CVS, HIS,IS,EPI,IPM,outreach

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Acknowledgement

First of all, I would like to forward my gratefully and deepest thanks to the almighty God for his guidance, help, support and who added days to my age, Glory to God.

Next, my heartfelt thanks go to my research advisors Dr.Eric lozarita for his invaluable advice, patience and constructive criticisms of this work, Prof. Melquiades R. Hayag, and Dr Francis for their cooperation. Thirdly, I would like to thank all interviewees from EPI staffs of the health centers for their honesty, suggestion and cooperation by giving interview.

My special thanks goes to my Mom Amit belay, because of you I come here is far and I treasured the long journey with you .May you live long to see my next achievements!. My heartfelt & deepest gratitude also goes to my uncle Iasu Gorfu and my aunt Mulu Girmay for their financial support and encouragement. I wouldn't have finished this thesis without their support and love.

Finally, I would like to thank everyone at the College of computing, Department of Information technology, AKU, who has encouraged and assisted to start this post graduate program in MScIT.

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Abbreviations

- EPI - Extended Program for Immunization
- IPM-Immunization Program Monitoring
- CHW- Community Health Worker
- VTC- Vaccine Traffic Coordinator
- DVS- District Vaccine Store
- CVS- Central Vaccine Store
- GUI- Graphical User Interface
- ISO-international standard
- BCG-Bacillus Calmette Guerin vaccine
- OPV-Oral Polio Virus vaccine
- DPT-Diphtheria-Pertussis-Tetanus vaccine
- HepB-Hepathis B vaccine
- PCV-Pnemonuical Conjugate Vaccine
- ODK-Open Data Kit
- HIS-Hospital Information system
- Mhealth-Mobile health
- KDD-Knowledge Discover in Database
- ICT-information communication technology
- SMS-Short Message Service
- DSRM-Design Science Research Methodology
- UNEPI-united nation extended program for immunization
- HCMIS- Health Commodity Management Information System
- UC-Use Case
- AD-Activity Diagram
- BPMN-Business Process Modeling Notation

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International Journal of Scientific & Engineering Research
ISSN 2229-5518

Chapter 1

The Problem and its Setting

1.1 Introduction

Infant mortality has been inversely associated with the immunization given to children WHO, UNICEF, World Bank Report (2008), WHO estimated that 1.5 million deaths of children under the age of 5 were due to diseases that could have been prevented through vaccinations. Vaccination has been identified as the most effective method of reducing the burden of infectious diseases (Andre et al. 2008); the worldwide eradication of small pox is one of the benefits of vaccination and the restriction of the spread of diseases such as tetanus, measles, and polio from much of the world. The World Health Organization (2014) began an ambitious campaign for the period 2011-2020 that is aimed at delivering vaccines to all and to unleash vaccines' vast future potential. To eliminate the risk of outbreaks of vaccine preventable diseases, several governments and other institutions have instituted policies that require vaccination of all people and especially the children. A good example is a British law passed in 1853 that required everybody to be vaccinated against smallpox in Britain, with non-compliant people lived fines In the United States, contemporary vaccination policies require that all children receive common vaccinations before enrollment in public schools (Cole, J. P., & Swendiman, K. S,2014). However, these policies are resisted by anti vaccinationists, a civil society group who object to vaccination and other scientific interventions. Common objections are that vaccinations do not work, that compulsory vaccination represents excessive

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government intervention in personal matters, or that the vaccinations are not sufficiently safe **(**Wolfe & Sharp, 2004**)**.

Parents and guardians are concerned about the safety and health of their children. Therefore they take great precautions to protect their children from being sick; it is every parent's wish for their children to be free of any sickness. To prevent children from getting sick, vaccination is one of the best options. However there are schedules to be adhered to for vaccination to be effective and the schedules vary from adult to children (Lance, E. R, 2005)

In the case of Ethiopia, The national Immunization program in Ethiopia was launched in 1980, with measurable achievement in terms of reducing morbidity and mortality associated with vaccine preventable diseases (VPDs) since its launch. At the national level, the maternal and child health directorate of the Ministry of Health (MOH) coordinates the program. The EPI case team is among the six case teams of the MCHN directorate, which is structured in order to harmonize and coordinate implementation of various immunization related initiatives. The EPI case team closely works with Policy and Planning Directorate in the MOH, Pharmaceutical Fund and Supply Agency, Ethiopian Public Health Institute, Food, Medicine, and Health Care Administration and Control Authority as well as other local and international partners. Administrative coverage in Ethiopia showed significant improvement from as low as 42% in the 1990s to more than 88% in 2013.The 2012 national immunization coverage survey showed a lower than reported coverage with wide regional variation and dropout

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rate. This decline in performance was also reported in the administrative coverage for the same years. **(EPI** Status in Ethiopia, *2011 & 2012)*

Through studying the current situation of the vaccination service in Ethiopia, the challenges of performing a quality of vaccination service in the low resources settings of Ethiopia are identified: the bad traffic condition, lack of supplements, heavy workload, and low level of data transaction. These problems cause the ineffective vaccination performance in current Ethiopia.

1.2. Statement of the problem

Child vaccination has begun long time ago in Ethiopia. But the coverage differs from area to area and especially children found in remote rural areas are the most victims. The application of information communication technology must be vital in Health Data collection components of public health systems. Decision makers, policy makers, and medical service providers need accurate and timely data in order to improve the quality of health services. So the intervention of ICT through the rapid development of mobile technology can narrow the information gap in this sector in Ethiopia.

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Hence, the aim of this study was to answer the following two research questions.

1. Does the determination of the frequent pattern vaccine usage among different vaccine types generate by the Ethiopia IPM prototype bring significant improvement in planning and preparation for the administrative staff?

2. Can the Ethiopia IPM prototype of this study also be used by the health workers administering vaccination in the actual community in updating real-time

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data using their android phone application?

1.3. Objectives

1.3.1. General objective

The objective of this study is to introduce the application of Android smart phones to improve child vaccination service through web based mobile systems for EPI sector in Ethiopia. In this case, a shift of the existing paradigm of monitoring child vaccination in Ethiopia will occur from manual to mobile system application. Although good progress has been achieved in expanding immunization of children in Ethiopia, disparities exist across different provinces. Information gaps both from the service supply and demand sides hinder timely vaccination of children in rural areas. The rapid development of mobile health technology provides unprecedented opportunities for improving health services and reaching underserved populations. However, there is a lack of literature that rigorously evaluates the impact of mobile health technology interventions on immunization coverage as well as the usability and of smart phone applications (apps). Through studying the related designs, the strengths of the mobile web-based system solution are stated: brings mobility and flexibility of usage; enhances the remote communication and data transaction among users; low level of data input error occurrence and quality data storage.

1.3.2 Specific objectives

This study performed the following listed approaches to achieve its main objectives.

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i. Reviewing mobile based child vaccinations related literatures to understand various related frameworks
ii. Data collections related to the current ICT infrastructure and usage strategy and efficiency in Ethiopian EPI health sectors.
iii. examining the potential benefits of web based android mobile systems and cloud hosting
iv. designing a web based android mobile framework and developing a prototype(GUI) for child immunization in Ethiopia
v. Evaluating the system based on ISO9421 usability standard

1.4. Significance of the study

1.4.1. To health workers

This study aims to help health professionals (CHW) in registering vaccinated children, DVS and VTC in managing their vaccine stocks and for the administrative staff for preparation of vaccines and planning of vaccination schedules, using their android phones

1.4.2. To parents/guardians

Parents or guardians are the most beneficial indirectly through their CHW to get a reliable vaccination service for their children

1.4.3. To future researchers

Other researchers can use this study as a base to improve and monitor child vaccination services using Android smart phones and add more features that make it more suitable according the environment they are going to apply it in.

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1.5. Scope

This study delivers the process of using web based Android mobile system that can be host in cloud server that improves and monitors routine child vaccination service that are provided under EPI for Ethiopian's children under age of 5 years. This can also simplify the effort of Health professionals .The system sends remainders and notifications to mobile application that can help parents to be informed about the vaccination schedules and related announcements through their CHWs. CHWs and nurses can update vaccination information using their android phones and VTCs and DVS also manage and track vaccines. The system generates inferences and conclusions for the health professionals that can help to predict immunization frequencies and vaccine demands and to prepare and plan for proper upcoming vaccinations especially for the managerial staff in the health centers. This in turn can help to decrease child mortality rate by sustainable child health in Ethiopia.

1.5.1. Limitation

The design of the child immunization service system only considers the EPI organizational structure of Ethiopia, economical and geographical distribution of Ethiopian population and for children getting vaccination less than 5 years old. the mobile IPM is limited to run on Android phones and chrome browser.

1.5.2. Delimitation

For the purpose of data collection this study is delimited to the child vaccination service in Tigray region. The evaluation of the system depends only

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on ISO 9241 usability standard. And the language used for the prototype is only limited to English

1.5.3. Deliverables: Artifacts

The prototype of the study will provide three artefacts to be delivered regarding the Ethiopian child vaccination service (EPI). These are:

1. A Stakeholder system model: for identifying the necessary stakeholders
2. Process models and organizational structure model; for providing a framework for innovative comprehensive vaccination service delivery
3. Graphical User Interfaces; for mobile applications for involved stakeholders

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Chapter 2

Review of Related Literature

2.1 EPI Target Disease and Vaccines

The EPI has six most common vaccine preventable diseases which greatly affects the children. These include tuberculosis, measles, poliomyelitis, whooping cough, diphtheria and tetanus. According to the endemicity and resource of the country other disease were also added to the EPI program. These include yellow fever and hepatitis. Currently, the EPI administers eight vaccines: BCG (tuberculosis vaccine), oral polio vaccine (OPV), diphtheria-Pertussis-tetanus (DPT) vaccine, hepatitis B (HepB) vaccine, measles vaccine, yellow fever vaccine, and homophiles influenza type b and tetanus toxic (TT) vaccines . In Ethiopia, currently the EPI program has eight vaccine preventable diseases. These are HepB and Hib in addition to the six known EPI program disease (Belachew Etana, 2011)

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2.2. Addressing Information Gaps in Developing Countries

For computing to truly address the information gaps in developing regions, information services must be composed by non-programmers, deployed by resource-constrained organizations, used by minimally-trained users, and remain robust despite intermittent power and connectivity. To address these challenges, we developed Open Data Kit (ODK), a modular, extensible, and open-source suite of tools designed to empower users to build information services for developing regions (Carl Hartung, Yaw Anokwa, Waylon Brunette, Adam Lerer, Clint Tseng, Gaetano Borriello, 2010)

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The recent years have seen an increasing focus on HIS as important for effective and efficient health systems, especially in developing countries. The international community has also emphasized the need for better HIS to track the MDGs, and several initiatives have been set up to tackle the challenge. In 2005, the Health Metrics Network was created as "the first global partnership dedicated to strengthening national health information systems" (HMN 2005). At the same time, many of the challenges countries face with their HIS come from fragmented systems propagated by the diverse international organizations supporting them, leading HMN to become a strong advocate for the building of national HIS integrating data from the various health services and health programs as well as from various donor initiatives. Following the HMN initiative, many developing countries are in the process of strengthening and revamping their national HIS. On the ground, however, HIS development in developing countries has proved difficult due to organisational complexity, fragmented and uncoordinated organizational structures due to similarly uncoordinated donor initiatives all maintaining their own HIS, unrealistic ambitions leading to a "design-reality gap" and more generally, due to the problem of sustainability (Kimaro and Nhampossa, 2005)

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2.3. Advantages of MHealth Systems in Healthcare

MHealth (also written as m-health or mobile health) is a term used for the practice of medicine and public health, supported by mobile devices. The term is most commonly used in reference to using mobile communication devices, such as mobile phones, tablet computers and PDAs, for health services and information(Cipresso, P., Serino, S., Villani, D., et al. ,2012)

In mHealth, users have the possibility to remotely participate in the health care operation; remote users are normally valuable contributors for collecting and transferring data regarding diseases and health care concern. Through the improvement of the mobile technology, mHealth has a great potential to improve the health communication to achieve healthier lifestyles, and enhance healthcare quality by improving access to medical and health information. Remote operation and communication could increase the accessibility of the vaccination service. In comparison with the current mode, where a large number of clients go unplanned to specific health care points of limited capacity; mHealth could let health care workers perform outreach service, remotely performing vaccination service (RUI XUE, 2012)

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2.4. Medical Data Mining Applications and its Uses

Health care data are primarily generated from the delivery of patient care. Therefore, medical data mining involves both privacy issues and legal issues. Data mining in health care is essential because nature of medical data is incomplete as different person suffering from same disease may not undergo same kind of test and diagnostic procedure because of the factors like age, family history, work environment etc. Too many diseases are now available for decision making and there is increased demand for health care services like creating disease awareness. The onset of disease has to be detected in a cost-effective, non-invasive and painless way. The quality of

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medical data is inferior because of missing values (Ichise, R., and Numao Learning, M., 2001) and Hospital Information System (HIS) or database designed for financial or billing purpose. Today, health care industry generates large amounts of data about patients, hospital resources, diagnosis of diseases, electronic patient records, medical devices etc. This large amount of data is to be processed for knowledge extraction that enables support for cost-savings and decision making. Data mining introduces a set of methods that can be applied to this pre-processed data to discover hidden patterns that provide healthcare professionals an additional source of knowledge for making clinical and administrative decisions. But how ever at last the decision rests with health care professionals (Gayathri. P, Dr. N. Jaisankar, 2015)

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2.4.1. Data Mining in KDD process

Data mining in KDD process can be defined as a set of applications of specific algorithms for pattern extraction from pre-processed dataset (Fayyad, U., Piatetsky-Shapiro, G., and Smyth, P.,1996). The successful data mining application provides useful health care knowledge that can be used to support clinical decisions like process of diagnosis, prognosis prediction and therapy. It can also support administrative decision making like health care coverage, staffing estimates and hospital resource usage. Researchers believe data mining as one of the step in KDD process Knowledge discovery in databases (KDD) is organized into data cleaning, data integration, data selection, data transformation, data mining, pattern evaluation and knowledge presentation

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(Illhoi Yoo, Patricia Alafaireet, Miroslav Marinov, Keila Pena-Hernandez, Rajitha Gopidi, Jia-Fu Chang, Lei Hua 2011).

2.5. Advantages of Cloud Hosting Service for Web Based Applications

A Private Cloud, or internal cloud, is used when the cloud infrastructure, proprietary network or data centre, is operated solely for company or government departments who prefer to keep their data in a more controlled and secure environment, and serves customers within the business fire-wall (B. Furht, 2010). The private cloud allows organizations to outsource the management of their IT infrastructure while retaining tighter control over the location and management of the resources. The price to pay for this is that the costs are likely to be higher because there is less potential for economy of scale, and resilience may be lower because of the limit on service resources available (Larry Ryan, 2012).The difference between a private cloud and a public cloud is that in a private cloud-based service, data and processes are managed within the organization without the restrictions of network bandwidth, security exposures and legal requirements that using public cloud services might entail (VenkateRao J. et.al. 2011). Isolation is one of the key techniques for ensuring security and, while in the public cloud applications and data exist in a shared environment, the private cloud offers greater isolation by dedicating resources to a particular customer.

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2.6. Related Work

Many ICT interventions have been introduced to address health challenges including those of rural communities. Rohit and Borriello (2010) designed a mobile phone based system FoneAstra (2010) for remote monitoring of the temperature and location of vaccines. The system is equipped with a temperature sensor and integrated with a vaccine cold-box that is used to store vaccines in a temperature regulated environment. FoneAstra monitors on a regular basis the temperature of the cold-box, aggregating the readings over time. It uses a mobile phone, to which it is coupled, to send periodic SMS messages with routine temperature reports or immediate alerts if it detects temperature above the threshold. Additionally, it enables location-tracking of vaccines on transit, based on the mobile phone's Wi-Fi.

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Zhang, Wang, Liu, and Hou (2006) designed a system for fall detection using off-the-shelf electronic devices to detect the fall. They used a smart phone with an embedded tri-axial acceleration sensor. Information from the sensor is evaluated with a decision tree model to determine whether a fall has taken place. If a fall is recorded, a notification is raised to require the user's response. If the user's body is hurt and unable to respond, an alert via SMS is sent to a guardian. Therefore, the fallen individual can be cared for immediately.

Anas, Alaa, Chulawadee, and Adib (2011) designed a web-based system to ensure pregnant mothers are notified regarding their pregnancy progress via SMS message.

Osama (2012) developed a mobile phone SMS-based system for diabetes self-management. The system allows the patient to be connected to his or her physician and send insulin measurements, insulin intake, and other vital data, making continuous real time health monitoring possible. The physician also sends motivational SMSs or reminders to the patients to do some exercises and attend health care appointments.

United Nations Foundation (2010) developed a Rural Extended Services and Care for Ultimate Emergency Relief (RESCUER) application that combined use of two way radios with ambulances and bicycles to adequately respond to obstetric emergencies, which resulted in a 50% reduction in mortality rates of women in Ethiopia. Sherwani et al. (2011) developed a speech-based health information access system called Health Line for low literate community health workers in the Sindh Province of Pakistan. The community health workers were unable to read or did with a lot of difficulty. The system uses an instructor to guide the health workers in the field. Saurav Gupta, D. K. Jain(2015) developed mobile based vaccination service for low resource settings of India.

From the litratures reviewed, the researcher concludes that mobile applications can best address the information gaps that is happening in EPI health centers in Ethiopia too. The development of the prototype is followed by hosting the application program in cloud server and centrally administrating the immunization data.

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Chapter 3

Research Methodology

The main aim of this chapter was to design the methodology to carry out the study, which included:

- Determining design strategy for the study including a conceptual framework, defining the deliverables, and articulating the methodology.
- The requirements to this study were: developing the knowledge base about the state of the problem and the importance of its solution to define the problem
- Developing the knowledge base about the state of the problem and current solutions to identify the requirements; The knowledge of theory that brought to bear in a solution to design the proposed web based mobile IPM framework and
- Developing evaluation tool to measure the performance of the resulting framework. Thus the tools used to develop the knowledge base to the study requirements were data collection using interview and review of relevant literature including similar studies.

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3.1. Research design

The research method used in this study is based on the design science paradigm in IS research (Nunamaker et al., 1990; Walls et al., 1992; Hevner et al., 2004).followed by qualitative analysis technique. The design science research is a prescription-driven and problem-solving paradigm that seeks to create viable artifacts in the form of a construct, a model, a method, or an instantiation (design artifacts) which provide solutions for management problems (Hevner et al., 2004; Gregor and Jones, 2007; van Aken, 2004). a researcher constructs an IT meta-artifact (Iivari 2003) as a general solution concept (van Aken 2004) possibly to be instantiated (March and Smith 1995) into a specific solution concept (van Aken 2004) or a concrete IT artifact (application) to be and used in a specific context. The study focused to use a consensus building approach to produce the framework based on well-accepted elements of the DSRM process, which contains four phases discussed below (Peffers et al., 2007).

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3.1.1. Problem identification and motivation

This phase includes defining the knowledge of the state of the problem and the importance of its solution. Researcher begun by defining the specific research problem and justify the value of a solution by conducting interview and rigorous analysis of literatures on web based mobile IPM in the EPI sector of health centers in Ethiopia. Since based on the problem definition the researchers atomize the problem conceptually to capture its complexity for developing the proposed mobile IPM framework that can

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effectively provide a solution. The value of the solution also justified to motivate the researcher and the audience of the research to pursue the solution and to accept the results and to understand the reasoning associated with the researcher's understanding of the problem. Accordingly the researcher identified stakeholders of the EPI process are follows.

3.1.2. Define the objectives for a solution

This phase aims at to identify or drive the requirements for developing the proposed mobile IPM framework from knowledge of the state of problems and current solutions. The researchers infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible to align with the EPI requirements. The qualitative objectives are used, which described how a proposed framework is expected to support solutions to problems not hitherto addressed. The researcher used the conceptual framework to inferred objectives rationally from the problem specification. In order to develop the study conceptual framework, researchers started with the literature review to gather relevant requirements and aspects of existing mobile IPM frameworks.

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3.1.3. Design and development

Conceptually, a design research artifact can be any designed object (models, frameworks or instantiations) in which a research contribution is embedded in the design. This phase includes determining the artifact's desired functionality and its architecture and then creating the actual artifact. The knowledge of theory that can be brought to bear in a

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solution is required to move from objective of a solution to design and development of the proposed framework. Based on the required knowledge of a solution identified in phase one and two with the literature review and expert interviews analysis to develop the proposed framework: particular processes are selected; the type of deployment model is decided; strategies for storing data with different security requirements and complexities are developed; After determining the framework functionality and its architecture, the proposed web based mobile IPM framework for EPIs with the implementation plan to deploy application on the cloud could be developed.

3.1.4. Evaluation

This phase aims to Observe and measure how well the framework supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the framework in the demonstration. It requires knowledge of relevant metrics and analysis techniques. Depending on the nature of the problem venue and the artifact, this study took the qualitative evaluation analysis techniques which include: a comparison of the proposed framework functionality with the solution objectives from activity two above, objective qualitative performance measures, based on ISO9421 usability standard are measured. Conceptually, such evaluation could include any appropriate empirical evidence or logical proof. At the end of this activity the researchers can decide whether to iterate back to step three to try to improve the effectiveness of

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the artifact or to continue on to communication and leave further improvement to subsequent projects. The nature of the research venue may dictate whether such iteration is feasible or not.

3.2. The Existing system of EPI in Ethiopia

3.2.1 Interview and observation in Tigray region

The Ethiopia health care system is characterized by a decentralized management system and different health care levels. There are six, plus one levels (top down)

- National Referral Hospitals,
- Regional Referral Hospitals,
- General Hospitals,
- Health Centre and
- Health posts – these are actually Community Health Workers/Village Health Teams. In general, the lower the level the more rural the location of the facility is and the less service is being offered.

Interviews were conducted between April 15 and April 30, 2016 and responses were obtained from all selected informants selected based on their job authority in EPI from health centers (see appendix A for interview questions).The objectives and concepts of the study were briefly explained for interviewees. Each informant was interviewed individually by the researcher. During the two weeks in , people were interviewed at health centers, health posts ,. This

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included nurses, CHWs .health offficers.VTC. DVS.

Through interviewing the health care workers and observing their work, many aspects about the current Ethiopia EPI service which we found through literature review were validated. For instance, there were no centralized client data exist, the up level management department did not have accurate records about the current vaccination performance situation. A Health officer in the Adwa health center said: “there is a book (UNEPI vaccine and the injection material control book) records each family’s situation and children’s vaccination status, but it never viewed by upper level administrations .they require only a numerical report.” The researcher conducted semi structured interviews and observations with 60 health workers that are selected through purposive sampling in this visit. They were all educated and had the essential ability to read and write, however, their experience of using smart phones in some of them is limited. As a result of the researcher analyzed that a simple system interface design is essential for the mobile Ethiopia IPM. The interviews with people around health centers especially provided input regarding details of tasks and documents they used for inventory tracking , child registration and vaccine details (which provided input to the GUI).

Secondary source of data are also gained from the health centers and considered in this study. The researcher took comprehensive EPI Guide for health workers and UNICEF vaccine injection material control book as guide to develop the artifacts of the system and data input for the Ethiopia IPM mobile system.

3.2.2. Outreach program

A characteristic of vaccines, setting it apart from many other medicines in health care, is that they need to be stored in certain temperatures to remain functional usually between 2°C and 8°C (CDC, C. for D.C. and P. 2003). This presents a challenge, both in terms of distribution, as well as stationary storage, since the chain of a properly regulated storage temperature for vaccines must not be broken. The NURSE prepares the vaccine without accurate planning quantity; she does not even know how many clients (children) will attend the vaccination session. Without any coordination with the NURSE, the CHW writes the client's vaccination registration information on a piece of paper. Later on, he has to explain to the supervisor what he wrote, thus furthering the inefficiency of his role. The central warehouse delivers the amount of material stock confidentially and without plan. This results in an exhaustion of certain health centers' resources and stock, while also causing a surplus in other centers, where the supplies are not necessarily needed. In conclusion, the decentralized system is not suitable in managing the vaccination.

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3.2.3 .Logistics (The power of real time data)

Matching supply and demand requires knowing the levels of supply and demand in real time. It's simple to understand, but a lot more complicated to achieve. The solution though can be easily stated: data visibility. If people managing the supply chain know what demand is and what their supplies are, at any moment, at each level in the system, they can begin to effectively match

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supply and demand. However, achieving data visibility remains a major challenge.

In Ethiopia, the Pharmaceuticals Fund and Supply Agency (PFSA) maintain the vaccine supply chain and is taking significant steps to ensure real time data and information on supply and demand can be available at any time. Working with the USAID | DELIVER PROJECT and the Bill & Melinda Gates Foundation-funded Vaccine Supply Chain Transition project implemented by John Snow Inc. (JSI), PFSA now has visibility for vaccine supply data at central and regional hub levels and can use this information to deliver vaccines to district level**.** The Health Commodity Management Information System (HCMIS), currently manages the supply chain for essential medicines across the country, and a new module within the system is being used to provide ready data on the vaccine stock on hand, expiration dates, and other key metrics. The HCMIS Vaccine Management platform, which is being rolled out across the country, has a customizable dashboard that puts real time supply chain data in the hands of decision makers who need it most.

Currently, the vaccine management features of the HCMIS have been introduced at the central level and at three of the PFSA Hubs in Bahir Dar, Mekelle, and Jimma. And deployment is currently in progress to the more than 61 woredas (districts) in the Tigray and Afar regions served by Mekelle Hub. Based on the results there, the transition team will determine if and how to roll out the system to other woredas around the country**.** (Paul Dowling, al shiferaw, 2015).

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But this system doesn't consider the low ICT infrastructure of Ethiopia and is only limited to three regions yet. The study concept is mainly applicable here.

3.3. Analysis of the Existing system

Through studying the current situation of the vaccination service in Ethiopia, the challenges of performing a quality of vaccination service in the low resources settings of Ethiopia are identified: the bad traffic condition, lack of supplements, heavy workload, and low level of data transaction. These problems cause the ineffective vaccination performance in current Ethiopia. The table below summaries the existing system of EPI

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	Existing system
System Mode	Decentralized
Amount of Professional Staff	Lack
Work condition	Not suitable
Facility	Disrepair
Medicine (vaccine)	Unbalanced
Data transaction	Invisible
Performance	Inefficient

Table 1.existing system of EPI in Ethiopia

3.4 The Expected outcomes of introducing IPM in Ethiopia

After reviewing related literatures and conducting observations and interviewees in the EPI sector in Tigray, the researcher made a design solution

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followed by developing mobile IPM GUI for Ethiopia that considers the EPI health organization structure, ICT infrastructure and outreach program immunization issues that can be as an answer to the overall research questions. Its implemented design features are supported and argued for both in relation to other ISO92411-110 standards and to the problems that was designed to address in terms of the local situation of vaccination service in the low resource settings of Ethiopia.

3.5. Design of artifacts

3.5.1. Stakeholders' roles and responsibilities

There are four stakeholders in the system:

- VTC (vaccination traffic coordinator)
- DVS (district vaccination store)
- NURSE
- CHW (community health worker)

The roles and responsibilities (tasks) of each stakeholder are presented below table,

Title	Role	Interaction
Vaccination Traffic Coordinator (VTC)	The VTC's role is to manage and monitor parts of the vaccination process so that other	Information: Central store; DVS; Nurse; CHW

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	agents in the system could receive the right information at the right time to do their tasks.	
Responsibility		
• Setup and maintain an individual child's schedule for vaccination session • Sending order information to Central store for delivery to DVS based on stock on hand (DVS inventory) • Sending order information to DVS and NURSE for delivery to nurse based on vaccination sessions • Sending session information to CHW for execution. Maintaining stakeholder accountability by doing checkups on service quality: Occasionally calling families to evaluate last vaccination session performance		
GUI format		
VTC uses the computer (interface desktop based)		

Table 2.VTC's roles and responsibilities

Title	Role	Interaction
District warehouse Store (DVS)	The DVS maintains and delivers vaccines and other equipments used by nurses during outreach. This means that DVS	Information: VTC

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	person is responsible for making sure that the vaccination session material is available at time of need. The DVS also manages the local inventory.	
Responsibility		
• Receive monthly orders of vaccines and other related equipment • Maintain vaccines and other related equipments • Pick together vaccines and other related equipment for sessions • Deliver vaccines and other equipments to nurse • Conduct material inventory (non-used and waste) after sessions at DVS (together with nurse) • Update inventory		
GUI format		
DVS uses the computer (interface desktop based);		

Table 3.DVS's roles and responsibilities

Title	Role	Interaction
NURSE	The nurse's role is to perform vaccination for children in an outreach program manner. She is	Information: VTC

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	responsible for bringing the right vaccine and equipment to vaccination sessions.	
Responsibility		
• Retrieve vaccines and equipment before vaccination sessions • Bringing the right vaccine and equipment to vaccination sessions (by conducting delivery checking balance together with DVS personal) • Perform vaccinations • Providing the right vaccine for the right child in the right way • Reporting session outcome (to VTC) • Bringing back vaccines and related equipment to DVS		
GUI format		
NURSE uses mobile device, Android phone. (Mobile interface)		

Table 4.Nurse's roles and responsibilities

Title	Role	Interaction
CHW	The CHW's role is to act as a connection link between families and the health care service. She encourages families to attend vaccinations, registers them into the	Information: VTC

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	system, and mobilizes them when it's time for the next session. Before sessions she is responsible for preparing the Arena for the nurse (e.g., Gathering families; preparing workstations, etc.). At the session she assists the nurse by putting in the information the nurse's orders her into the nurse's digital device.	
Responsibility		
• Register families • Mobilize families for sessions • Prepare Arena on day of session		
GUI format		
CHW uses mobile device, Android phone; (mobile interface)		

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Table 5.CHW's roles and responsibilities

In short, the model works in the following way

- All children living within a specified area meet up with nurses at pre-defined dates

- at a pre-defined location to receive vaccinations – these days are referred to as “vaccination sessions”;
- The vaccination location – village center, village market, church or health center – is referred to as Arena and has a catchment area of 5 kilometers;
- Each Arena is normally visited once every month to provide timely vaccinations in accordance with the vaccination schedule;
- CHW registers and mobilizes families within an area to join vaccination sessions;
- Nurses perform outreach vaccination service;
- Nurse’s base point is located in the district’s District Vaccine Store where the vaccine and related material is fetched;
- Staff at the DVS collects and delivers vaccine and related material to nurse, and;
- A Vaccination Traffic Coordinator (VTC) is in charge of enabling and coordinating tasks for and between stakeholders.

In this step, the researcher identifies the stakeholders involved in the vaccination service system: VTC, DVS, CHW, NURSE; the next step is to define their roles and responsibilities, which turns into user tasks and needs for system interface design.

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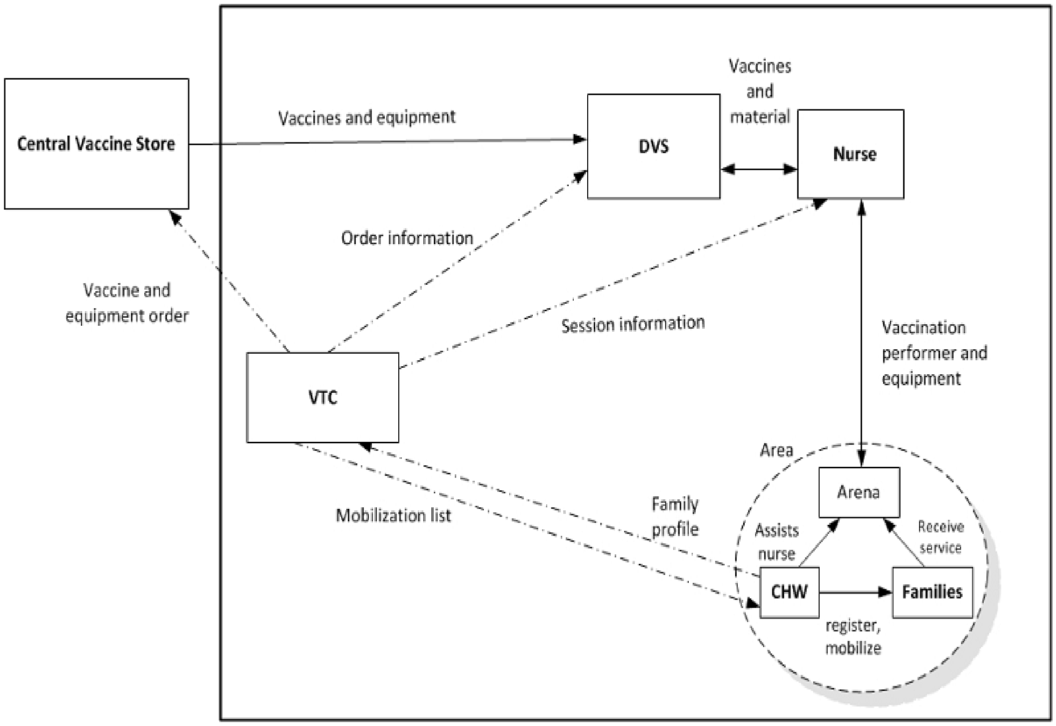

Figure 1: stakeholder roles and interactions (*RUI XUE, 2010*)

The VTC is a hub for information flow and uses the information to perform or order actions. With information at hand the VTC can, for example: Setup children's vaccination schedule; Schedule children for Arena and provide CHW with this information in a timely manner; Order vaccine and related material for DVS to collect for the nurse; Order the amount of vaccines and related material from Central Vaccine Store to DVS to cover one month of supply for the whole district. The double sided arrows between DVS-Nurse and Nurse-Arena depicts that vaccines and related material are brought back from sessions and replaced in the DVS who also updates its local inventory.

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3.5.1. Process model and organizational structure

This section aims to explain operational processes developed by the researcher, thought to bring vaccination service delivery to children in Ethiopia. This will be done through visual models depicting stakeholders' tasks from beginning to end, followed by supportive text. Two methods are used for depicting processes: (1) Activity Diagrams and (2) Use Case Diagrams. The activity diagrams involve stakeholders interacting with other stakeholders. The use case diagrams involve stakeholders interacting with a system. In the perspective of the reader, the difference between the two can be said to be that activity diagrams depicts general processes to explain the functioning of the system, while use case diagrams are more specifically for the use of programmers when developing applications. Activities and use cases are separate yet still interdependent. Some activities may rely on stakeholders interacting with the system to complete a process (and vice versa), and the results of some activities may have implications in later use case diagram processes (and vice versa) for example when information is sent from one stakeholder for later use by another stakeholder.

During "normal" circumstances, the activity diagrams and use case diagrams follow a certain order in relation to each other, for example, an activity diagram is process wise sometimes followed by a use case diagram which in turn is followed by an activity diagram. An example of this is when the CHW first registers a family – activity diagram – and then the VTC acts upon that information to create the child's vaccination sessions – use case diagram. Since

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there are only two use case diagrams which cover matters which the activity diagrams do not, we have decided to put them in the same section.

Information sent and received between processes is given a reference id which readers will need to refer to better understand processes and the information dependency between them. In this step, the researcher identifies the stakeholders involved in the vaccination service system: VTC, DVS, CHW, NURSE; the next step is to define their roles and responsibilities, which turns into user tasks and needs for system interface design

The activity modeling method chosen is the official Business Process Model Notation (BPMN) language. The version used is BPMN 2.0 which is the latest official release. Below is an index explaining symbols used in the BPMN diagrams(Adopted from Simon Karlsson,2012). In order to increase the understanding of the system as a whole, processes are put in beginning-end order sequence: From the registration of a family to the session performance (and monthly supply order from the Central Vaccine Store to the DVS). Note that the use case diagrams will not be displayed, only explained briefly in text format.

1. Family registration

The CHW starts by visiting a village's Local Council (LC) to ask for permission of going to the home of families to register them. Under normal circumstances this is not a problem. The LC provides the CHW with new information about a baby being born or a woman being pregnant. He also provides the CHW with direction of finding the families' house. CHWs know their communities very well, and should have no problem finding houses. Upon

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reaching a family, the CHW explains the program and her role in it. She answers any questions the family might have. She finishes by asking if the family wishes to join. If the family responds “Yes”, the CHW starts a registration process (for detailed info, see “Family registration” under the Graphical User Interfaces section). When finished, the information is sent to the VTC who can use the profile information to create a child’s sessions (see Appendix C)

2. Vaccination session setup

The VTC puts all newly registered children into sessions – the whole schedule for each individual child is planned. All children are also allocated with the vaccines they require for each particular session. A list of the material needed for all children for a session is sent to the DVS. The same list plus the profile list of children for that session is sent to the nurse. The CHW is sent a list of the children to be mobilized to the upcoming session in a particular Arena (see Appendix D)

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3. Mobilization visit

The CHW starts by reading the information sent from VTC containing the names and address of people to mobilize. As usual, the LC is first contacted and notified of the CHWs attempt to inform families about an upcoming session. When a family is found, they are informed about the upcoming session. The CHW provide time and place of next visit. The family can confirm their visit if possible; this information is good for a CHW to have at the session day so that she and the nurse do not have to wait in vain for a caretaker not planned to show

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up. The CHW then continues to the next house for a similar procedure (see Appendix E)

4. DVS prepares session material

The DVS starts by reading the information sent from VTC containing a list of material which is to be prepared for the nurse till the day of session. All material is picked together – vaccines and support material such as dilutes and alcohol. When all material has been collected, a written note is put on the boxes/bags with the unique session code sent with the material list. This is done since a DVS might prepare material for multiple sessions. When the nurse comes to pick up the bags/boxes, she and the DVS will compare their session codes to confirm the right session has been prepared (see Appendix F)

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5. Nurse retrieves session material

On the day of the session, the nurse starts by reading the information sent from VTC containing a list of material (as well as a child profile list) which the DVS should have prepared for her. At the DVS, her session code is compared with that of the DVS personals. They should match, leading the DVS to hand over the boxes with that code on them. If there is no match, something has gone wrong. In this case the VTC should be contacted. The VTC should be able to sort out the situation and provide the correct material list. After this. The nurse and DVS both double check the delivered material to agree on type and quantity, but the nurse will be the person responsible for bringing the correct content. When agreed, the DVS saves the information about material delivered for later until the nurse returns. The inventory is updated first after the return of the nurse to account for material used and wasted. The nurse and driver heads to the Arena. Note that several sessions may be prepared at once and that a nurse might visit multiple arenas in one outreach (See Appendix G)

6. Vaccination session performance

(Only the nurse uses a device in this process, but the CHW can assist her by inputting information into the device as instructed by nurse or follow instructions from nurse based on information from the device.) When the nurse arrives at the Arena, she and the CHW starts preparing the work stations to use. When the families arrive, the nurse starts checking attendance of families as indicated by device. The families are educated in group. (Note that it is not specified how this is done, for instance if done verbally or through video display). The process of performing vaccinations starts by the CHW calling out the name of the child (and caretaker) who are to receive vaccination. The family is identified through name and photo shown on the device. If photo is unclear and name misspelled, the serial number can be used if brought by the family. When the family is identified, the process of performing and registering vaccination starts. The performance and registration of children continues until the last child has been served. The session is over. The nurse and CHW both sign the process into the mobile device to prove that both attended the performance and stand behind the information registered. The information is sent to VTC. All equipment used, including empty vaccine vials and waste (e.g., syringes and needles), is collected

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to be brought back to the DVS. CHW and nurse help out dismantling the stations. The nurse and driver then heads back to DVS (or next Arena)(see Appendix H)

7. Material return and inventory update

The nurse and driver returns to the DVS. She displays her session code, and based on this the DVS retrieves information saved earlier. Some vaccine vials will still have doses left, but depending on their temperature they might not be in condition to use again. Nurse and DVS help out to decide whether or not they are The DVS decides which are to be used again and hence put back into storage. When the vials are put back, the inventory is updated (see Appendix I).

8. VTC orders monthly supply

The VTC has access to the same database as the DVS uses. Based on the individual DVS's stock on hand, the VTC places an order of supply to cover the needs for a month. The list is sent to both DVS and the Central Vaccine Store for balance checking at delivery. (see Appendix J)

9. DVS receives supply

When the truck from the Central Vaccine Store arrives, they (DVS staff and driver) check and compare order numbers provided by the VTC. Upon agreement, material is provided to the DVS. DVS staff and driver checks the type and quantity of the material provided. The DVS is responsible for making the decision of accepting or declining the shipment. The results are put into digital device and the database is updated (see Appendix K).

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3.6. Conceptual Framework Abstraction

IT meta-artifacts are artifacts that support the development of concrete artifacts to be used in practice, especially IT applications (Iivari 2003). They are general solution concepts in terms of van Aken (2004), whereas concrete IT artifacts (applications) are specific solution concepts. Hence the Meta artifacts in this study are going to be used as a method of investigation for concrete IPM for Ethiopia. For increasing awareness about vaccines, the use of mobile technology and text messages have achieved success in different parts of the world (N. Willis et al, 2013).it was hard to generate report from the data written on paper and this in turn affect the preparation and planning for Upcoming vaccination schedules. Hence the researcher found a useful reference for this study in that Data mining in KDD process can be defined as a set of applications of specific algorithms for pattern extraction from preprocessed dataset. The successful data mining application provides useful health care knowledge that can be used to support clinical decisions like process of diagnosis, prognosis prediction and therapy. It can also support administrative decision making like health care coverage, staffing estimates and hospital resource usage. the Architecture for the KBS was designed as follows. From conducting observation and interviews in EPI health centers and later from the Meta artifacts, the researcher came up with the following framework for EPI service in Ethiopia

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3.6.1. IPM framework for Ethiopia

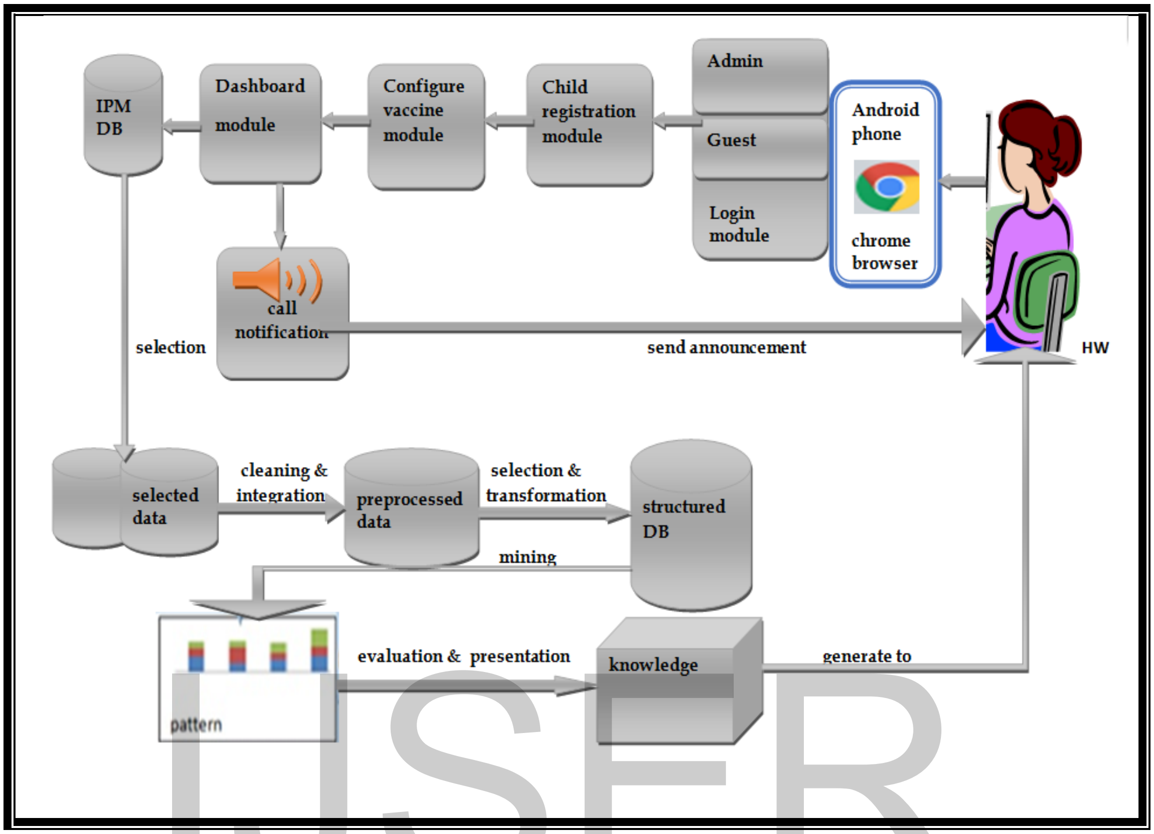

Figure 2: IPM architecture

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3.7. Instrument design

In order to develop the knowledge base about the current state of IT need, structure and usage in Ethiopian EPI the researcher used a qualitative research approach. This approach was selected because this study aims at to investigate existing IT usage, understand what is happening, and find alternative solution from an operational point of view. The contribution of qualitative studies is normally based on its ability to present a new way to investigate existing phenomena, understand what is happening, and find new phenomena and perspectives from an operational point of view (Koskinen et al., 2005).

Hirsjärvi et al. (2009) describe qualitative research with three key characteristics. First, qualitative methods such as interview are used. Second, inductive reasoning is employed, which means that diverse analysis of the data and revelation of unexpected things are essential for formulating a problem and developing the working framework from an operational point of view. Third, purposive sampling is used in data collection, which means that the best suitable respondents are chosen in order to understand some activity or phenomenon better and discover new viewpoints instead of making statistical generalizations.

3.7.1. Sampling method

Sample designs are basically of two types: non-probability sampling and probability sampling. Probability sampling is based on the concept of random selection, whereas non probability sampling is 'non-random' sampling. Under probability sampling design, every item of the universe has an equal chance of inclusion in the sample. Under non-probability sampling each item in the population has of being included in the sample (Kothari, 1990).Purposive sampling was used for data collection in this study, which means that the best suitable respondents were chosen from different health centers in order to understand some activity or phenomenon better and discover new viewpoints instead of making statistical generalizations (Kothari, 1990). Under this sampling the organizers of the inquiry purposively choose the particular units of the universe for constituting a sample on the basis that the small mass that they so select

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out of a huge one will be typical or representative of the whole. According to Kothari (1990), in purposive sampling, personal element has a great chance of entering into the selection of the sample. The investigator may select a sample which shall yield results favorable to his point of view. Accordingly different types of health workers were selected including health officers, VTC , DVS, and CHWs and Nurses from every health structures .The criteria for selecting interviewees were their position of authority due to formal position or expertise and knowledge in some specific area to this study.

Table 6: Sample size for data collection.

Health center name	Number of respondents selected
Mekelle health center	20
Axum health center	20
Adwa health center	20
Total	**60**

3.7.2. Data Collection and Analysis Technique

3.7.2.1 Data collection

Data collection can be derived from a number of methods, which include interviews, focus groups, surveys, telephone interviews, field notes, taped social interaction, questionnaires, and from various publications. Data collected to this study could be a base to understand and identify the EPI IT needs, structure and usages. Data collection consists of either primary or secondary data. Primary data is information that is collected a fresh by the

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researcher to answer his current research questions. There are several methods of collecting primary data; it can obtain either through observation or through direct communication with respondents in one form or another or through personal interviews (David & Sutton, 2004; Saunders et al., 2009; Sekaran&Bougie, 2010).

Secondary data is use of information already collected by someone else. Secondary data may either be published data or unpublished data. Usually published data are available in various publications of the organizations, governments, researchers, individuals, and others sources of published information. The sources of unpublished data are many; they may be found in diaries, letters, unpublished biographies and autobiographies and also may be available with scholars and research workers, trade associations, and other public/private individuals and organizations. The already available data should be used by the researcher only when the data are reliable, suitable and adequate (Kothari, 1990).The decision of which information acquisition method to use depends on the research goals and the advantages and disadvantages of each method relative to those goals. Because it is worth remembering that one method of data collection is not inherently better than another method (Nyaora, 2012). This study has preferred to use both primary data and secondary for different reasons. Firstly, primary data is up to date/fresh, and this is vital where the research is looking at issues to identify the real ICT requirement of EPI sector in an environment with a rapidly changing technologies. This original data

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is important for identifying the real requirements of EPI.

For the purpose of this study interviewing the best suitable respondents selected through purposive sampling are used as information acquisition method. Interview was selected as the information acquisition method because as Hirsjärvi et al. (2009) and Hurme (2008) argue, it is good method when working with unknown or less explored topic and when predicting answers beforehand is difficult. They also argue that interview is good method because it makes possible to expand the information, clarify desired answers, and get illustrative examples. This method was used to develop the knowledge base to identify the requirements for mobile based IPM provisioning strategy and its elements for constructing service framework for EPI . Hirsjarvi and Hurme (2008) define interview by suggesting that interviewer's task is to mediate picture of respondent's thoughts, opinions, experiences, and feelings. Interviews area systematic way of talking and listing to people (Nyaoro, 2012). The researcher often uses open questions to obtain responses from the interviewee, who is the primary data for the study. There are many types of interviews, which include: structured interviews, semi structured interviews and unstructured interviews (Sauders et al., 2009). In structured interview the aim is for all interviewees to be given exactly the same context of questioning so that their replies can be aggregated. Questions tend to be closed ended, pre-coded, or of fixed choice. Structured interviews make probing a problem area difficult because they introduce some rigidity to the interview (Corbetta, 2003). Nevertheless,

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the common format utilized within this types of interview makes it easier to code, analyze and compare data (David & Sutton, 2004). Semi-structured interviews, on the other hand, are non-standardized and are frequently used in qualitative analysis. The interviewer does not do the research to test a specific hypothesis. Instead he has a list of key themes, issues, and questions to be covered (David & Sutton,2004). Semi-structured interviews give the researcher flexibility to establish own style of conversation depending on the direction of the interview (Corbetta, 2003). This flexibility enables probing, which is a way for the interview to explore new path which are not initially considered (Gray, 2004). The unstructured interview or in-depth interview takes a further step towards a more open discussion where no predetermined question is needed. The interviewee is encouraged to speak freely about events, behavior, and beliefs, with reference to the subject. The problem with this is that the researcher may not know what to look for or what direction to take the interview especially if his interviewers are inexperienced. Respondents may talk about irrelevant and inconsequential issues and also it may be difficult to code and analyze the data.

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3.8. Analysis Technique

After interviewing all selected informants, the collected data are analyzed and summarized for better understanding of the current ICT need, structure and usage. Interpretation, description, classification, and/or combining of the data are few standardized analysis techniques for qualitative data (Jaatmaa, 2010). The procedure followed in this study was: using the interview to collect data, describing the data, grouping the issues, and interpreting what is happening. In terms of analysis the research deploys the following approach: results and findings from the interview will be described and analyzed, findings from the interview would be compared and contrasted to relevant literature review findings. The analysis made based on the finding of the literatures and the data collected from the interview for presenting the requirements to constructing the framework intended in this study. Analysis of business requirements through comparisons of information obtaining from primary data and secondary data with relevant literature finding was necessary to fulfill the gap in current research. The survey of concerning literature happens to be the most simple and fruitful method of formulating precisely the research problem or developing framework (Kothari, 1990). According to Kothari (1990), researcher may review two types of literature: the conceptual literature concerning the concepts and theories, and the empirical literature consisting of studies made earlier which are similar to the one proposed. In this study literatures on use of mobile systems for child immunization including similar studies were reviewed. Accordingly interview and review of relevant literature and the guides of EPI which is a base for Ethiopian child immunization system are employed for this study to develop the knowledge bases required for developing the proposed IPM framework model in Ethiopia.

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3.9. Survey and testing

This study conducts a survey and user testing to derive interpretations and conclusions. The survey is presented in accordance with the statement of the specific problem. It will also conduct Usability testing based on ISO 9241 standard. This study specifically considers ISO9241-110 which deals with the extent to which a product can be used by specified users to achieve specified goals with effectiveness (Task completion by users), efficiency (Task in time) and satisfaction (responded by user in term of experience) in a specified context of use (users, tasks, equipments & environments).This technique used in this study to evaluate the GUI for Ethiopia mobile IPM. A Questionnaire based on ISO9241-11is prepared for respondents (see Appendix B).

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3.10. Statistical method for frequent pattern analysis

For extracting frequent pattern analysis from the monthly vaccine usage .the researcher selected Apriori Algorithm. Apriori algorithm is proposed by AgrawalR, ImielinskiT, and SwamiAN that implements Mining Association Rules between Sets of Items in Large Databases. (R. *Agrawal, T. Imielin´ski, and A. Swami, 1993)*

Apriori principle: -Any subset of a frequent item set must be frequent. If an item set is frequent, then all of its subsets must also be frequent, or if an item set is infrequent then all its supersets must also be infrequent. Apriority principle holds due to the following property of the support measure:-

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$$\forall X, Y : (X \subseteq Y) \Rightarrow s(X) \geq s(Y) \qquad \text{.................. (i)}$$

Support of an item set never exceeds the support of its subsets. This is known as the anti-monotone property of support. The support of a rule can be calculated by combining the support count of the antecedent and consequent rule over the total number of transactions on the dataset

$$support(A \rightarrow B) = \frac{s(A \bigcup B)}{N} \qquad \text{.................. (ii)}$$

Apriori Algorithm:

Method:

Level-wise algorithm:

1. Let k = 1

2. Generate frequent item sets of length 1

3. Repeat until no new frequent item sets are identified

   1. Generate length (k+1) candidate item sets from length k frequent item sets

   2. Prune candidate item sets containing subsets of length k that are infrequent ¾ How many k-item sets contained in a (k+1)-item set?

   3. Count the support of each candidate by scanning the DB

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4. Eliminate candidates that are infrequent, leaving only those that are frequent. The process of joining and pruning will be repeated until the frequent item sets will become null. Thereafter, the algorithm is aborted and the association rules generation begins. The confidence level of the rule must satisfy the user specified confidence threshold. The confidence level of the rules can be calculated using the equation:

$$confidence(A \rightarrow B) = \frac{s(A \bigcup B)}{s(A)} \quad \text{................ (iii)}$$

The association rules of the frequent item sets can only be accepted if the confidence level of the rule satisfies or exceeded the user specified confidence threshold.

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3.10.1. Mining association rules in Apriori Algorithm

The system aims to extract knowledge to guide the administrative staff in the EPI for strategic planning and it can be attained through frequent pattern extraction and association rules generation from the patient vaccinated data. The Apriori algorithm enables the knowledge extraction became possible and has been put to use due to the fact that it is widely known and is considered as a standard algorithm for mining association rules. In this study Apriori algorithm uses a multidimensional association rule that is between items or attributes at different levels of abstraction, i.e., at different levels of concept hierarchy. Given a frequent item set L, find all non-empty subsets f ⊂L such that f →L – f satisfies the minimum confidence requirement.

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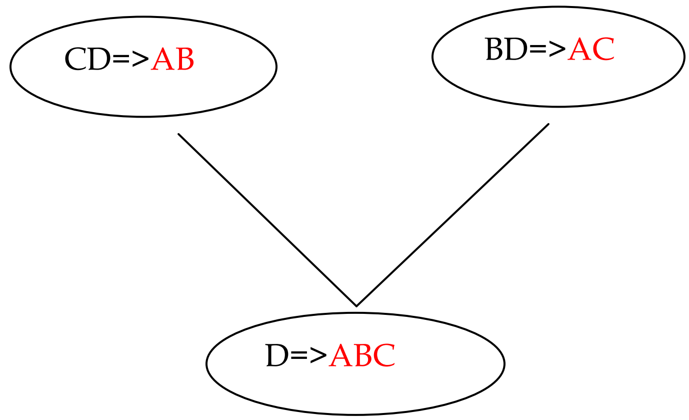
Candidate rule is generated by merging two rules that share the same prefix in the rule consequent.



Join (CD=>AB, BD=>AC)

would produce the candidate

rule D => ABC

III. Prune rule D=>ABC if its subset

AD=>BC does not have high confidence

Pattern Evaluation for Apriori algorithm

Association rule tend to produce too many rules many of them are uninteresting or redundant. Redundant if {A,B,C} →{D} and {A,B} →{D} have same support & confidence Interestingness measures can be used to prune/rank the derived patterns .In the original formulation of association rules, support & confidence are the only measures used.

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3.10.2 Application of Interestingness Measure

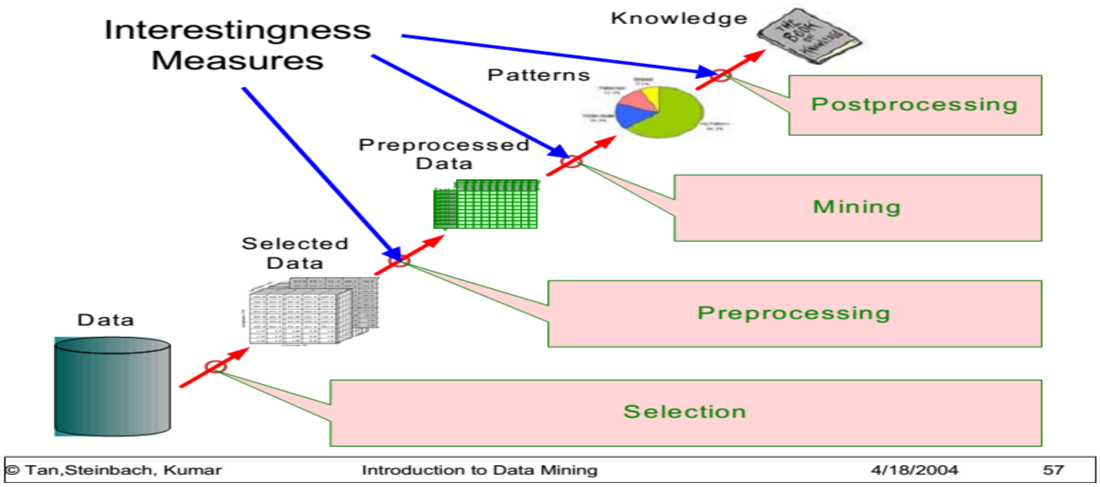

Figure 3: Interestingness measure

Correlation analysis using lift: At some point, a rule could be a misleading rule where an antecedent rule does not have any relationship to the consequent rule although it satisfies the confidence threshold, under those circumstances, the need of correlation analysis is significant. A correlation measure called lift is used to determine the correlation of a rule. It measures the interestingness of a particular rule. The lift can calculated using the equation:

$$lift(A \rightarrow B) = \frac{s(A \cup B)}{s(A) \times s(B)}$$ .... (iv)

Negative correlation of a rule occurs when the resulting lifts value of is less than one. It indicates that the occurrence of the antecedent rule, more likely, leads to the absence of the consequent rule. A rule is independent rule if the resulting lift value is equal to one or there is no such correlation between the antecedent and the consequent rule. Moreover, if the resulting lift value of a rule is greater than one, it follows that the antecedent and consequent rules are positively

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correlated. It denotes that the occurrence of the antecedent rule implies the occurrence of the consequent rule. A and B negatively correlated, if the value is less than 1; otherwise A and B positively correlated (*Glenn* Paul P. Gara and Francis Rey F. Padao, 2015)

Rules visualization: The unpruned rules that satisfy the confidence and lift value (positively correlated) are automatically presented through the Google charts tool. The support of a rule will be supplied to the Google charts for visualization purposes. (*Glenn* Paul P. Gara and Francis Rey F. Padao, 2015).

The attributes for pattern evaluation are

- vaccination session
- vaccine type

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Chapter 4

Presentation, Analysis, and Interpretation of Data

This chapter presents the results of the research study. the implementation results are described and evaluated according to ISO9241-110 usability metrics .this standard evaluates the quality of the web based mobile Immunization program monitoring of a GUI .

4.1. Creation of GUI

In this study, the GUI prototype is the fruit of the practical work. The web-based mobile GUI prototype is the final fruit of the design process in the study through analyzing the GUI, the statement of the problem of this study which mentioned earlier will be answered. Once the conceptual model was defined and the stakeholders' role and interactions were identified as described in chapter 3 , the researcher started to design the prototype. In the GUI design process, the aim of the researcher is to improve the usability of the system by applying data mining in KDD that help experts in decision making.

4.1.1. Technology requirements of mobile IPM GUI design

- Java,
- MySQl relational database ,
- Tomcat application server ,
- cloud server,
- Android phone

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– chrome browser

The researcher decided to use Android OS due to its fast growth and de facto acceptance as well as openness in its operating system and Application Programming Interfaces (APIs).The GUI can be accessed both from PC and Android phones .but the user characteristics determine which device to use.CHW works in the village to register and mobilize the vaccination information to clients, so they need a mobile device to remotely interact with the system; DVS needs to manage the vaccination material inventory system, they need to work around the storage to prepare the material for NURSE to perform the vaccination service. As a result of that, they only need a desktop PC to complete their work. java is a powerful high level programming language, it is used to design a cross-platform and standards-based web interface. Java has many new features such as natively embedded audio and video; incorporated user's geographic location and caching external dependencies for offline web browsing, etc which could all be used to support the system GUI design and chrome browser is very fast .Based on that the researcher has developed a web based android mobile system, hosted it in cloud server and made user testing to evaluate it. According the results of the evaluation has presented in this chapter.

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Figure 4: IPM login interface

Users of the Ethiopia IPM system obtain username and password from the system Admin and can login to the system through their android phones by using 3G or their PC in the presence of internet connection. Only Authorized users and system admin can login to the IPM

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4.2. Purpose

From the theoretical study, the researcher has discovered important findings which could support the system interface design process, such as the collected data. The purpose of presenting the research results is to elaborate on how the researcher designs the system interface by applying the theoretical findings, meanwhile to verify the theoretical findings and answer the research questions.

4.3. Quality of design results

As previously discussed, the quality of design focused on ISO9241-110 usability metrics: ISO 9241 criteria's are introduced to guide the quality of design

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in this study. As a result of that, the results of how these criteria influence the design work are presented in this section.

Table 7: Respondant distribution

Age group			Sex		Authority				
18-25	26-45	>46	M	F	Health officer	DVS	VTC	nurse	CHW
20	**32**	**8**	**16**	**44**	**3**	**9**	**3**	**21**	**24**

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Table 8: evaluation of overall system performance based on ISO9241-110

	Rating scale	**Respondents result**
Strongly agree	5	46.11%
Agree	4	52.22%
Neither agree nor disagree	3	1.67%
Disagree	2	0%
Strongly disagree	1	0%
Overall percentage		100%

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Table 9: Tabular representation of respondents' data per individual ISO9241 metrics

Health Center	suitability for the task	Suit self-descriptiveness	Controllability	Conformity with user expectations	Suitability for individualization	Suitability for learning
Mekelle Health Center	4.38	4.23	4.23	4.25	3.93	4.03
Axum Health Center	4.38	4.20	4.33	4.45	4.45	4.43
Adwa Health Center	4.48	4.60	4.58	4.60	4.48	4.48
Overall Mean	**4.41**	**4.34**	**4.38**	**4.43**	**4.28**	**4.31**

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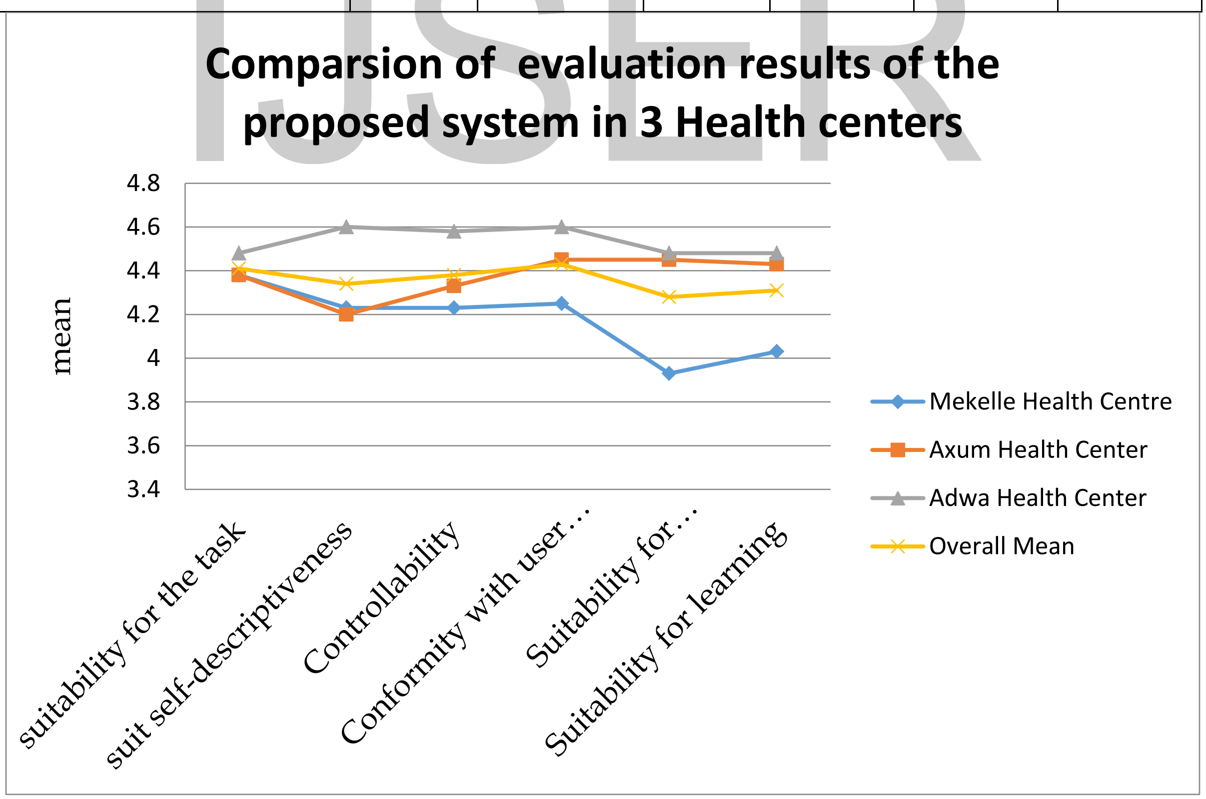

Figure 5: Evaluation of survey results

1. Suitability for the task

This explains the overall suitability of all interfaces implemented in the web based mobile IPM. the system should provide interfaces to register children by the CHW ,vaccinated by the nurse , has to consolidate material and vaccine inventory by DVS and CVS and it has to generate frequent pattern vaccine usage in the form of a graph that can be a pre-knowledge for the administrative staff to prepare for upcoming vaccination. The survey overall result shows that the respondents answer lies between agree and strongly agree. It means that they can perform their required tasks using the system.

2. Suit self-descriptiveness

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The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order. Although Ethiopia is not an English speaking country, most of the health workers are able to read and write English and doesn't create them difficulty because almost all medical terms are in English and they are adapted to it. System interface is structured following the real procedure of vaccination service, which all matches the system with the real world. Subjectively evaluating the system, the respondents agreed on the system language representation of what the system does in the real vaccination terms

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3. Controllability

"Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo. Currently, chrome web browsers support java web page and mobile operating system like Android and normally provide the basic command control navigator such as forward and back in the system. The system provides a hard menu bar at the bottom of the screen, which is constantly displayed in the GUI when user navigates the web page. The user is given freedom to control from the hardware support; indeed, the main navigation bar appears constantly on the top of the system interface, which gives users flexibility to modify their work. The respondents agreed on the easy of control over the system in performing activities.

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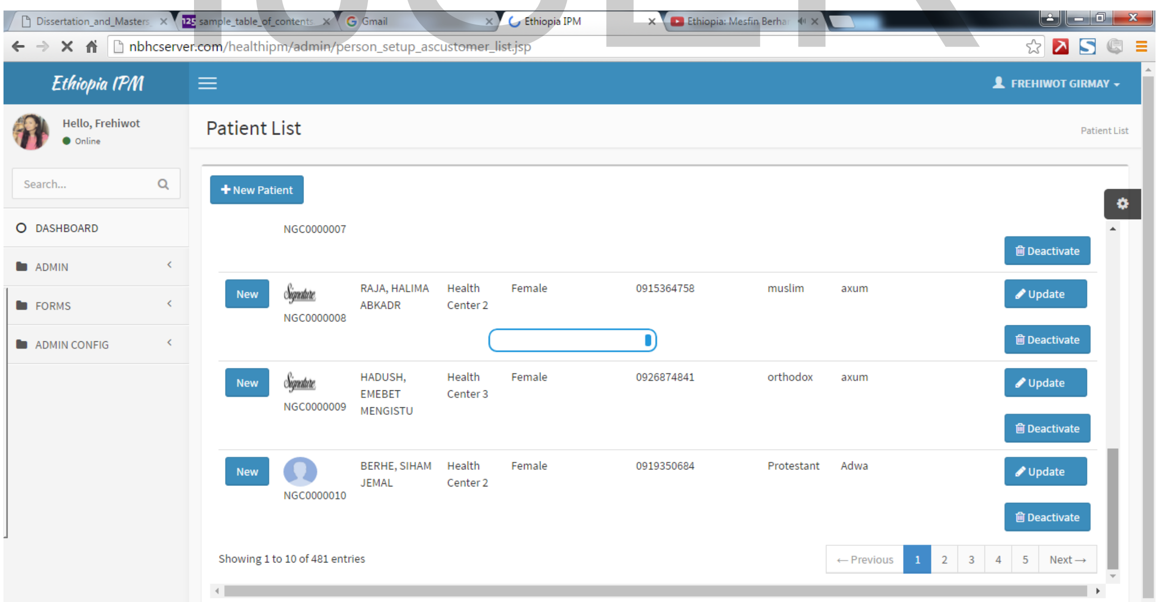

Figure 6: Navigating webpage in patient list

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4. Conformity with user expectations

Conformity means users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions. Conformity is an important aspect of the user interface design because it helps the user to become familiar with using and learning the system, it also improves the efficiency and effectiveness of system usage, meanwhile reducing the percentage of error occurrence. The researcher designed the system interface with unified visualized standards to provide the conformity of the system. For instance: The basic color of the system GUI blue which could let the user to get familiar with the system quickly. The navigation bar is on the top of the screen constantly, which decreases the chance of getting lost .As the mean result from the graph shows the system agrees with the user expectations of the system.

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5. Suitability for individualization

Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate. Observations from the field study: due to the lack of professional health workers in current situations, each CHW and NURSE had to cover a large area to perform the vaccination service. hence he researcher kept in mind that, the design solution has to reduce the workload in order to increase the quality of service; the system should be easy to operate without confusion. Thus, the researcher created the system interface with clear structure and tried to eliminate unnecessary information to reduce user's memory load.

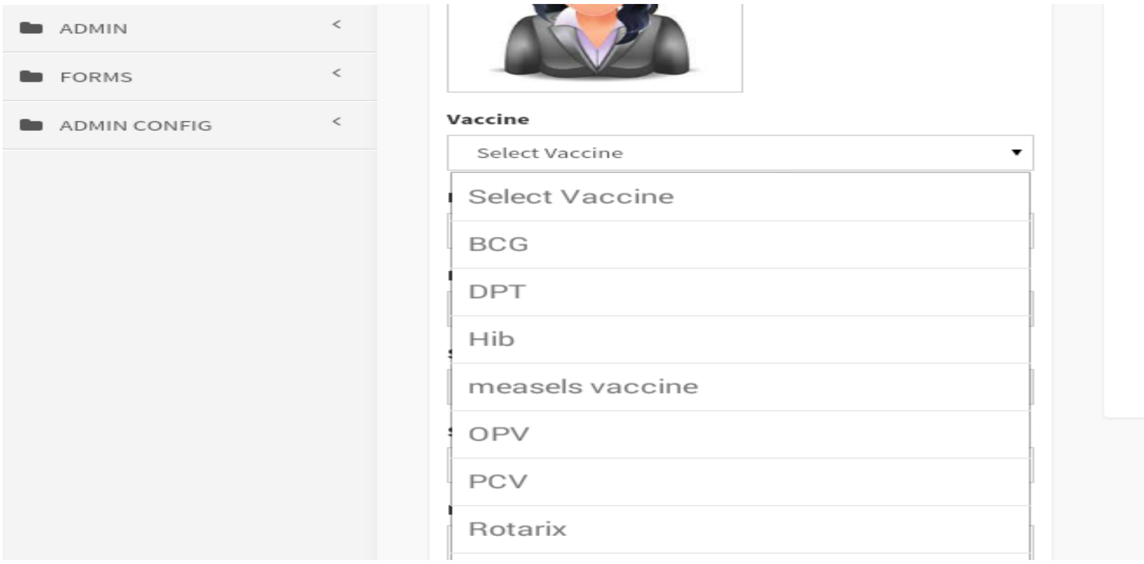

Figure 7: vaccine setup

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6. Suitability for learning

Accelerators -- unseen by the novice user --may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions. The researcher did not consider the system custom adjustment in this design solution, because the study goal is only to design a GUI prototype with essential usability, packaged in with limited time and resources., because most of the Ethiopia health workers are mostly beginning users they do not have too much experience in using either computer systems or mobile phones. As simple is the key factor to lead this design's success, too many control options may cause

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unexpected chaos of use. the respondents agreed on the suitability of the system for learning new things in their experience.

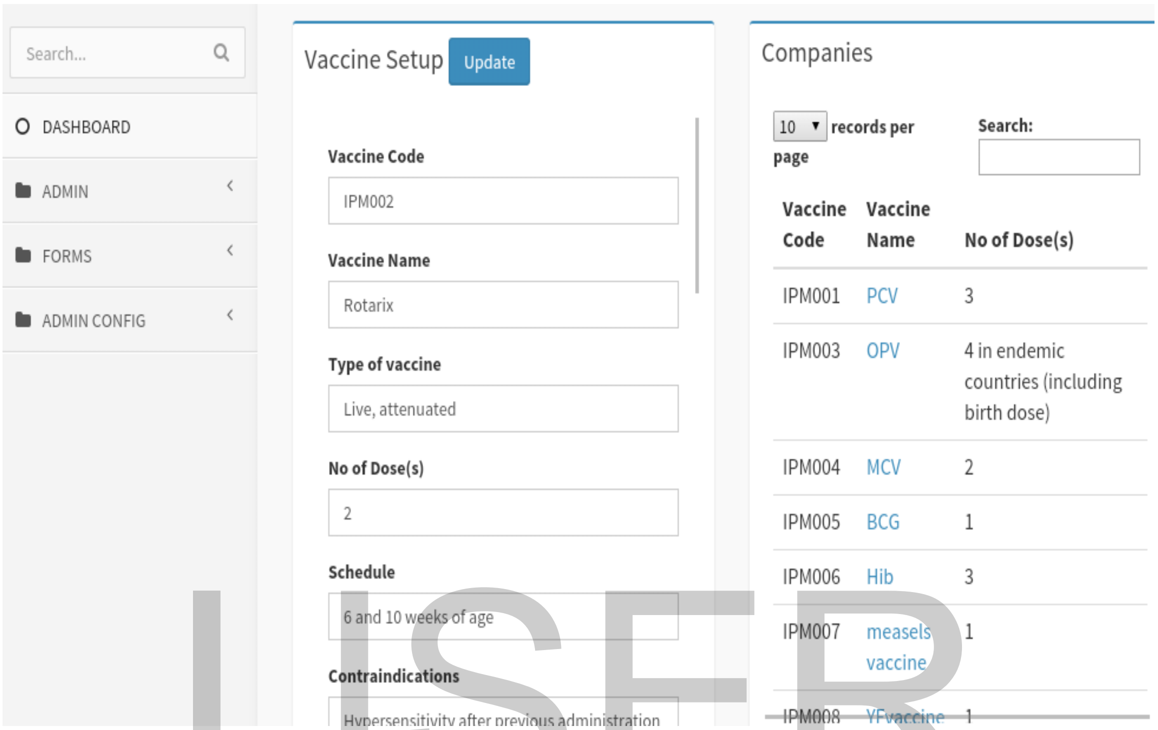

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Figure 8: vaccine library

4.4. Discussion

In this section, the researcher uses the design process and results to set the ground for conclusions on research questions. Through answering the research questions the results found from field study and survey are discussed.

1. Does the determination of the frequent pattern vaccine usage among different vaccine types generate by the Ethiopia IPM prototype bring significant improvement in planning and preparation for the administrative staff?

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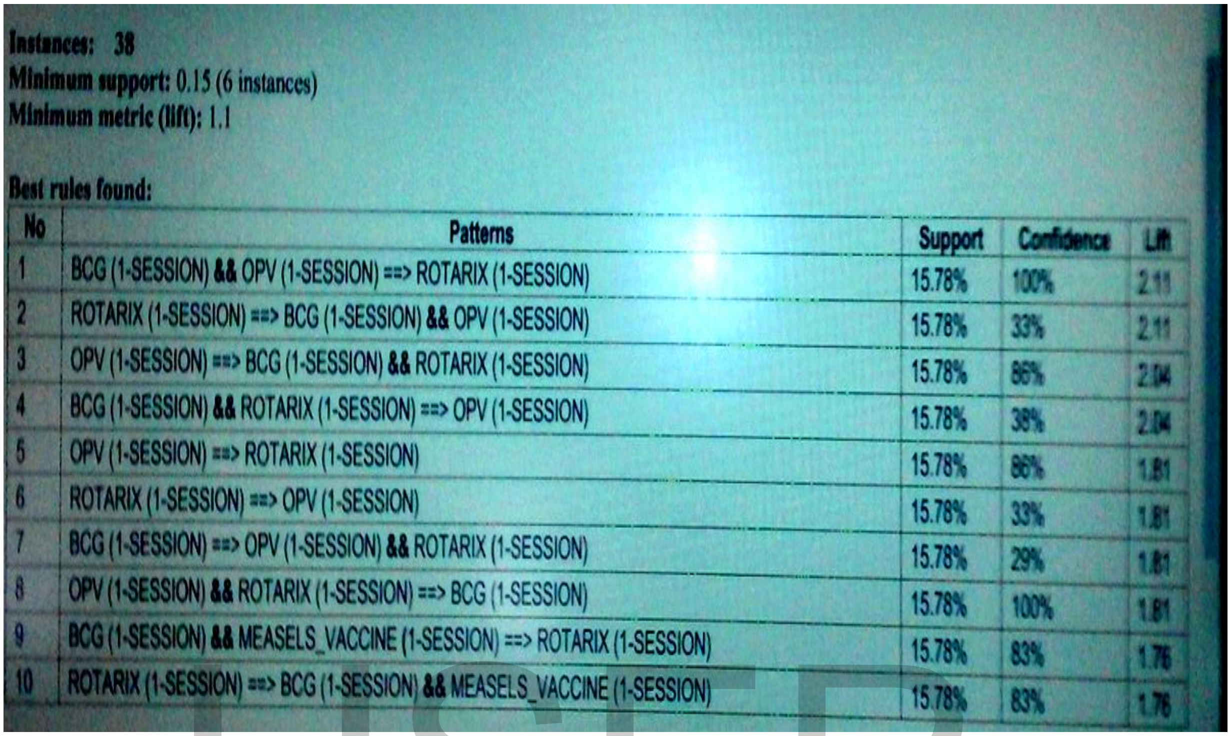
chart of Analysis



Instances: 38
Minimum support: 0.15 (6 instances)
Minimum metric (lift): 1.1

Best rules found:

No	Patterns	Support	Confidence	Lift
1	BCG (1-SESSION) && OPV (1-SESSION) ==> ROTARIX (1-SESSION)	15.78%	100%	2.11
2	ROTARIX (1-SESSION) ==> BCG (1-SESSION) && OPV (1-SESSION)	15.78%	33%	2.11
3	OPV (1-SESSION) ==> BCG (1-SESSION) && ROTARIX (1-SESSION)	15.78%	86%	2.04
4	BCG (1-SESSION) && ROTARIX (1-SESSION) ==> OPV (1-SESSION)	15.78%	38%	2.04
5	OPV (1-SESSION) ==> ROTARIX (1-SESSION)	15.78%	86%	1.81
6	ROTARIX (1-SESSION) ==> OPV (1-SESSION)	15.78%	33%	1.81
7	BCG (1-SESSION) ==> OPV (1-SESSION) && ROTARIX (1-SESSION)	15.78%	29%	1.81
8	OPV (1-SESSION) && ROTARIX (1-SESSION) ==> BCG (1-SESSION)	15.78%	100%	1.81
9	BCG (1-SESSION) && MEASELS_VACCINE (1-SESSION) ==> ROTARIX (1-SESSION)	15.78%	83%	1.76
10	ROTARIX (1-SESSION) ==> BCG (1-SESSION) && MEASELS_VACCINE (1-SESSION)	15.78%	83%	1.76

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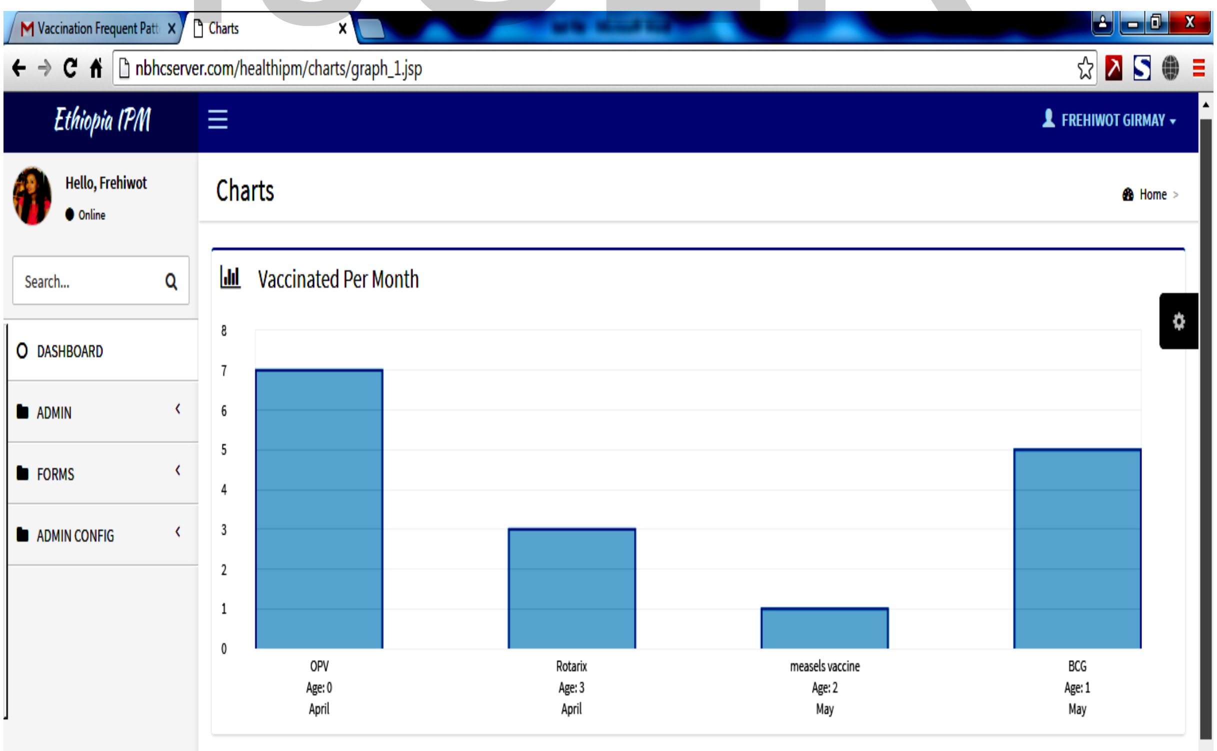
Figure 9:rule representation



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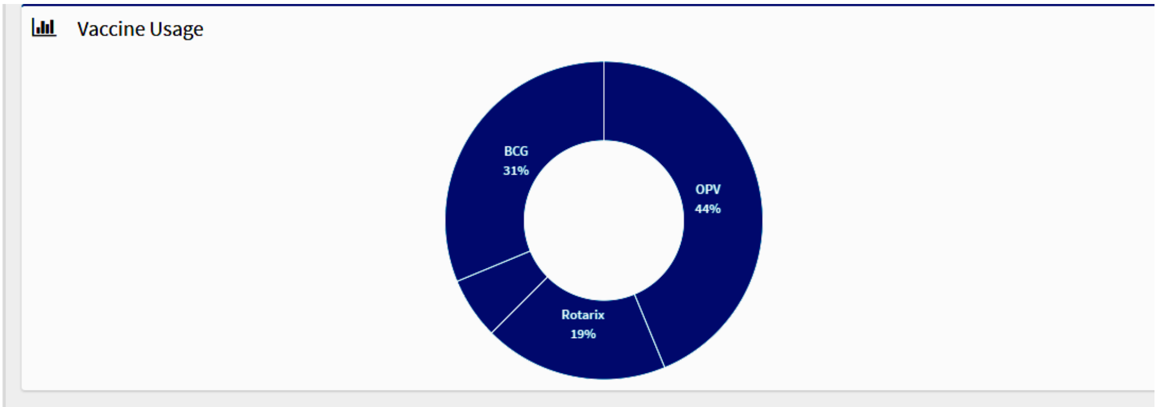

Figure 10: Result chart view

An input of 500 vaccinated children was taken to generate the frequent patterns. The system generates frequent pattern that helps Administrative professionals get knowledge based on monthly input data from vaccination history .through multidimensional association rule generation in Apriori algorithm applied in this study. It generates monthly vaccine information based on the vaccine the patient (child) took and the vaccination session. Accordingly the system generated 10 association rules derived from the user-specified support count and confidence threshold. In figure 13, it is evident that the 1st rule is interesting since it is the rule that generated high percentage of confidence and support count. This explains that those children who took BCG and OPV vaccination in session 1 are children who already took Rotarix vaccination in session 1. This rule is supported with a lift value of 2.11, which is greater than one indicating that the antecedent rules are positively correlated to the consequent rules. The occurrence of the antecedent rule implies the occurrence of the consequent rule. This knowledge enables the administrative people to strategically plan and prepare their offered vaccines

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associated with their upcoming session plans to the children who took BCG and OPV vaccines from session 1.focus of the vaccines associated to the session time must focus on the type of vaccines taken in previous session. On the other hand, the rules are presented graphically using a Google pie chart as seen in figure 9 in order to visualize the support count of each rule.

2. Can the Ethiopia IPM prototype of this study also be used by the health workers administering vaccination in the actual community in updating real-time data using their android phone application?

Child registration

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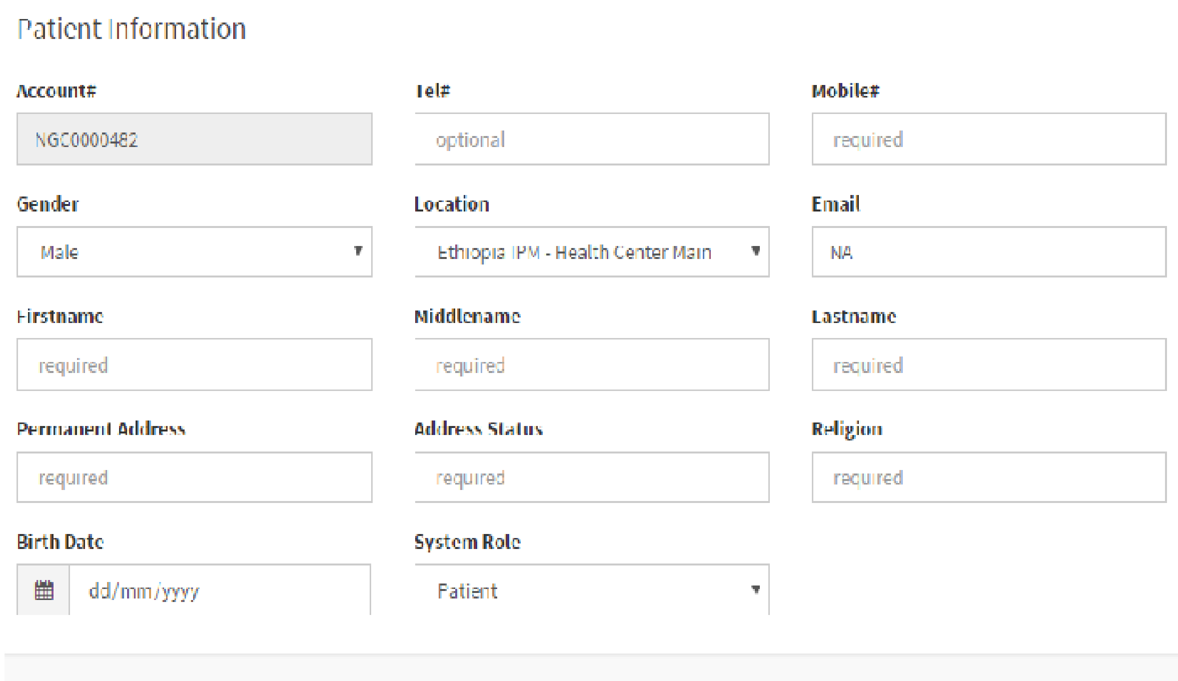

Figure 11: child registration

This is a GUI for CHW to register the new client. The mobile device allows the CHW to fill in the personal information and take a photo of the member which is registered to the profile. The device also automatically and asynchronously produces an ID number, based the CHWs registration information which makes it unique. Address information helps VTC to organize the session plan; the vaccination record also helps VTC to avoid duplication of vaccine performance.

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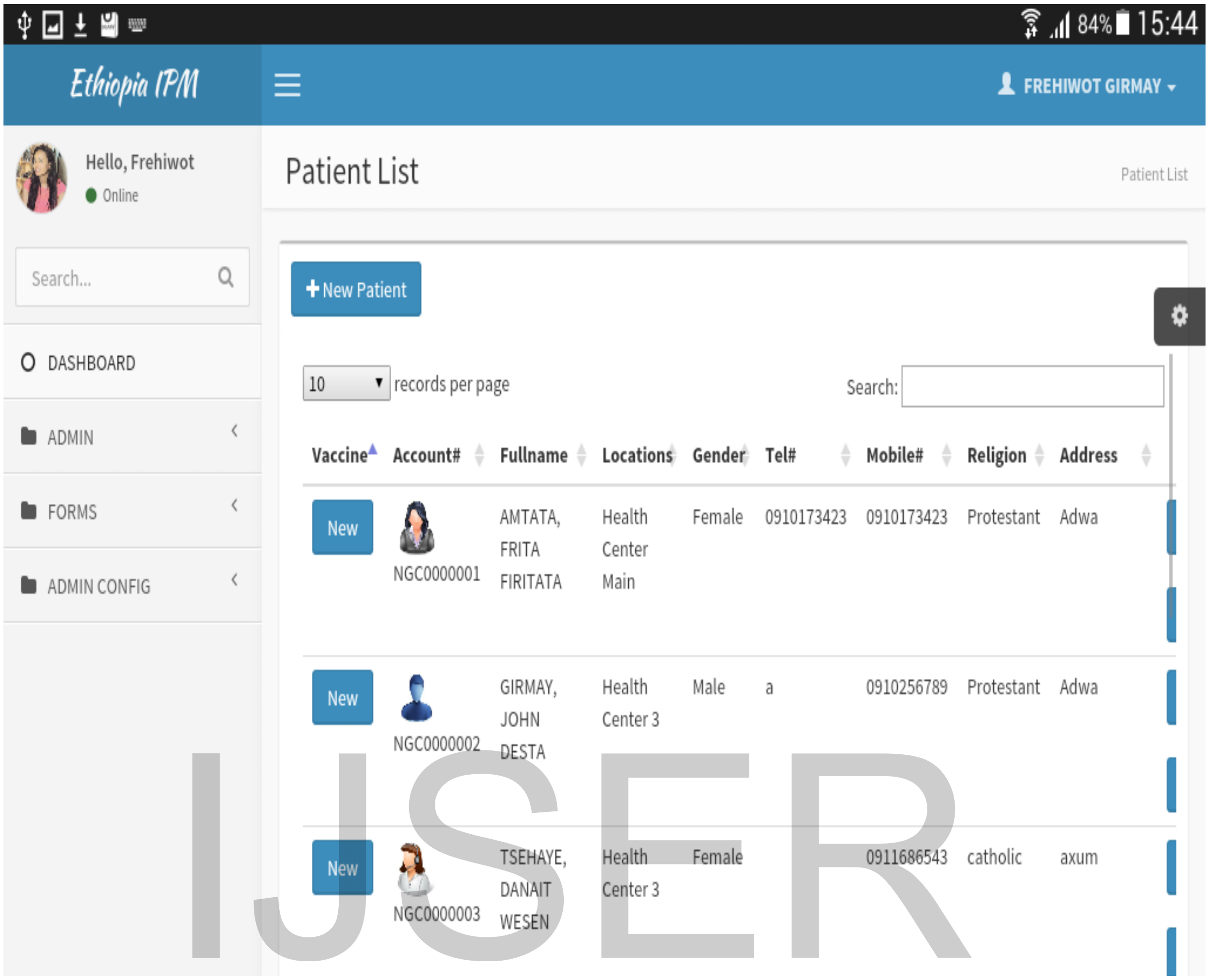

Figure 12:patient(children) for vaccination

VTC receives a new registration from CHW, which is categorized by address. VTC sends the session plan request to DVS, DVS needs to check the inventory system to make sure he has enough stock to supply the session performance.DVS could reject the session plan if he does not have enough stock to support this session. If DVS confirms the session plan, this session plan will be affirmed and sent to CHW and Nurse.

Dashboard module

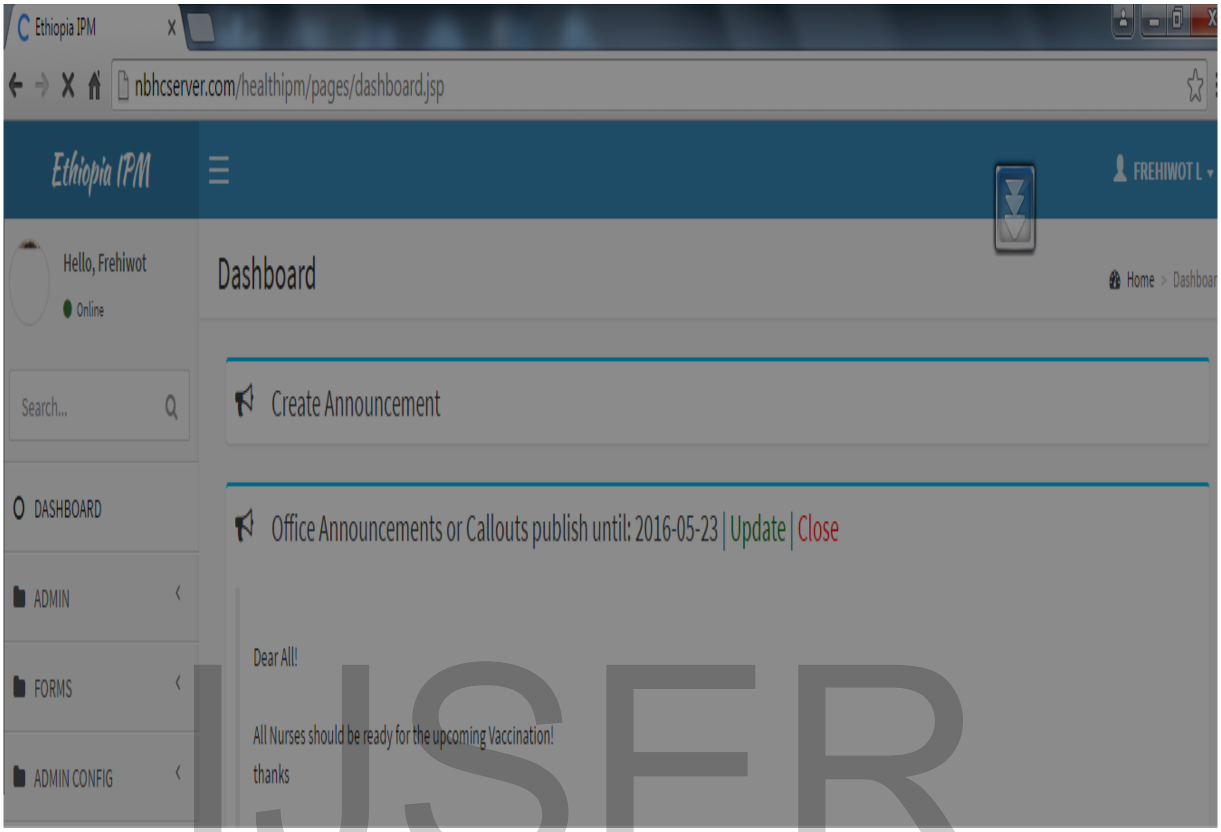

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Figure 13: call notification page

The dashboard helps all stakeholders to publish updates or exchange messages with regarding vaccinations issues to other health professionals. The information contains publish and expire date. The information can be normal, warning or dangerous.

chart of inventory

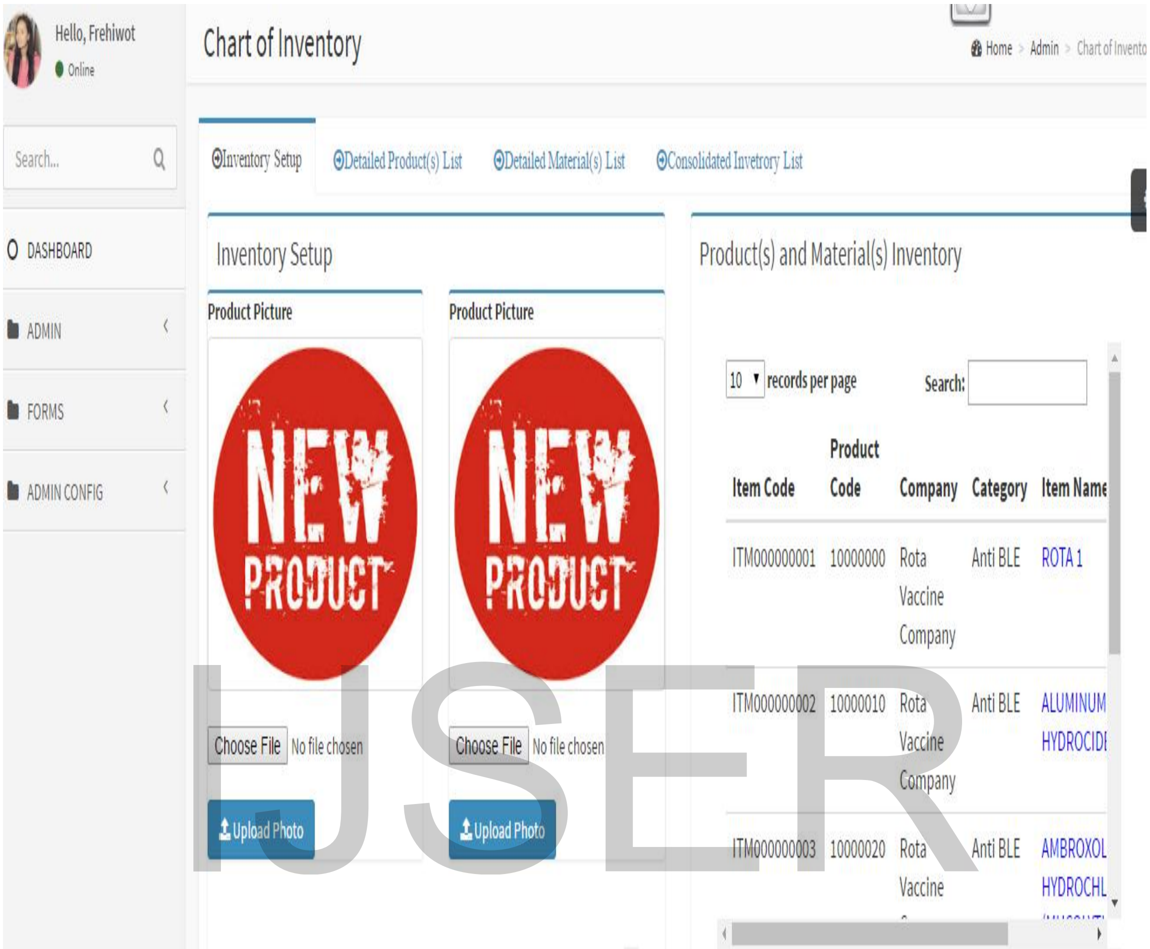

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Figure 14: stock inventory menu

The inventory chart contains all stock information in the database of the central vaccine store. When VTC requests for material and vaccine requirement the CVS has to check the consolidated inventory if there is enough stock in the warehouse for vaccination sessions, so that it will be transferred to the DVS based on the quantity ordered by the VTC. Database consolidates the inventory result. This interface keeps the vaccine management easy

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Chapter 5

Summary of Findings, Conclusions and Recommendations

5.1. Summary of findings

In this section, the researcher uses the findings found in chapter 4 to summarize the overall performance of the system and to recommend further works of the study.

5.1.1. Comparisons of the old system with the proposed system and its major improvements

Characteristics	Existing system	New system
System Mode	Decentralized	Centralized
Amount of Professional Staff	Lack	Same quantity, but reduces workload
Work condition	Bad, Paper record, unplanned session and inventory system,	Mobile web-based system embedded, planned session and inventory system,
Facility	Disrepair	Saved workload could be used for facility testing and repairing,
Medicine(vaccine)	Lack	Well organized inventory system

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		guaranteed sufficient supply ordering,
Data transaction	Invisible	Visible
Performance	Inefficient	Efficient

Table 10: comparsion of the existing and new system

5.2. Conclusions

The goal of this master thesis was to design a mobile web-based vaccination service system to improve the quality of vaccination service in Ethiopia. Through the literature and field study about the local situation of vaccination services, the design challenges and the advantage of applying KDD for decision support system is described. User's characteristics were stated, and helped the researcher to identify the system usability. Additionally, ISO9241 metrics for software usability criteria were used to influence the interface design, in order to design a user-friendly system. Through the study of related designs and the survey result found from the respondents of EPI workers in Tigray through testing the Ethiopia IPM, the benefits of using mobile web-based system solutions in this study were discussed: brings mobility and flexibility of usage; enhances the remote communication and data transaction among users; low level of data input error occurrence and quality data storage. These strengths motivated the researcher to use the mobile web-based system solution. A centralized mobile web-based vaccination service system was designed. Compared with the Existing system, the new system increased the health related data transaction speed; digital format information delivery and storage improved the information

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availability and safety. The new system saved workload: the simple interface decreased the error input occurrence. The new inventory system optimized the stock ordering and usage and the frequent pattern analysis of the data (chart) help in providing necessary information for administrative staff and health professionals to improve the vaccination service process in the EPI sector of Ethiopia.

5.3. Future work

While carrying out this study, the researcher has come across some research plans that could be further processed. However, due to the time and resource limit, these ideas were not done in this research.

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Firstly, most CHWS, and nurses can easily understand the local language of Ethiopia. Accordingly if the prototype of this thesis is developed in local languages like Amharic it may increase ease of use for end users.

Secondly as the mobile penetration rate in Ethiopia has got increasing and making sure that every parent can afford to buy android mobile phones, the system should be modified with interfaces that involve parents in direct interaction with the system.

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Appendices

Appendix A: Interview questions

1) What are the ICT services and supports that are provided for internal and external users of the health centers regarding child immunization by your office?

   A. For internal users, health workers and management staff?

   B. For external users, partners and vaccine suppliers?

2) Do you think these services are enough to achieve your mission and vision, in improving quality immunization to children, reducing workloads to health workers optimizing ICT usage efficiently, dynamic scalability of resources, improving low level of data transaction and modernizing your organization?

3) What are the limitations in providing an efficient child immunization services?

4) what predictions do you use for preparing vaccines and planning vaccination schedules for upcoming vaccinations.?

5 What is your suggestion in formulating a new paradigm for including ICT services and supports in the EPI sector?

6) As an health officer, what do you think is best strategy to provide ICT services for EPI to support with the current economic, geographical ,technological and health sectors structure context of Ethiopia?

7) If a web based mobile application based on cloud computing infrastructure is to be adopted that could be used by all EPI in health centers of Ethiopia to provide ICT services, what will be your reaction to this strategy?

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Appendix B: Questionarie

Dear participants

the purpose of this questionnaire is to asses the usability of Ethiopian Mobile IPM. by completing it you are enabling us to identify and remedy any shortcomings ,with the aim of enhancing its user friendliness.the questionnaire contains statements about the user friendliness of the software.please indicate the extent to which you agree or disagree with each of these statements , making use of scale provided in each case.Thank you!

Job Authority

- ○ regional health officer
- ○ CVS
- ○ DVS
- ○ VTC
- ○ Nurse
- ○ CHW

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Age

- ○ 18-25 years
- ○ 26-45years
- ○ > 46yearrs

Sex

- ○ male
- ○ female

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1.The patient and vaccine recording tasks implemented in the software are helpful in performing my work

- ◯ strongly disagree
- ◯ disagree
- ◯ neither disagree nor agree
- ◯ agree
- ◯ strongly agree

2.The chart analysis helped me to plan and prepare for upcoming vaccination

- ◯ strongly disagree
- ◯ disagree
- ◯ neither agree nor disagree
- ◯ agree
- ◯ strongly agree

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3. I realized immediately what is meant by the messages displayed by the software

- ◯ strongly disagree
- ◯ disagree
- ◯ neither agree nor disagree
- ◯ agree
- ◯ strongly agree

4. I can easily tell the difference among feedback messages, requests to confirm inputs or commands, warnings, and error messages

- ○ strongly disagree
- ○ disagree
- ○ neither agree nor disagree
- ○ agree
- ○ strongly agree

5. The possibilities for navigating within the software are adequate

- ○ strongly disagree
- ○ disagree
- ○ neither agree nor disagree
- ○ agree
- ○ strongly agree

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6. It's easy for me to navigate back and forth between different windows.

- ○ strongly disagree
- ○ disagree
- ○ neither agree nor disagree
- ○ agree
- ○ strongly agree

7. I can anticipate which screen can appear next in a processing sequence

- strongly disagree
- disagree
- neither agree nor disagree
- agree
- strongly agree

8. My impression is that the same possibilities are consistently available for moving within and between different parts of the mobile and or web application

- strongly disagree
- disagree
- neither agree nor disagree
- agree
- strongly agree

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9. The mobile and web app lets me easily adapt forms, screens and menus according to my basic preferences.

- strongly disagree
- disagree
- neither agree nor disagree
- agree
- strongly agree

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10. I am able to regulate the amount of information (data, text, graphics, etc.) displayed on-screen to my needs.

- ◯ strongly disagree
- ◯ disagree
- ◯ neither agree nor disagree
- ◯ agree
- ◯ strongly agree

11. So far i have not had any problems in learning the rules for communicating with the mobile and or web app, data entry

- ◯ strongly disagree
- ◯ disagree
- ◯ neither disagree nor agree
- ◯ agree
- ◯ strongly agree

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12. I am stimulated by the software to try out new system functions by trial and error.

- ◯ strongly disagree
- ◯ disagree
- ◯ neither disagree nor agree
- ◯ agree
- ◯ strongly agree

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Appendix C:Family registration

---Information reference output:

1ADi or 1ADii

1. Family registration   ID: 1AD

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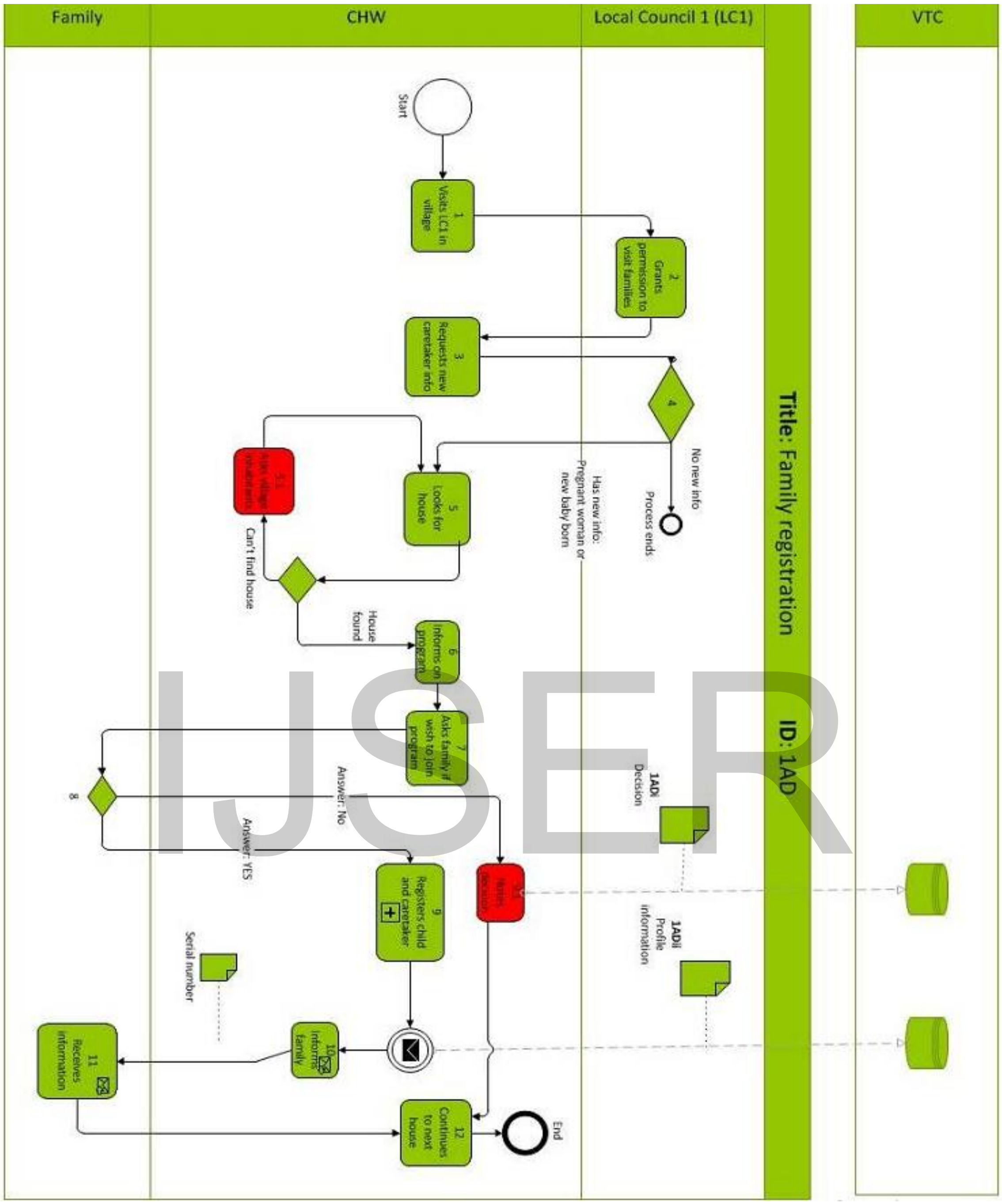

Family registration process

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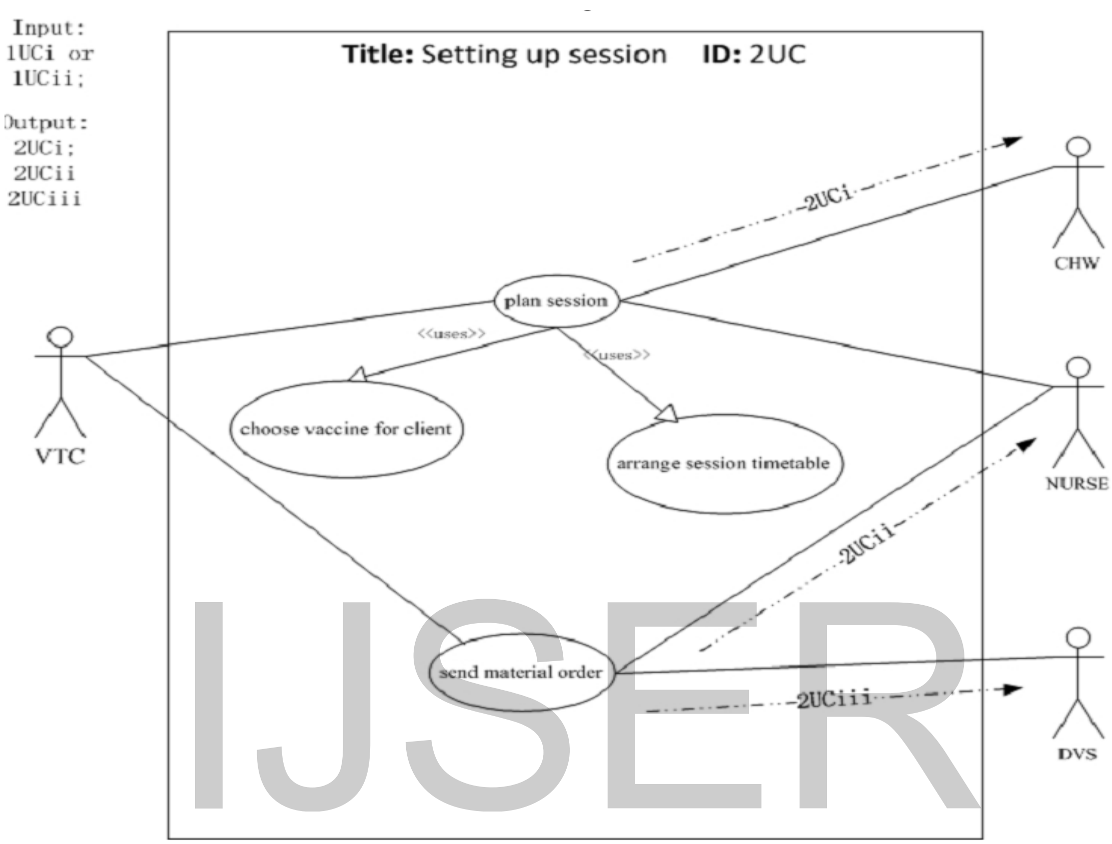
Appendix D: Vaccination session setup

2. Vaccination session setup   ID: 2UC



Appendix E: Mobilization visit

Information reference input:

1ADi or 1ADii

Information reference output:

2UCi; 2UCii; 2UCiii

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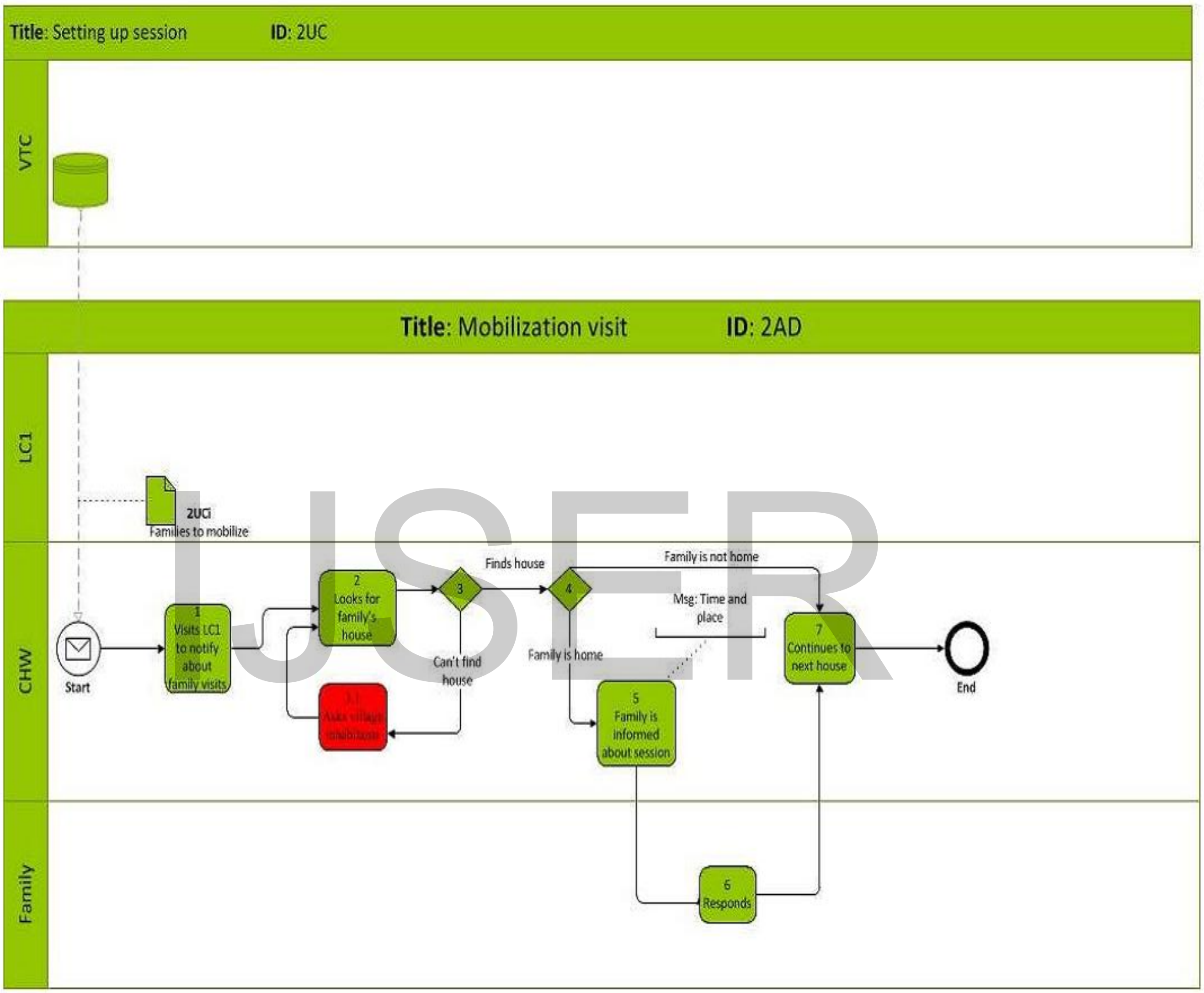
International Journal of Scientific & Engineering Research
ISSN 2229-5518

3. Mobilization visit



Appendix F: Preparing session

Information reference input:

2UCi

Information reference output:

---

4. DVS prepares session material   3A

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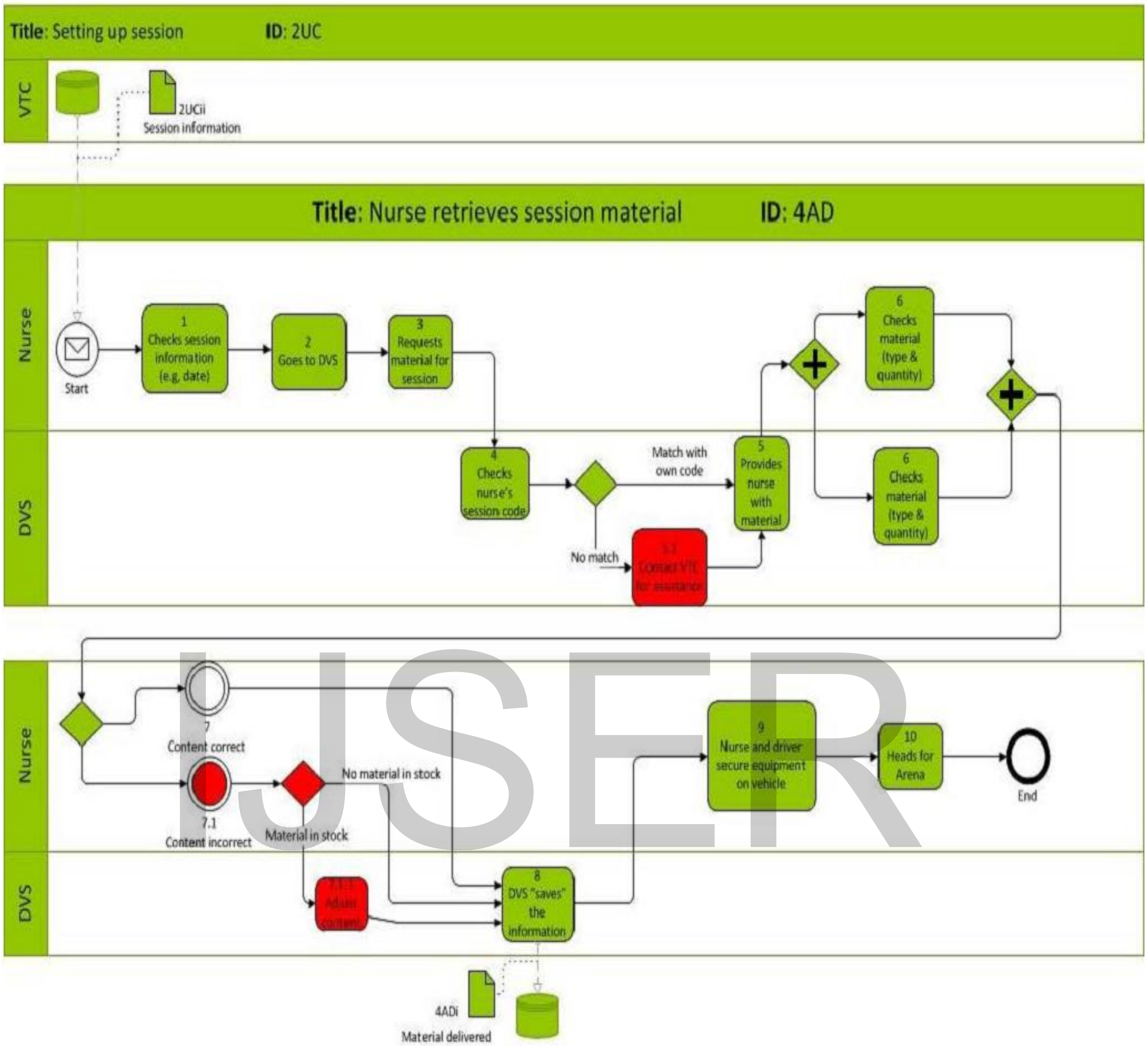
Appendix G: Retriving session material
Information reference input:

2UCiii

Information reference output:

---

5. Nurse retrieves session material 4AD



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Appendix H: Session performance

Information reference input:

2UCii

Information reference output:

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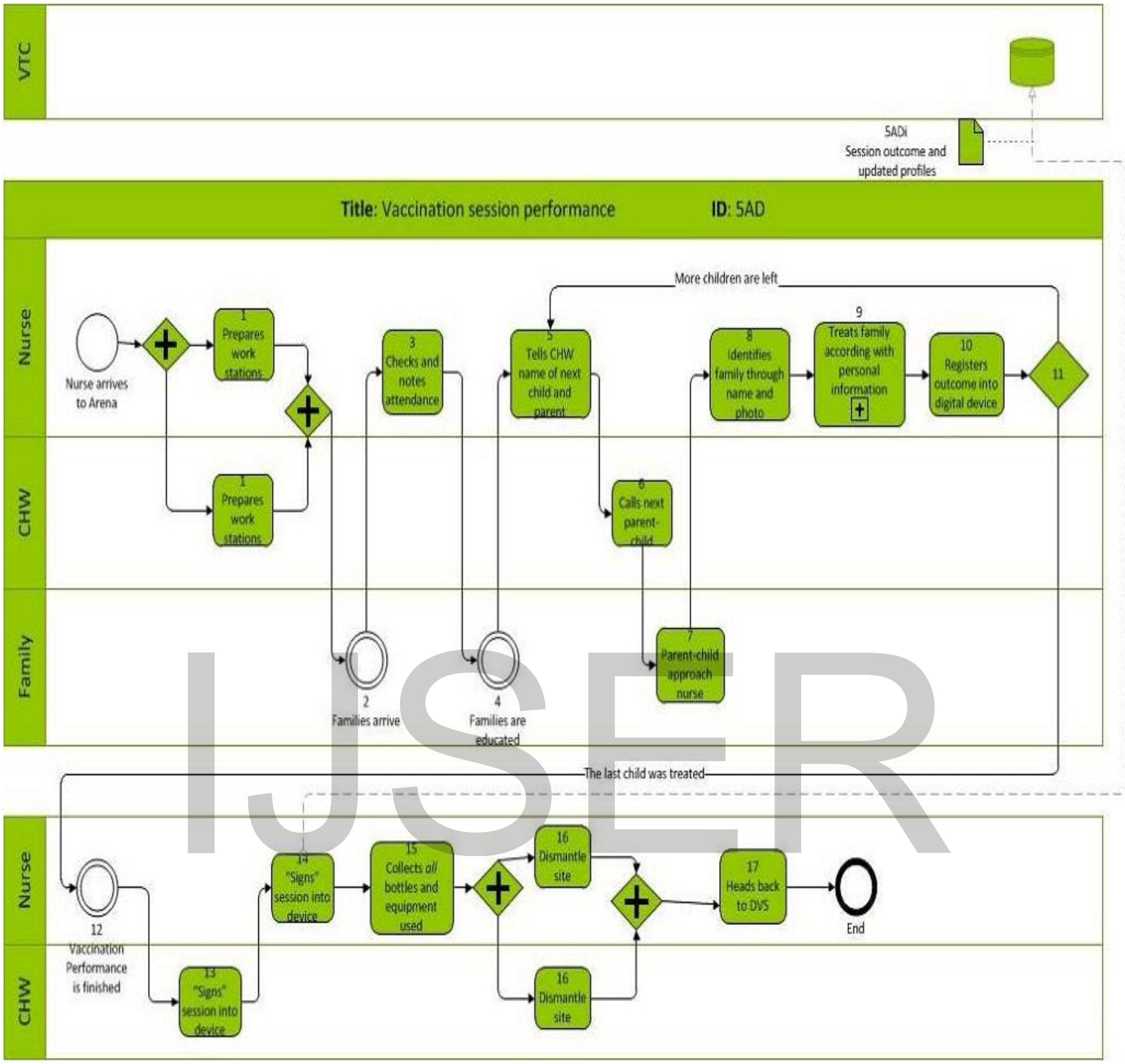
6. Vaccination session performance   5AD



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Appendix I: Material return and updating inventory

Information reference input:

---Information reference output:

5ADi

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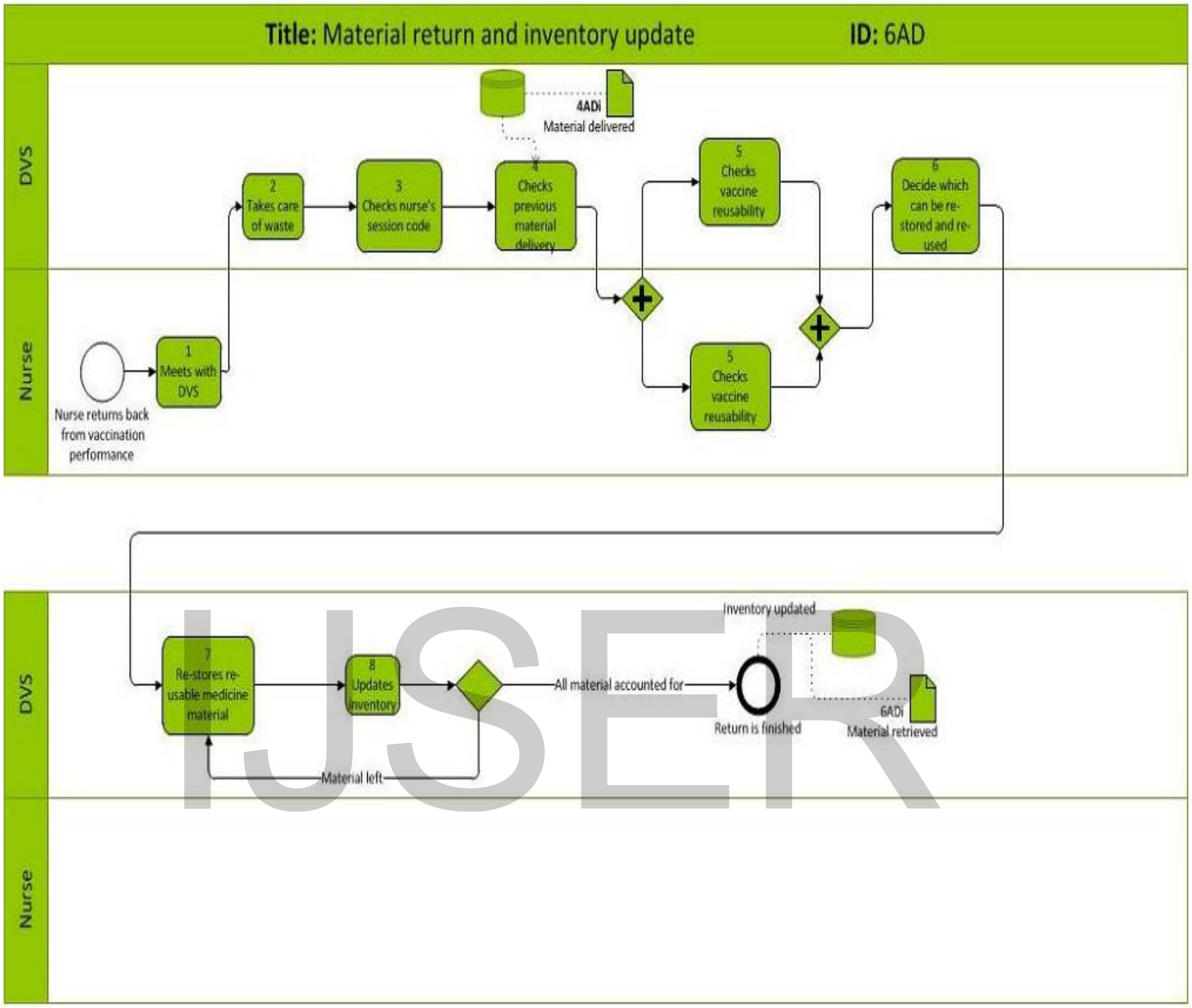
7. Material return and inventory update 6AD

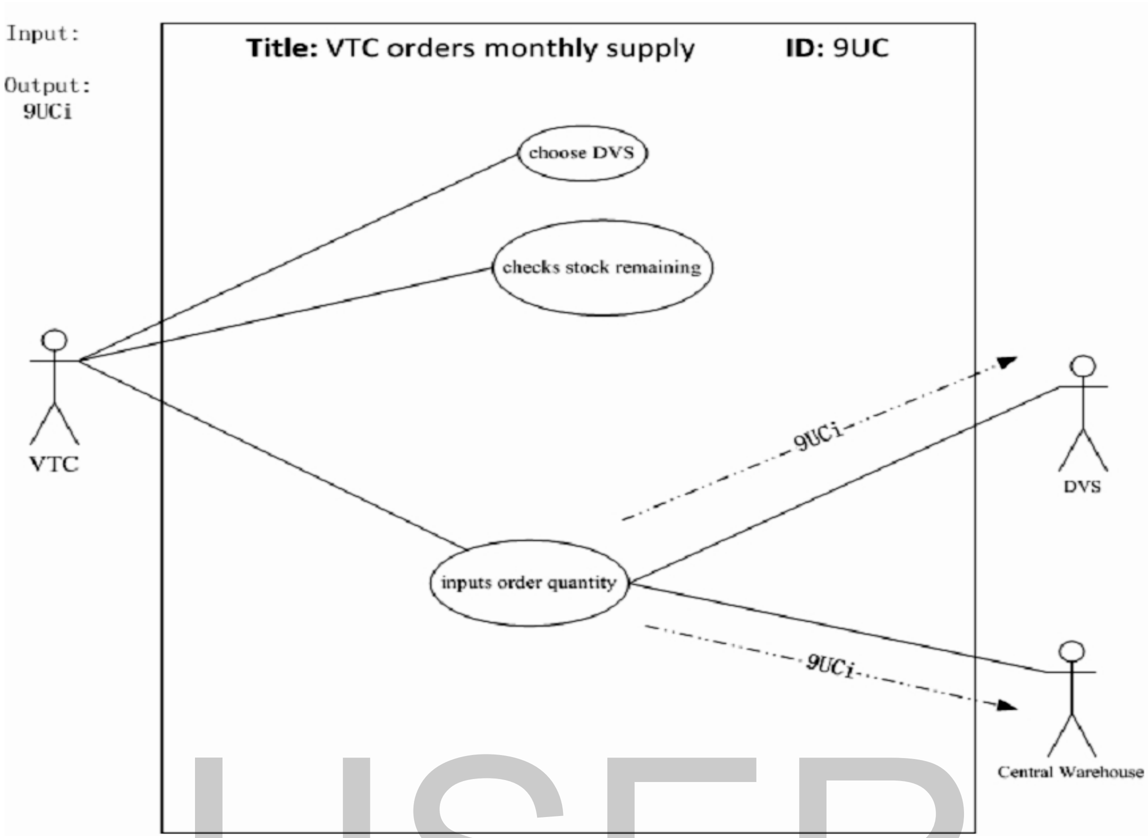


Appendix J: Monthly supply order

4ADi;

Information reference output:

8.VTC orders monthly supply 6ADi;



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Appendix K: Reciving supply

Information reference input:

---Information reference output:

9UCi

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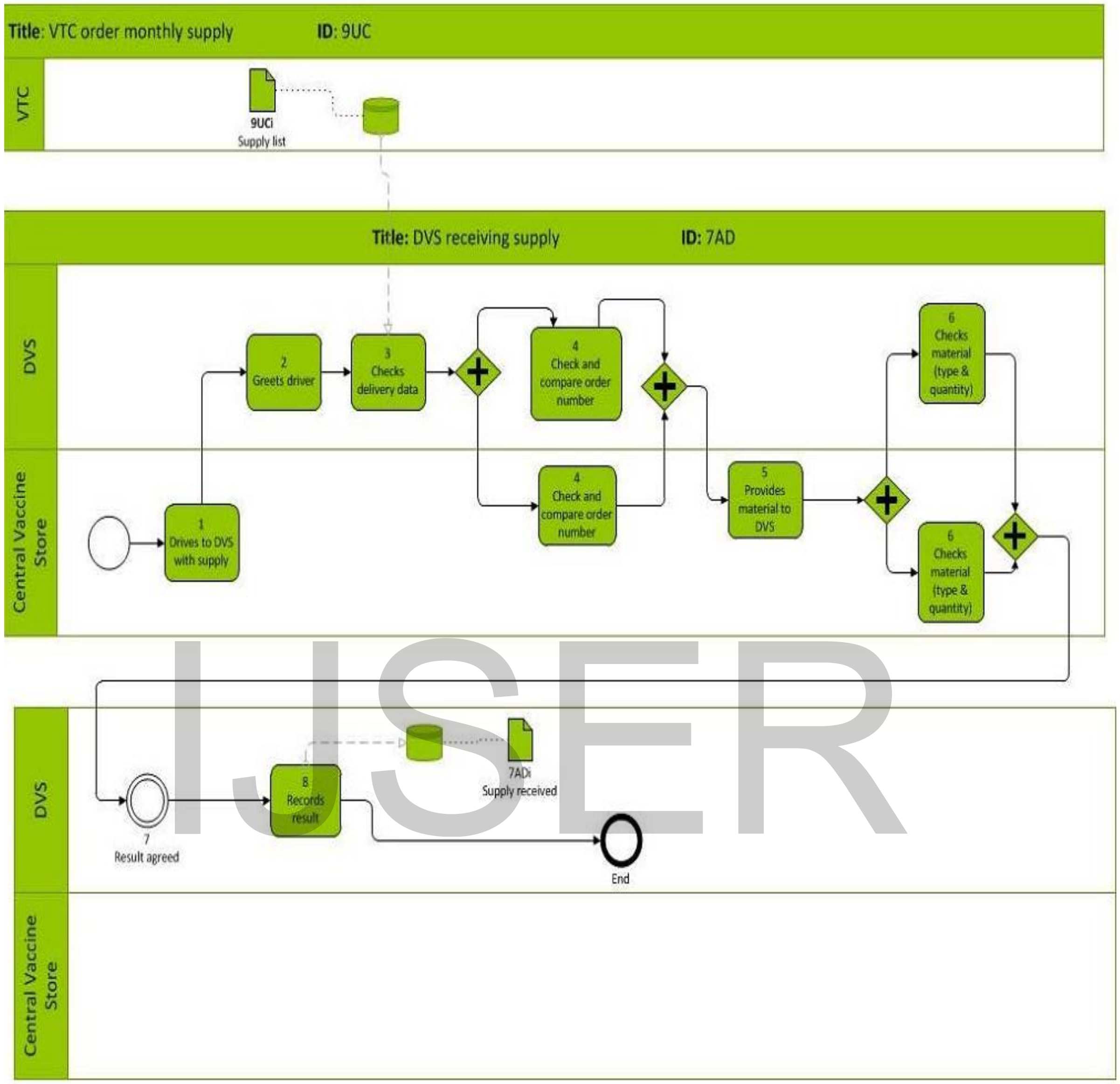
9. DVS receives supply 7AD



Information reference input:

9UCi

Information reference output:

- 7AD.

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