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Maternal Monitoring: Lowering Child Mortality by Use of ICTs

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Abstract
In this paper, we describe the creation and development of an Electronic Health Records System that automates record keeping procedures for both patients and medical practitioners in a health facility. We also demonstrate how maternal monitoring by use of ICTs can lower child mortality in developing countries. It should be realized that lowering child mortality is one of the 8 Millennium Development Goals to be achieved by less developed countries by 2015. The Infant and Maternal Monitoring System (IMM System) seeks to lower infant mortality rates by encouraging pregnant women, as well as mothers to take their new born babies and infants to visit the nearest health centers for required healthcare checkups, vaccinations, or immunizations. This can be achieved through the creation and use of SMS functionality on the created system. This system improves communication and collaboration between medical practitioners through discussion forums, thus increasing the rapidity and quality of patient care
Keywords: ICTs, Maternal, Mortality

1.   Introduction

The United Nations ranks "Reducing Infant Mortality" as the fourth goal in the Millennium Development Goals (MDGs) to be achieved by 2015. Every year worldwide, four million infants die within their first month of life, representing nearly 40 percent of all deaths of children under age of five years. Almost all newborn deaths are in developing countries with the highest number in South Asia and the highest rates in sub-Saharan Africa (Sines et al., 2007).

In Uganda the infant mortality rate is still abnormally high, with as many as 137 children out of 1,000 live births dying before their fifth birthday. On the other hand, 76 infants out of every 1,000 live births die before their first birthday (Mukasa, 2008).

High quality prenatal and post natal care improves the survival and health of infants, while providing an entry point for health contacts with the pregnant women and mothers at a key point in the continuum of care (Lincetto et al., 2006). If provided, promoted, monitored, researched, and further tested, health care services such as: antenatal care and vaccinations will create lasting improvements in health systems and constitute major progress in meeting the MDGs. More importantly, it will save the lives of thousands of mothers and children annually (Sines et al., 2007).

Lincetto et al., (2006) consider pregnancy as a crucial time to promote healthy behaviours and parenting skills. Good antenatal-care links the woman and her family with the formal health system, hence contributing to good health through the life cycle. Inadequate care during this time breaks a critical link in the continuum of care, and affects both women and their babies.

One proposed explanation hindering the progress in lowering infant mortality in Uganda has been a decline in vaccinations, especially in the late 1990s. Moller (2002), states that the overall share of fully immunized children fell from 47% in 1995 to 37% in 2000 yet vaccinations are directly relevant to lowering infant mortality. Also, the share of pregnant women receiving at least one tetanus toxoid injection has fallen during this period, to the detriment of progress on infant mortality. Nevertheless, the recent substantial increases in public health expenditures should help to reverse these trends.

In the past 20 years Information Technology (IT) has revolutionized virtually every facet of people's everyday lives. Organizations of all types have long seen that IT when viewed comprehensively and deployed effectively can replace old challenges with new possibilities.

The Infant and Maternal Monitoring System is one such feasible solution and, its practical uses are discussed below:

Pinto (2006) notes that an automated Electronic Health Records System, (such as the Infant and Maternal Monitoring System), creates efficiencies and dramatically streamlines processes such as: patient registration and records management. It also improves communication by offering an intellectual knowledge base for medical practitioners over discussion forums which eases the rapidity of patient care.

Poissant and Kawasumi (2005) noted that an Electronic Health Records System offers more comprehensive security measures than previously used methods such as locked cupboards or room storage. Password protection limits access to patient information to authorized users: Doctors, nurses, and midwives.

In addition to the above, it solves the archived-records dilemma where pre-existing health records are in paper form. An electronic record stores both archived and active patient records in a centralized database (Pinto, 2006). It manifests itself as a cost-effective and technologically-viable alternative to manually paper-based patient record keeping and ensures that medical practitioners have access to the right patient data at the right time.

An Electronic Health Records System efficiently reduces documentation time, and leads to better patient care with an increase in patient-interaction time (Jareethum and Titapant 2008; Poissant and Kawasumi, 2005) such as the implementation of the Infant and Maternal Monitoring System.

2.   Methodology

Before the model for the Infant and Maternal Monitoring System was designed, research aims / objectives needed to be identified.

Research aims:

i To investigate factors that have bearing on infant mortality in Uganda.

ii To design an Infant and Maternal Monitoring System

iii To implement the Infant and Maternal Monitoring System

iv To test and validate the system

These research objectives give rise to the following research questions:

i What are the factors that affect maternal mortality in Uganda?

ii What tools are needed to design an Infant and Maternal Monitoring System?

iii What technologies are needed to implement an Infant and Maternal Monitoring System?

iv How can the system so developed be validated?

In the selection of a sample area, purposive sampling was used. It is a non–probabilistic technique of sampling that bases the selection of a given sample on the researchers' judgement. The main justification behind the use of the above mentioned technique

is that health care facilities in Kampala are countless and widely dispersed.

The selected health care facilities were highly reputable and the healthcare personnel had a wealth of experience in the fields of antenatal and infant health care. Doctors, nurses and midwives (16 respondents in all) of 4 randomly selected highly prominent healthcare facilities; with over 3 years experience in the fields of antenatal and infant health care were a manageable sample for the researchers to question and analyze the findings.

The data collected from the questionnaires, interviews, referenced documents and from observation was carefully analyzed in order to reveal factors that influence high infant and maternal mortality rates as well as to come up with functional and non-functional requirements. These were essential in the development of the IMM System. Medical professionals (doctors, nurses, and midwives) provided insight into antenatal and infant health care, while also acting as end user representatives to validate the accuracy of the information and to test the final system.

3.   Analysis of collected data

The careful study and examination of the collected data (from the questionnaires, interviews, referenced documents and observation) exposed factors that are responsible for high infant and maternal mortality rates. It was upon further investigation that it was revealed as to how the Infant and Maternal Monitoring System may possibly help in the lowering these rates

A breakdown of the data (from questionnaires and interviews – See Appendices A and B) revealed that an average of 350 pregnant women are registered annually in a given health center. Of these women approximately 200 of them complete the recommended minimum of 4 antenatal care visits. Each antenatal check-up over the course of the pregnancy (9 months or 3 trimesters) is of great importance in terms of effectively monitoring the health, progress, and development of both the mother-to-be and her child, Sine et al., (2007)

Table 1: The relevance of health care services [Adapted from United Nations Department of Economic and Social Affairs (2008).]

PREGNANCY STAGE	HEALTH CARE SERVICES	RELEVANCE
First Trimester (1-3 months)	**Early trimester:** • Health history is noted • Physical examination is done • Blood and urine tests are carried out.	To confirm the pregnancy
	Late trimester: • Foetal ultrasound is performed • Listen for a foetal heart beat using a Doppler • Pelvic Exam , Pap Smear and Breast Exam is done • Blood Screening for HIV, and other STIs is done. • Blood pressure is checked • Mother's weight is recorded • Urine is screened for protein and sugar • The fundal height is measured to check baby's growth • Additional prenatal testing is done as needed	**Ultrasounds** provide an image of the foetus and placenta. **Screening tests** uses the pregnant woman's blood or urine sample to check/ perform a battery of tests especially where infections or discrepancies are suspected so that the correct precautions are taken All the performed examinations serve to check the developmental progress of both mother and child
Second Trimester (4-6 months)	• Foetal ultrasound • Record mother's weight • Fundal height is measured to check baby's growth • Blood pressure is checked • Urine sample is screened • Blood screening for HIV amongst others. • Additional prenatal testing as needed	**Ultrasounds** are used to monitor foetal heart beat and to identify any foetal problems in growth **Screening tests** uses blood or urine samples to perform a battery of tests especially where infections or discrepancies are suspected so that the correct measures are taken.
Third Trimester (7-9 months)	• Foetal ultrasound is done • Foetal and placental check • Blood is screened for HIV amongst others • Urine sample is taken to screen for sugar and protein • Mother's weight is recorded • Baby's heart beat is checked • Palpate to check baby's position (vertex, breech, posterior, etc.) • Fundal height is measured to check baby's growth • Reviewing of delivery plan is done • Mother's blood pressure is checked	**Ultrasounds** are used to monitor foetal heart beat and to identify any foetal problems that may bring about high risk factor in delivery **Screening tests** uses blood or urine samples to perform a battery of tests especially where infections or discrepancies are suspected so that the correct precautions are taken

NOTE: All pregnant women ought to be screened for Human Immuno-deficiency Virus (HIV) infection to help prevent newborn HIV infection.

Information collected from the questionnaires and interviews, as well as observations made by authors: Lincetto et al. (2006); and Ssewanyana and Younger (2005), isolated various reasons as to why many pregnant women fail to go for their antenatal checkups or bring their infants in for basic health care. Those that were overlapping and recurring to these studies were most notably: ignorance and/or forgetfulness, inadequate finances to pay off medical bills, and long distances from health centers.
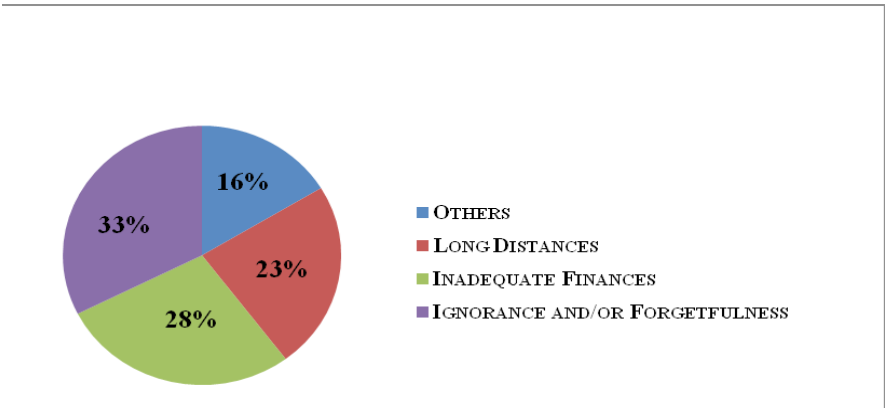

Figure 1: A pie chart showing ranking reasons women give for missing antenatal checkups

As observed in Fig. 1 above, ignorance and/or forgetfulness stands out as the major reason why pregnant women in Kampala miss crucial antenatal checkups. This is a problem that the Infant and Maternal Monitoring System may remedy using its SMS functionality; which will constantly remind these women to go for these much needed medical checkups.

Out of the approximate 130 births recorded monthly in an average health center, data collected from questionnaires and interviews estimated that 50 to 90 mothers out of the annually recorded 350 start and finish the immunization process. This figure comparatively matches the notable drop in immunization levels from 47% in 1995 to 37% in 2000 as noted by Moller (2002). Many of these mothers believe in the use of traditional remedies or self medicating their children for a number of treatable illnesses such as malaria.

These activities have influenced the numbers of recorded infection rates of both immunizable diseases and treatable illnesses in comparison to other ailments; this is illustrated in Fig 2 below
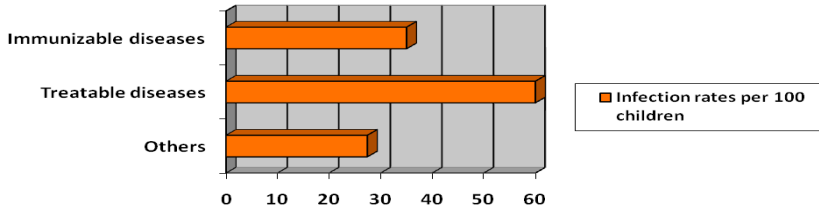

Figure 2: A bar chart showing disease contraction of infants in an average health center

Ssewanyana and Younger (2005) noted that, most infant deaths result from a combination of preventable or treatable diseases such as: Pneumonia, Diarrhoea, and Malaria and immunizable diseases such as Tuberculosis and Measles. Some of these diseases can easily be prevented through simple improvements in basic health services and proven interventions, such as: oral rehydration therapy, insecticide-treated mosquito nets, and vaccinations. Though the government through the Ministry of Health has endeavoured to curb these high infant mortality rates by carrying out malaria awareness campaigns (calling for the use of insecticide-treated mosquito nets) and recent immunization drives, the above as well as other factors still contribute to such high statistics. These are expanded on in Table 2 below.

Table 2: Factors that contribute to such high infant mortality rates and the rationale behind them

FACTORS	RATIONALE
Poor immunization coverage	• A notable drop in immunization levels from 47% in 1995 to 37% in 2000 as noted by Moller (2002). • Low political support for vaccination policies, Ssewanyana and Younger (2005). • Lack of popularity for the National Immunization Programme, Mukasa (2008).
Malnutrition or under-nutrition	• Families especially in rural Uganda cannot afford to have a balanced diet which is vital to the proper growth and development of a child's health. United Nations Department of Economic and Social Affairs (2008)
Low soci-economic status	• Families usually cannot afford basic health care. This is worsened by recent economic turmoil with the "credit crunch" This was noted by United Nations Department of Economic and Social Affairs (2008)

Poor antenatal and post natal care	• Inadequate services:
	
	  i. One midwife has over 200 pregnant women to oversee, Ssewanyana and Younger (2005).
	
	  ii. The proportion of deliveries assisted by a trained medical professional was essentially stagnant at 38% in 1989 and 39% in 2001, Lincetto *et al.* (2006)
	
	• Poor attitude of health workers who are overworked and underpaid, Mukasa (2008).

High HIV infection rates amongst pregnant women	• The presence of HIV has serious implications for antenatal care and delivery , it increases risks of maternal and infant mortality, Sine *et al.,* (2007)
Ignorance of young mothers	• This is especially because of the high number of adolescent pregnancies which contribute to the cycle of maternal deaths and childhood mortality, Ssewanyana and Younger (2005)

All in all, the medical professionals (the 16 respondents) were in total agreement that by reminding pregnant women to have antenatal checkups as well as reminding mothers or guardians to bring their children for immunization would be a positive step toward lowering infant mortality rates especially if implemented alongside with the already existing health campaigns that the Ministry of Health has already put in place.

4.   Imm system design

The existing medical Information System uses paper-based records with specialized cards designed by the Ministry of Health for healthcare units in Uganda. In a given health care facility, a pregnant woman is presented with an antenatal card which is used to capture her background information as well as her answers to pertinent health-related questions. This information is helpful to the midwife or doctor that is administering pre-natal health care.

This same card serves as a progress form for the pregnant woman for the duration of her pregnancy, with the aim of ensuring normal foetal health and development.

In the case of an infant, a child health card is presented at birth indicating birth weight, other relevant health and background information. It is using this form that an infant's health progress is monitored in terms of immunization, de-worming, weight gain, and general growth to ensure normal progress.
Patients are registered once, after which, with each visit, their medical records (cards) are pulled up for viewing, editing and updating their medical progress.

Table 3: Activities of existing system users

SYSTEM USER	SUMMARY	DESCRIPTION
DOCTOR	Individual responsible for diagnosing, and treating extreme medical cases	• Query system for extreme medical cases • Views and updates an infant's or a pregnant woman's medical records and reports
NURSE	Individual responsible for handling child ailments and immunizations	• Registers infants • Query system for existing infants medical records • Modify/update/delete an infant's medical records. • Refer extreme medical cases to the Doctor.
MIDWIFE	Individual responsible for monitoring and maintaining the health of pregnant women	• Registers pregnant women • Query system for existing patient's antenatal medical records • Modify/update/delete a pregnant woman's medical records. • Refer extreme medical cases to the Doctor.

4.1 system Analysis
The requirements of the system are categorized into functional, non-functional requirements and system specifications.

4.1.1   Functional Requirements
The following are the system's functional requirements:
- The system should capture processes and store patient information.
- The Infant and Maternal Monitoring System should permit the querying of patient records by authorized users.
- The system should allow users to view patient information as needed and generate patient reports based on end users command.
- The system should send SMS text messages to respective patients when necessary.
- The system users should be able to post articles on the website as well as discuss topics in the discussion forum.

4.1.2 Non-Functional Requirements

These are not directly concerned with specific functions delivered by the system. They pertain to system properties such as: reliability and accuracy to mention but a few, Sommerville (2001). The following are the non-functional requirements:

- The system allows access to only authorized users who are expected to have a username and password.
- The system is easy to learn and use by its end users.
- The system is efficient so as not to waste system resources
- The system is portable so that it may easily run on most operating systems
- The system is reliable because the application is a standalone system relying on database stored on a remote server hence allowing for fast system start up.
- The data output will be accurate since the input data is validated.
- The system is easy to maintain since it is modular and object oriented
- The system can be adapted to allow for system expansion in patient numbers or staff hence scalability.

4.1.3 system Specification

In order for the system to perform as expected, these are its specifications for hardware and software

Table 4: Hardware Requirements

Hardware	Minimum System Requirements
Processor	Intel Pentium IV or Higher for desktops
Memory	512 MB of RAM or higher
Hard Drive space	10GB
Monitor display	1024 × 768 High color-16 bit Recommended

Table 5: Software Requirements

Software	Minimum System Requirements
Operating Systems	Windows 2000, Windows NT, Windows XP and Windows Server 2003 Enterprise Edition
Database	MS SQL Server 2005
Server	MS SQL Server 2005, Ozeki Messaging Server

4.1.5 System Constraints

i.   The system will only be accessible to authorized users.
ii. A patient may only register once.
iii. Different users are limited to particular views of information.
iv. An Internet connection is required.

4.2   System Architecture

The Infant and Maternal Monitoring System (IMMS) acts as the vehicle for various functionalities (SMS functionality, data storage, discussion forum capabilities, etc). The SMS functionally operates as the cornerstone of the IMM System. It is achieved through the use of Ozeki SMS Server - an interface between the system database and a telecom company service provider which then routes messages (reminders for appointments) to the respective patient's mobile telephone.

The Data Storage functionality creates a secure record keeping facility that stores and maintains data concerning mainly patients (Pregnant women and Infants), while structuring the interaction with third party applications that allow system users (doctors, nurses and midwives) to register themselves and their patients. A query system for existing patients' medical records as well as systems users' records is in play. The system has provisions for these records to be modified, updated, or deleted. Extreme medical cases can be referred to more qualified medical specialists if need be.

These system users are also entitled to use of a discussion forum over which they may interact with one another over the internet. IMM System's schematics are expressed in the diagram below.
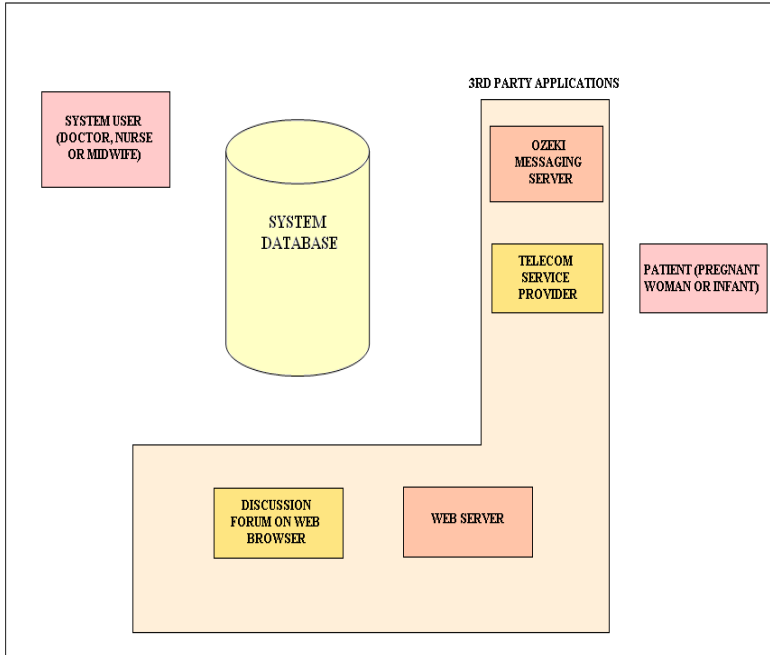
IMM System

Figure 3: A simple architectural layout of IMM System

5. Implementation

Several technologies were used during the implementation of this project. Most of the software used was chosen owing to the fact that it was readily available, cheap, and most importantly it supported rapid development time. These technologies are further explained below:

● MS SQL 2005 was the Database Management System (DBMS) used to implement the system's database. It was chosen because it was easy to use, highly customizable, yet low maintenance as a database management system.

● IIS (Internet Information Service): A web server application developed as a part of Windows server 2003 OS, with the aim of hosting web applications for example websites or other application that require web connectivity to share and access resource. It acts as the system's web server and functions as a launch pad for sending short messages to the different mothers.

● Visual Basic.Net (VB.NET): a multi-purpose computer programming language

from Microsoft that is suitable for most development needs. The language was employed with Rapid Application Development in mind; it provided several tools to shorten development time. VB.NET served to create the electronic medical forms and patient records.

● ASP.NET: a web application framework developed and marketed by Microsoft to allow programmers to build dynamic web sites, web applications and web services. This web development language helped in the programming of the system to send SMS' to the different mothers.

In conjunction with HTML (HyperText Mark-up Language) it also served to help in the creation of a website that enables a registered user to send questions and receive answers from other registered users. Pregnant women with internet access may also post their queries and learn more about healthy living.

● Ozeki: An SMS Messaging Server serves as an interface between the system application and the telecom company service provider which then routes messages to the respective patient's mobile telephones with the help of SQL queries.

Ozeki Message Server connects to the database through a standard ActiveX Data Objects (ADO) or Open Database Connectivity (ODBC) connection (Figure 4.2). Using this connection, Ozeki periodically queries the system database with the help of SQL queries and creates a database table called ozekimessageout from where it then broadcasts the messages accordingly.
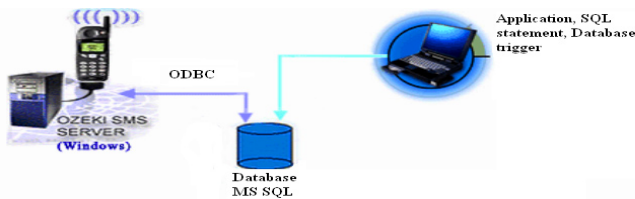

Figure 4.2: Infant Maternal Monitoring System SMS Functionality using Ozeki Message Server [Adapted from http://www.ozeki.hu]

5.1   The Prototype

The prototype has a front end interface, whereby a user has to enter his\her user name and password to Login. This is important since it ensures that the system is only accessed by authorized users. As seen below.

Figure 5.1: User Login for the System

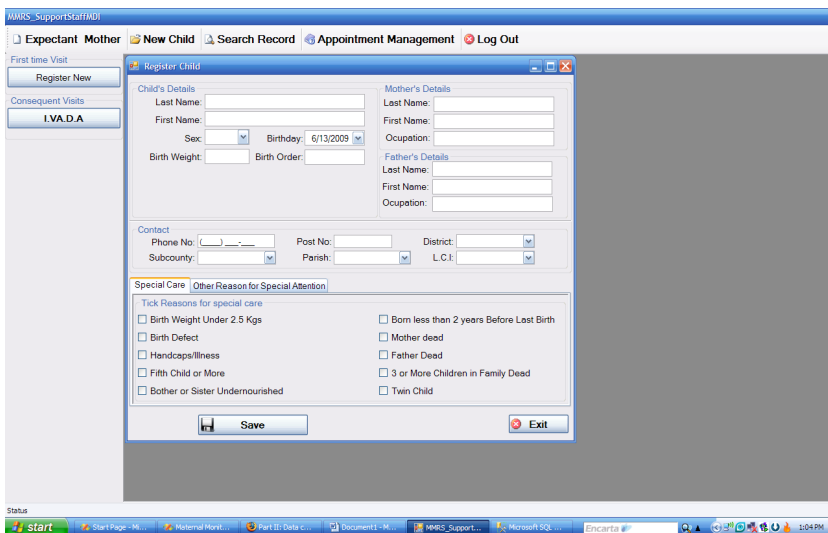*Electronic medical forms are used to register patients. These help to ensure accuracy*

Figure 5.2: Registration Form

Reports are important to enable medical practitioners to monitor the progress of a patient. The system allows for antenatal progress reports and child health reports.
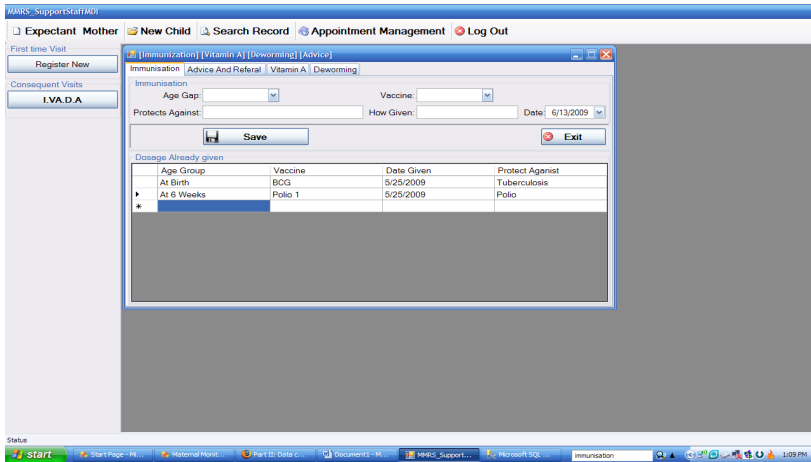
Figure 5.3: Child Immunization Report
Discussion forums allow medical practitioners to share information amongst themselves and to a small extent the general public. The forums are located on the website.
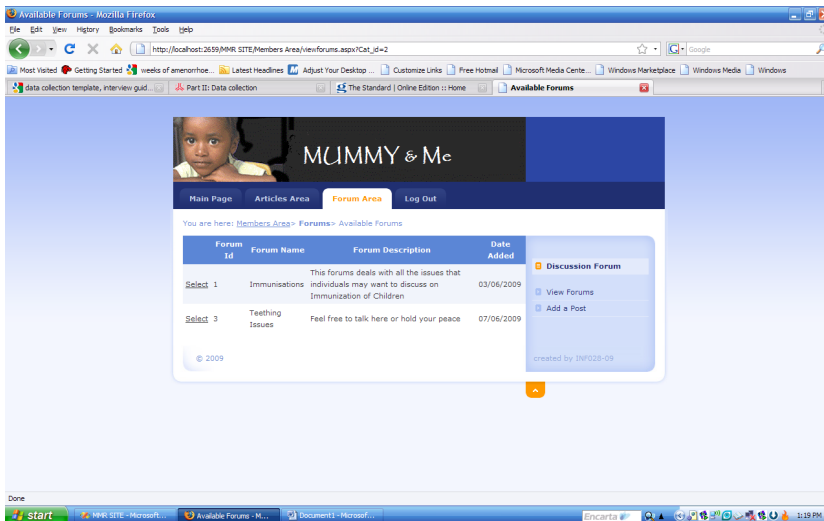

Figure 5.4: Discussion Forum

5.2   Sstem Testing and Validation

System testing involved internally checking the IMM System to identify errors and weaknesses and correct them accordingly. The following tests were used:

i. Unit testing: Which involved testing each module, class, or functions identitified in the system.

ii. Integration testing: Which consisted of the study how two (or more) units work together within a system

iii. System testing: This testing was carried out when all modules were integrated.

System Validation is the process of checking input data of a system to ensure that it is complete, accurate, and reasonable, Connolly and Begg, (2004). Usability testing was carried out with the complete system presented to end user representatives to verify whether it addressed all the user requirements and satisfied all the intended user needs. A questionnaire was designed to capture their responses, thoughts, and impressions for consideration by system developers. Adjustments were made accordingly to make the system more user-friendly, (see Appendix C).

6.   Conclusion

The research objectives were realised in the following ways:

Four randomly selected highly reputable health care facilities and the healthcare personnel - doctors, nurses and midwives (16 respondents in all) with a wealth of experience in the fields of antenatal and infant health care provided valid insight into those factors that have bearing on infant and maternal mortality in Uganda. The most prominent of which are, ignorance as to the importance of healthcare and generally forgetting important medical appointments. These can be resolved with the Infant and Maternal Monitoring System with the use of the Short Message Service (SMS) functionality to encourage pregnant women and mothers/guardians to take their infants to visit their nearest health centers to enable them get the required healthcare checkups, vaccinations or immunizations and basic health care.

The system design was realised by use of data flow diagrams and entity relationship diagrams.

The implementation was realized using MS SQL 2005, IIS 2003, VB.Net and Ozeki Message Server for the SMS functionality.

Added benefits IMM System offers include a discussion forum functionality, which improves communication and collaboration between medical practitioners thus increasing the rapidity and quality of patient care. All the while, the system as a whole automates the existing manually driven patient record keeping facility.

 Upon carrying out usability testing, end user representatives (medical professionals – doctors, nurses, and midwives) of the selected sample area were in agreement that

the Infant and Maternal Monitoring System if properly implemented would go a long way to help lower infant mortality rates.

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