Final Report

Zambian Electronic Perinatal Record System

SUBMITTED TO:

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RTI Project No. 0208330

14 June 2006

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Acknowledgements

The Authors would like to thank the hard-working Zambian medical personnel and students who contributed to the development and testing of one of the first networked electronic medical record systems and one of the most extensive wireless computer networks in sub-Saharan Africa. The Authors would like to give special thanks to the following CIDRZ and Lusaka Health District staff: Ethel Mwenzi, Emelda Kabwe, Dr. Christopher Ngandwe, Chafye Siulata and Dr. Macha. They were instrumental in ensuring that the software and training were appropriate and effective in Lusaka. In addition, we give special thanks to local team members Dennis Nkula, Francis Banda, and Jamie Mwenzi for their commitment and dedication to its success of this project. We also want to thank our colleagues at the University of Alabama Birmingham (UAB) for their dedication over many hours of tedious review to ensure that the software meets the needs of medical professionals and enhances the quality of care.

The authors wish to dedicate this work to the memory of Dr. Henry Phiri of the University Teaching Hospital in Lusaka, Zambia. Dr. Phiri was our senior Zambian medical adviser in determining the requirements for the ZEPRS Electronic Medical Record System. The loss of Dr. Phiri in 2004 was a serious loss to all who knew this fine man, including the members of the RTI ZEPRS team.

Executive Summary

The Zambian Electronic Perinatal Record System (ZEPRS) is a web-based Electronic Medical Record (EMR) system designed for public obstetric clinics and the University Teaching Hospital (UTH) in Lusaka. RTI International (RTI) has developed ZEPRS under contract to the University of Alabama at Birmingham (UAB) with funding from the Bill & Melinda Gates Foundation. A team of UAB and Zambian doctors conceived the idea based on the very successful model of a perinatal records system that the UAB had built in Birmingham, Alabama, that had improved patient outcomes there.

This project was designed to improve the quality of perinatal care in 24 participating clinics and the UTH in the Lusaka Urban Heath District (LUHD) by:

- allowing better and more timely access to patient records;
- implementing patient-care prompts into the system to make sure critical care issues are addressed during each pregnancy and from pregnancy to pregnancy;
- enabling health administrators and researchers to access data to help design interventions to further improve perinatal patient care; and
- providing health researchers with data needed to target and design interventions to improve public health.

The project began by designing and developing a wireless network interconnecting 24 clinics, the UTH, the Lusaka District Health Office, and the Centre for Infectious Disease Research in Zambia (CIDRZ). This network expanded to connect multiple buildings at delivery clinics and to network all relevant departments within the UTH using a combination of fiber-optic, wired, and wireless networking technologies.

In July 2004 the connected clinics and the UTH began using a web-based electronic patient referral system developed by this project. This application proved the functionality of the ZEPRS wireless network and the ability of Zambian medical personnel to use such a web-based application effectively.

The ZEPRS Version 1.0 (v1.0) integrated EMR and referral system was released officially by RTI on November 21, 2005. Nine clinics, four clinic labor wards, and two blocks at UTH are now using ZEPRS v1.0. Nearly four thousand new antenatal patients and nearly five thousand total visits have been entered into the system. The ZEPRS v1.0 roll-out is on schedule with two to three new clinics being added each month. Early evidence indicates that the system is already helping to improve the quality of patient care. Feedback from users and rapid adjustments are helping to build user ownership of the application.

Prolonged electric outages at a few clinics, lightening damage to network equipment, and a stretched technical support team pose challenges. RTI added the capability to print patient record summary cards that can be used for reference and recordkeeping during extended electrical outages. RTI is currently testing enhancements that enable ZEPRS users to continue using the system during network outages. This feature caches data off-line and resynchronizes with central databases when network connectivity is restored.

RTI developed ZEPRS using open-source components and best-of-breed extensible web-based layered architecture. This minimizes operating costs and makes it easier to expand usage within Zambia and to transfer and adapt the application to other countries.

Signatures and Approvals

Zambian Electronic Perinatal Record System

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Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
ANC	Antenatal Clinic
AP	wireless network Access Point
ART	Anti-Retroviral Therapy
BS	Base Station
CAZ	Communication Authority of Zambia
CB	Citizens Band
CBOH	Central Board of Health
CIDRZ	Centre for Infectious Disease Research in Zambia
CPU	Central Processing Unit
DALY	Disability Adjusted to Life Years
DNS	Domain Name Service
EDD	Estimated Date of Delivery
EGA	Estimated Gestational Age
EMR	Electronic Medical Record
GHz	Gigahertz
HIV	Human Immunodeficiency Virus
HP	Hewlett-Packard
IBM	International Business Machines
ICT	Information and Communication Technology
IT	Information Technology
JDBC	Java Database Connectivity
JVM	Java Virtual Machine
LAN	Local Area Network
LOS	Line of Sight
LUHD	Lusaka Urban Health District
LUDHMB	Lusaka Urban District Health Management Board
LUDHMT	Lusaka Urban District Health Management Team
Mbps	Megabits per second
MoH	Ministry of Health
MRTG	Multi Router Traffic Grapher
MVC	Model-View-Controller
NICU	Neonatal Intensive Care Unit
ORM	Object Relational Mapping
PBX	Private Branch eXchange
PC	personal computer
PEPFAR	The President's Emergency Program for AIDS Relief
PMTCT	Prevention of Mother to Child Transfer
PTP	Point-to-Point
PTS	Patient Tracking System
RADIUS	Remote Authentication Dial-In User Service
RTI	Research Triangle Institute
SMS	Short Message Service
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
SQL	Structured Query Language

SU ..... Subscriber Unit
U ..... network rack Unit
UAB ..... University of Alabama Birmingham
UI ..... User Interface
UNICEF ..... United Nations Children's Fund
UPS ..... Uninterruptible Power Supply
U.S. ..... United States of America
USD ..... U. S. Dollar
UTH ..... University Teaching Hospital
VA ..... Volt-Ampere
VCT ..... Voluntary Counseling and Testing
VHF ..... Very High Frequency
VoIP ..... Voice over Internet Protocol
WAN ..... Wide Area Network
WEP ..... Wired Equivalent Privacy
WHO ..... World Health Organization
WUG ..... What's Up Gold
XML ..... eXtensible Markup Language
ZAR ..... South African Rand
ZEPRS ..... Zambian Electronic Perinatal Record System
ZNBC ..... Zambia National Broadcasting Corp.

1 Introduction

On July 22 and 23, 2004, nurses and midwives in the Chawama, George, and Chipata health clinics in Lusaka, Zambia, referred patients for treatment to the labor ward, the antenatal clinic, and the neonatal intensive care unit of the University Teaching Hospital (UTH). For the first time, nurses entered the information into a computer that transmitted the information to a centralized database that the hospital accessed over a high-speed wireless network. The system instantly alerted medical staff in the appropriate department of the hospital, giving them vital information with which to prepare for patient arrival. When the patients arrived at the hospital, medical personnel were ready. They knew when the patients would arrive and what to do. They used the same system to notify the referring clinic when the patients had arrived and what action had been taken. Historical information on referrals remains accessible to authorized medical personnel at UTH and the 24 clinics over the wireless network.

The Zambian Electronic Perinatal Record System (ZEPRS), a Web-based electronic medical records and referral system, is one of the first of its kind in sub-Saharan Africa. It is designed to help improve perinatal care in Lusaka, and contains features designed to help in Prevention of Mother to Child Transmission (PMTCT) of HIV/AIDS, including support for voluntary counseling and testing (VCT). ZEPRS provides online management of records for perinatal patients in 24 networked clinics, the University Teaching Hospital, the Lusaka District Health Management Team, and the Ministry of Health over the ZEPRS high-speed wireless network. ZEPRS has been developed by RTI, the University of Alabama at Birmingham (UAB), and the Centre for Infectious Disease Research in Zambia (CIDRZ) with funding from the Bill & Melinda Gates Foundation.

ZEPRS is designed to improve the quality of perinatal health care by:

- improving access to patient records;
- alerting medical personnel automatically to make sure individual critical care issues are addressed;
- enabling Zambian health administrators and researchers to access data needed to further improve patient care; and
- providing health researchers with data needed to target and design interventions to improve public health.

ZEPRS is built using open-source components and best-of-breed extensible Web-based layered architecture. This minimizes software licensing costs and makes it easier to expand usage within Zambia and to transfer and adapt the system to other countries. The application and electronic patient records are maintained in a central data center established at CIDRZ. Medical personnel in connected facilities access the ZEPRS application through a Web browser. In 2004, RTI worked with the UAB and CIDRZ to develop a derivative web application for managing ART patient treatment. This application does not require network connectivity, but can use a central database if network connectivity is available. RTI is currently testing enhancements that enable ZEPRS to continue to be used in facilities through extended network outages.

The original period of performance for this project was January 1, 2002 through June 30, 2005. On June 21, 2004, the contract was amended to add $300,716 in funds for higher than expected

wireless network equipment costs, and to add VoIP capability to the network. On July 26, 2004, the contract was amended to change the RTI Project Manager from Gordon Cressman to Eileen Reynolds, and to change the UAB administrative contact. On August 6, 2004, the June 21. 2004 contract amendment was resubmitted and signed under Project Manager Eileen Reynolds. The contract was further amended on August 9, 2004, to transfer responsibility for managing software testing in Lusaka to the UAB, to clarify the fixed price payment benchmarks, and to grant a no-cost extension to September 30, 2004. A contract amendment on October 4, 2005, further extended the period of performance to November 15, 2005. Finally, on March 24, 2006, the contract was amended to add $99,856 to the cost reimbursement component for additional software enhancements, and to extend the period of performance to September 30, 2006.

2 Background and Objectives

In 2002 the World Health Organization (WHO) and UNICEF estimated that a Zambian woman's risk of dying in pregnancy was around 940/100,000. In comparison a woman's risk of dying in pregnancy was less than 12/100,000 in the U.S. A Zambian woman's lifetime risk of death in pregnancy was 1/25. The current Disability Adjusted Life Years (DALY) at birth for Zambian women was 30.7 years (compared with 72.6 years in the U.S.) Joint UAB-Zambian studies conducted in the Lusaka District clinics found that nearly one-third of pregnant women were infected with HIV. If untreated almost half of these women would transmit the fatal infection to their infants.

As described in the UAB PROPOSAL TO THE BILL AND MELINDA GATES FOUNDATION TO ESTABLISH AN ELECTRONIC DATABASE-DRIVEN PERINATAL RECORD SYSTEM FOR A DEVELOPING COUNTRY (2002), essentially all western-style health care for the roughly 2 million citizens in Lusaka was delivered through a network of 24[1] satellite clinics and the University Teaching Hospital (UTH). In 2002, 13 of the 24 clinics provided antenatal care. Some have small outpatient units, and nine had active labor wards. The total number of obstetric cases managed by the entire system was estimated in 2002 by the UAB to be 47,000 per year.[2] The treatment protocol and paper patient records system used by these clinics appeared in relatively good order on paper, but the UAB saw significant problems in operation. These included frequent failure to provide follow-up treatment for patients diagnosed with sexually transmitted diseases (STDs), and failure in some cases to test for these diseases at all. Patients may visit any of the clinics at any time, but the paper-based system did not allow clinics to share patient information easily. There was no central database for monitoring the patient population or the quality of care.

Exhibit 1 Medical Records at the UTH in 2002

A central database could also be used to design and monitor surveillance-driven interventions. This would help clinics implement individual diagnosis and treatment protocols thoroughly and efficiently. It would make it easier to monitor performance of clinics, medical personnel, and the entire system of clinics. Finally it would build a database for longitudinal outcome surveillance, analysis of potential interventions, and monitoring of selected interventions as they are implemented. Based on experience with a similar system in Birmingham over the

[1] The number of clinics in the original proposal and budget was 23. During the course of this project the LUHD completed the construction of a new clinic, Bauleni Clinic, bringing the total number to 24. All 24 clinics have been included in the ZEPRS project. The total number of facilities to be connected to the network in RTI's original proposal is 25. The total number of facilities actually connected is 27.

[2] In 2005 the total number of obstetric cases managed by this system was approximately 55,000.

previous 25 years, the UAB believed such a system should, if carefully designed and implemented, improve care, save many lives, and serve as a model that could be transferred to other developing countries.

The major objectives of this project are as follows:

- To improve the quality of perinatal care significantly in 24 participating clinics of the Lusaka Urban District.
- To build local capacity for badly needed research in pregnancy outcome improvement in Zambia.
- To adapt a perinatal record information system approach proven over many years in Birmingham, Alabama to the Zambian context so that it can be transferred easily to other developing countries.

Once operational in 24 clinics, the UTH, and the Ministry of Health, data from the perinatal record system could be used for the following studies:

- Longitudinal outcome surveillance on the population of mothers and babies served by the health system to identify priority areas of improvement.
- Assessing the impact of surveillance-driven interventions known to be effective and cost-effective
- Investigating new resource-appropriate interventions to improve priority areas identified by surveillance.
- Demonstrating the utility and practically of the perinatal record system for potential application in other developing countries.

3 Scope of Work

RTI worked in close collaboration with the UAB and local counterparts including the Zambian Ministry of Health (MoH), Lusaka Urban Health District, University of Zambia Teaching Hospital (UTH), and CIDRZ to complete the Information and Communications Technology (ICT) components of this project in Lusaka within the four-year period of performance (2002-2005).

These components included the following:

- A Local Area Network (LAN) of up to five workstations in each of 24 public health care clinics selected by the UAB
- A LAN of up to five workstations in the UTH[3]
- A LAN of up to five workstations in the Ministry of Health
- A data center supporting the electronic perinatal records management system
- A wireless Wide Area Network (WAN) connecting clinics, UTH, CIDRZ, and MoH into a single network with access to the perinatal records management system.
- A Web-based perinatal records management system designed in conjunction with UAB to serve the needs of the Lusaka Urban Health District

[3] As documented in this report, the LAN implemented by this project at the UTH is much more extensive than described in the original scope of work.

RTI has been responsible for the following tasks directly or through the use of consultants and subcontractors, and in concert with the UAB-Zambian team:

- Assessment of local ICT environment and providers
- Assessment of sites to be networked
- Overall technical strategy and systems integration
- Technical specification of all components
- Monitoring and supervision of ICT subcontractors
- Software design, development, and testing
- System documentation in English
- Development of user documentation in English

Following sections describe the results of these activities in detail.

4 Initial Assessment

RTI conducted an initial assessment visit to Lusaka in April of 2002. At the beginning of the project all patient records were maintained on paper. Perinatal patient records were maintained in small "obstetric blue books" carried by patients. These were sometimes lost, and historical records were not accessible for subsequent pregnancies.

Clinics, though relatively clean and orderly by developing country standards, were dusty, and often very crowded. There is very little unused space, and no air conditioning. The structures were masonry, including all interior partitions. Physical security was weak; some facilities had unprotected openings in walls and roofs.

A few stand-alone PCs had been installed in one clinic to test a Microsoft Access-based pediatric application. Only a few of the medical personnel in these clinics had ever used a computer.

Only 7 of 23 clinics had wired telephones. Clinics depended primarily on VHF radio for communications in emergencies, and for coordinating patient referrals. Each clinic had a radio mast. The wired telephone system in Lusaka was poor. There were no wired broadband providers. Most organizations used dial-up Internet access. Higher speed 2.4GHz wireless networks were becoming increasingly common so this frequency band was becoming congested.

No reliable data was available on electrical grid conditions. Interviews indicated that some clinics could be without power for up to two (2) hours at a time, while a few could be without power for several days during the rainy season. In the latter case clinics are often closed due to flooding in the area. We determined that all ZEPRS network and computer equipment would require at least four (4) hours of battery backup time. Clinic electrical systems were inadequate for computer and network equipment.

5 Network and Computing Infrastructure

When the ZEPRS project was first started, in early 2002, the design for a network of clinics i n the city of Lusaka, Zambia called for an expandable and robust Wide Area Network (WAN) to be setup. This network was meant to achieve the following goals of resiliency, expandability and low-cost and at the same time allow the interoperability of equipment from different providers.

To achieve these goals, RTI staff worked together with regional firms to decide on the basic design for this network and its minimum specifications together with a growth path for the coming years.

Given the low availability and reach of the communications infrastructure in the city (poor telephone lines, nonexistent metropolitan fiber optics rings) the most adequate option to interconnect all the centers in this network was using wireless links. The scenario is not uncommon to other cities in Africa and technical skills and equipment is usually available from local resellers.

As shown in exhibit ??, the basic layout called for a set of four "high sites" each one connected with a 45Mbps link in a star-shaped design and from each site a 10Mbps direct link to the participating clinics and centers.

This design allows for great flexibility and reduces the numbers of hops from the clinics to the datacenter while it can be easily interconnected in a partial mesh design to improve reliability.

Aware of the increasing saturation of the 2.4GHz band in Lusaka it was decided to use equipment in the 5.8GHz band for the network backbone and the last-mile connection to the clinics, while 2.4GHz equipment was used in some non-core point-to-point (PTP) links and mostly reserved for local networks.

Exhibit 2 General Illustration of Backbone Wireless Network Topology

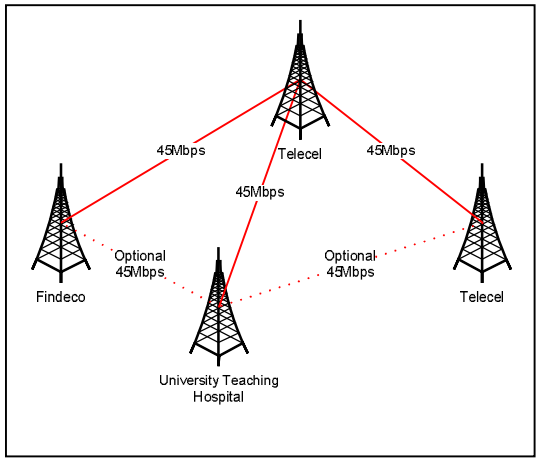
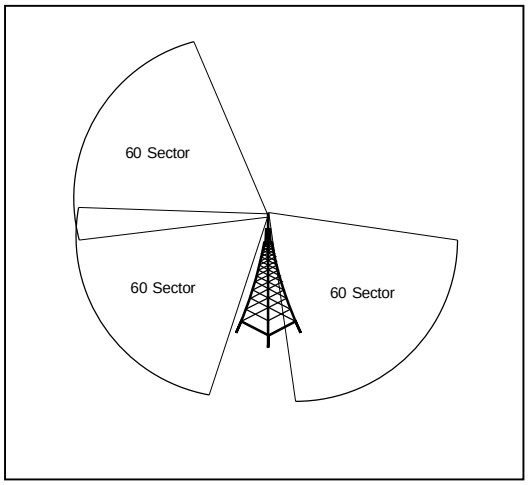


Exhibit 3 General Illustration of Sector Coverage by a High Site Wireless Network Base Station



5.1 Wireless Backbone Links

Arrangements were made with Telecel, a local mobile telephony provider, to co-locate our equipment in two of their 240 foot (61m) towers and with the administrators of the FINDECO building, almost 300 feet (91m) above surface. This avoided the cost of constructing masts needed for the main hub sites. With the

towers secured, the first 5.8GHz/45Mbps Tsunami point-to-point links were installed, building the network backbone and its main link to the datacenter, then still under construction.

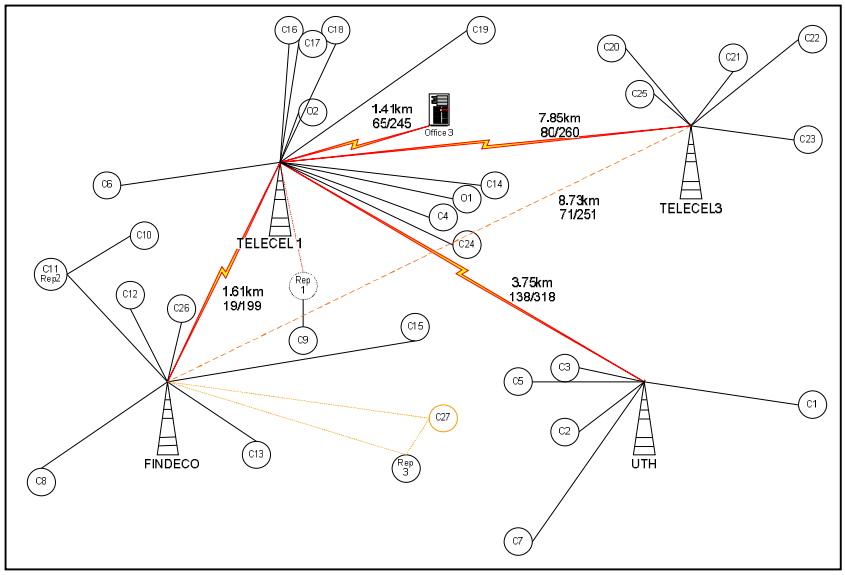
Each tower was provided with a set of point-to-multipoint base stations (BS) from Proxim, also in the 5.8GHz band and with a maximum throughput each of 20Mbps. Each base station covers an area of approximately 60? and each main site has from two to six base stations to cover a sector from 120? to 360?, depending on the physical location of the clinics it serves. The coverage area of each main site can be reconfigured by adding or removing base station units.

The range for each base station (10 Kms.) was appropriate for most base-station-to-subscriber-unit links, but since this band requires unrestricted line of sight (LOS) and since some places were located near the maximum reach of these units, additional point-to-point (PTP) equipment had to be installed in some locations to ensure proper coverage of all the clinics. The Quickbridge units from Proxim were selected due to their low cost and ease of installation at these locations.

5.2 Connecting Clinics

All the participating clinics were provided with one Tsunami subscriber unit (SU) capable of providing a maximum throughput of 17Mbps, each one pointed to one of the already installed base stations, and terminated internally on a 100Mbps switch.

Exhibit 4 Wireless Network Topology Showing Subscriber Links to Clinics

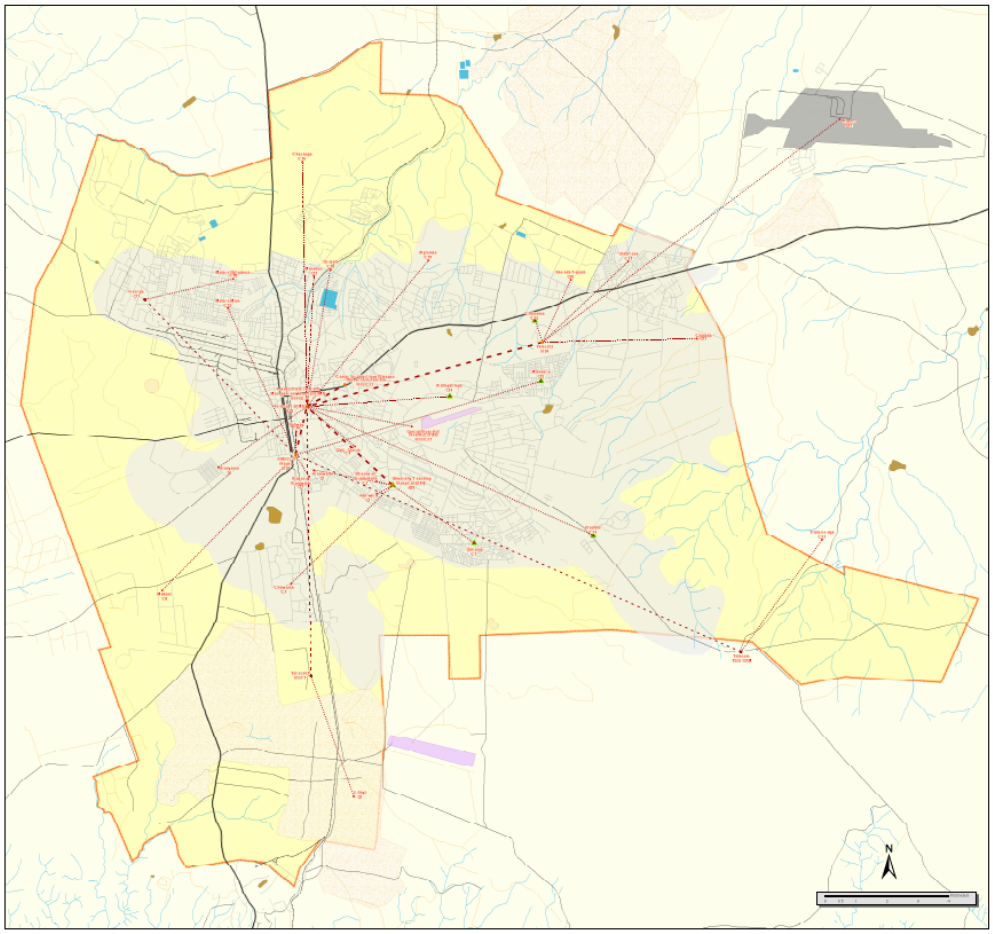


Indoor equipment at clinics, UTH, MoH, and CIDRZ was installed in wall-mounted 4U racks with fans and protected with an APC SmartUPS 1500 automatic battery backup unit. Automatic voltage regulators manufactured by TSi Power were installed between UPS units and utility power at all four high sites and at six clinics where data from UPS battery backup units indicated the need for additional upstream voltage regulation.

In order to protect this equipment against electrical discharges (such as lightning, very common in Zambia's rainy season), network lightening suppressors manufactured by Transtector (Part Number APLU-TSU) and Polyphaser (Part Number IX-2H2DC48/W) were installed using two units on each connecting cable, one near the outdoor unit, and one near the cable entrance to the building. This provided the best available protection against lightning. The power -over-Ethernet connectors (PoE) saved many hours of work during the installation and allowed us to protect both data and power lines with the same filter.

Upon completion of this backbone, the network connected 25 different locations in Lusaka and was ready to be expanded at each location. Exhibit 5 shows ZEPRS network sites and links in Lusaka, Zambia. Wireless network backbone links are shown by wide dashed lines, while subscriber links are shown by thin dashed lines.

Exhibit 5 Map of Lusaka, Zambia, Sh owing ZEPRS Network Sites and Links

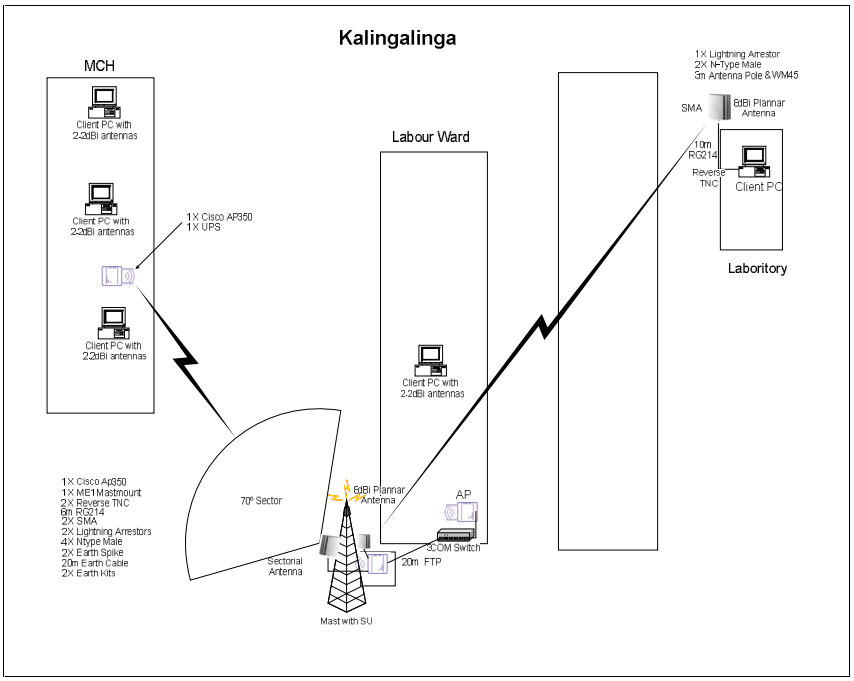


5.3 Local Area Networks

All clinic networks and most network equipment installed at the UTH is wireless. Due to its broad market penetration and interoperability, 802.11b was chosen as the standard (with a clear upgrade path to 802.11g in the future).

To simplify the required support skills and the time to troubleshoot the LAN equipment, all the clinics were furnished with the same LAN hardware consisting of one 100Mbps desktop switch, one SmartUPS 1500 with an additional battery, one MVP 210 VoIP adapter and one Cisco Aironet 350 access point, all located in a wall-mounted cabinet. From that basic LAN "kit," other devices were added to allow for extended wireless coverage: running cables to connect additional wireless access points at the UTH halls or directional antennas to link far-off wards with wireless repeaters. Exhibit ?? is an example diagram showing how multiple buildings are connected at Kalingalinga Clinic.

Exhibit 6 Diagram Showing Local Area Network Connections at Kalingalina Clinic



The LAN at UTH is extensive. It includes a fiber optic backbone connecting building switches that connect to wireless access points using Category 5 copper Unshielded Twisted Pair (UTP) cable. The fiber optic backbone runs the length of a covered walkway that interconnects the buildings of the hospital. On the Ground Floor of the hospital the network connects PCs in the Main Reception, Consultation Ward, Examination Hall, BO3 Ward, and B01 Ward. These locations are in three separate buildings. On the First Floor of the hospital the network connects PCs in the Labour Ward, Nursery, B13 Ward, C11 Ward, and Neonatal Ward. These locations are in four separate building. Wireless Subscriber Units mounted on the roof in two separate locations connect this network to the Base Station Unit mounted on a mast at the hospital Library.

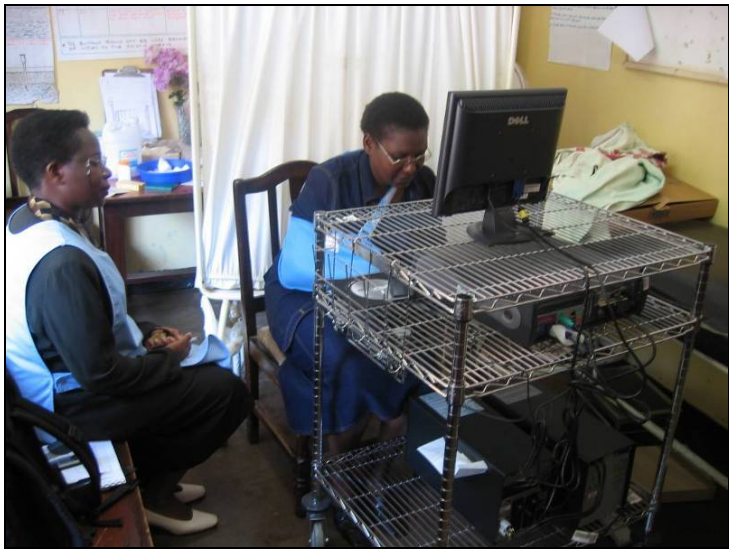
5.4 Client Computers

The main requirement for the computers within the clinics was mobility. Other important issues to consider were cost, theft-deterrence, and mobile printing capacity. The possibility of using laptop computers was discarded, and instead a series of small-footprint desktop

computers were selected (Dell Optiplex[4]) and installed on mobile carts, each provided with an APS SmartUPS 1500 battery backup system, an additional battery for the UPS, an HP LaserJet printer with a wireless print server, and security cables connecting every device to its metal cart for added security. Each battery set will provide up to seven (7) hours of uninterrupted operation. This is significantly longer than the (4) hour design requirement established by RTI based on information collected during the initial site assessment.

Initially the project had custom designed closed metal carts manufactured in South Africa. These proved expensive and provided a hiding place for rodents. Available commercial wire carts were found to be a better and less expensive solution. The carts can be moved very easily and are sturdy enough to ensure that the equipment is reasonably safe from accidental mishaps or theft. Cable locks with master keys have been provided to secure equipment to the carts, including keyboards and mice, and to prevent unauthorized users from opening the computers.

Exhibit 7 Midwife using a ZEPRS Mobile Computer Cart in a Clinic



There are three different computer models used at the clinics, hospital and datacenter, two from Dell and one from IBM. Local technical support staff created and maintained a desktop computer software image for each model. Performing the rollouts using standard software images allowed the team to keep a standardized software base and to reduce the time required for desktop troubleshooting.

All software updates are managed centrally through an instance of Windows Update Services running on the datacenter. Desktop computers are configured to check in at different times to download operator-approved software updates. Local technical support staff members have been operating with this model for more than a year now and through three separate computer rollouts with excellent results.

[4] PCs manufactured by IBM were used for the first deployment of PCs. Dell Optiplex PCs were selected for the second much larger deployment based on local support, features, and cost.

5.5 Datacenter

The datacenter for the project is located at CIDRZ. Three Dell PowerEdge 2450 servers running Linux, with an external storage unit and a multi-tape capable backup unit share the load for the Java application engine, provide replicated database services, web services, email services, Domain Name Service (DNS), wireless authentication security through Remote Authentication Dial-In User Service (RADIUS), and help on the monitoring of the network.

The Exhibit 8 lists the main products used at the datacenter.

Exhibit 8 Key Software Platform Components in the ZEPRS Datacenter

Platform Component	Selected Solution [5]
Server Operating System	Red Hat Enterprise Server 3
Server Backup	Arkeia Backup 5.2
Wireless Authentication	AEGIS Premium Server 1.1.4
Relational Database	MySQL 4.0
Web Application Server	Apache 2 + Tomcat 5
E-mail	Cyrus IMAP, Sendmail, Spam Assassin with Squirrel Mail E-mail Web Interface
Firewall	SonicWALL
Client Anti-virus	McAfee VirusScan 8
E-mail Server Anti-virus	AMaVIS

A Windows 2000 Server in the datacenter supports Windows-based monitoring applications and desktop computer software and virus signature update services.

A Dell tape changer simplifies the backup process and prevents errors that may result from inserting tapes out of sequence, or forgetting to replace them. All the backup functions are performed by an instance of Arkeia backup running under Linux and with agents running on the other servers to provide for centralized backup.

Internet connectivity is also provided and managed at the datacenter level, with one dedicated, multi-port firewall filtering traffic and keeping the different networks secure and one server providing caching and traffic shaping services for the client computers.

These servers, together with the communications equipment, including the existing Private Branch eXchange (PBX) system and the newly-installed VoIP system, are located in a closed room with a password-protected lock and protected by a 3000VA UPS connected to an auto-starting diesel generator.

[5] The indicated versions are those installed when the datacenter was completed. Upgrades within the same product line may have been installed since that time

5.6 Network layout

In its first stage, the network was conceived as a single switched broadcast domain, with 100Mbps switches at each main sites and 100Mbps switches at each clinic. This decision was based on the estimated total number of devices to be installed on the network (approximately 150) and the fact that each high site can be turned into a separate segment by adding a router if traffic or redundancy needs make it necessary.

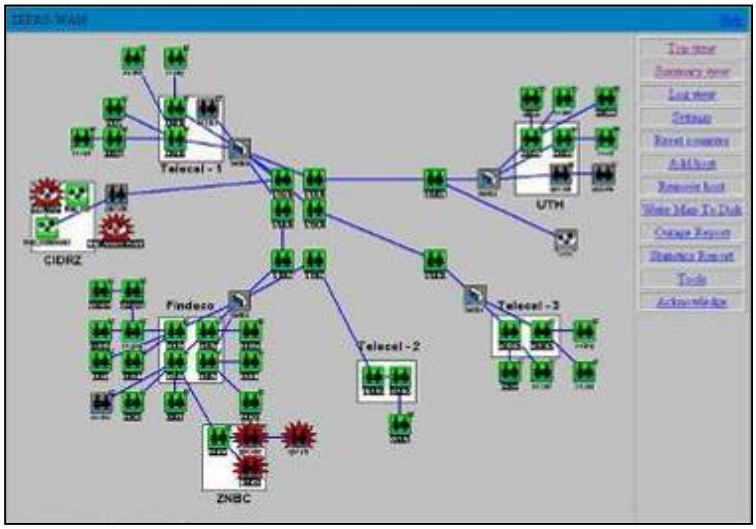
The initial traffic measurements and the ongoing monitoring of the network showed that excessive broadcasts were not an issue. To help reduce unwanted or "overhead" traffic to a minimum, the protocol and applications suite to be installed at each desktop was carefully evaluated to reduce network traffic.

5.7 Network Monitoring

All of the devices that form the network infrastructure, together with the servers and the services they provide are monitored 24 hours per day and seven (7) days per week from the datacenter. Data related to uptime, faults, and performance are collected regularly and can be queried easily to help troubleshooting and capacity planning efforts.

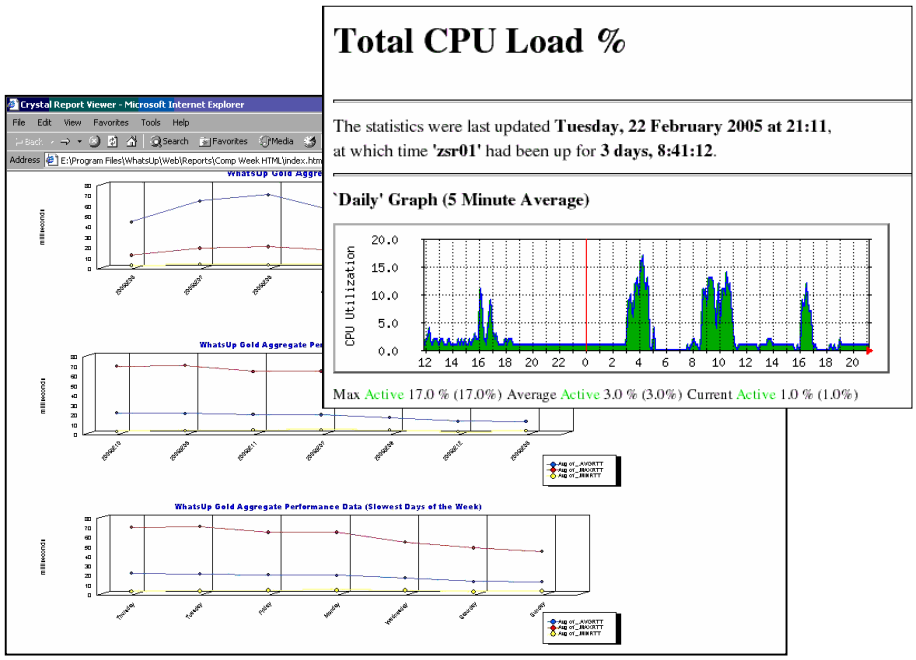
The main tool for real-time data collection and display is What's Up Gold (WUG). This tool keeps an updated map of the network, reporting information on failed links, sending alerts via email and Short Message Service (SMS) to the technical staff mobile phones. Exhibit 9 shows an example network monitoring display. Components shown in green are available, while those shown in red are not reachable.

Exhibit 9 Display Used to Monitor Network Status



WUG is compliant with the Simple Network Management Protocol (SNMP) Version 2 and can communicate with the SNMP modules running on the wireless devices and the servers. On a weekly basis, WUG's automated report generation tool provides staff and management with customized reports on network uptime. Exhibit 10 shows examples of displays used to monitor the load on servers in the ZEPRS data center.

Exhibit 10 Displays Used to Monitor Network Server Performance over Time



As a long-term data collection tool, the Linux-based version of Multi Router Traffic Grapher (MRTG) is being used. MRTG collects information though SNMP for base-lining and historical analysis of performance on network traffic, storage space availability, power availability, processor utilization on the main servers, etc.

The management suite is completed with some custom-made scripts that allow for interoperability between the UPS management software (PowerChute) and the Linux servers in the datacenter.

With strong Web access, all these monitoring tools were of immense value to monitor the functioning of the network from remote locations while it was being constructed and are being used by local staff for daily network monitoring and maintenance.

5.8 VoIP Services

Voice services are necessary for clinics that sometimes must deal with life-threatening situations, but for many clinics in Lusaka the luxury of a phone line was a distant reality, mostly due to cost or the unavailability of phone lines in the area.

To work around this limitation, some of the clinics already had two-way radio equipment, similar to the kind used for CB (Citizens Band). This equipment was expensive, more complicated to use than telephone handset, and not widely installed, only allowing certain clinics to reach the UTH to inform of patient referrals and other incidents.

To leverage the installed network, a complete Voice over IP (VoIP) system was installed and interconnected with the existing PBX at CIDRZ.

Each clinic was provided with a Multitech MVP210 unit, capable of up to two phone connections each. This unit was located together with all the networking equipment at the clinic level and protected by the same UPS.

At the datacenter level, several Multitech MVP 810 units were installed to allow for termination of the lines from the clinics and to interconnect the existing telephone lines, allowing the system to reach to the national grid.

The Multitech system allows restricting calls to certain numbers and thus keeping strict control on the costs of running the telephone system.

Clinics now have a much easier way to communicate not only with CIDRZ and UTH, but also with other clinics. Nurses use standard telephone handsets to communicate over the VoIP system. They require no training to use the system and in case of emergency they can also reach numbers outside the VoIP network. The cost of using the VoIP system is limited to the cost of maintaining the equipment. There are no usage costs.

5.9 Security Management

Providing network security in this highly distributed, high-transit wireless environment required a careful evaluation of the risks involved together with a balance between usability and security.

The distributed wireless Access Points (APs) in the clinics were one of the main security concerns. We installed a Remote Authentication Dial-In User Service (RADIUS) server at the datacenter to secure and audit connections to the wireless APs. The RADIUS server authenticates each connection request to any of the APs on the network and negotiates dynamic Wired Equivalent Privacy (WEP) keys to encrypt all subsequent communications between the authenticated device and the AP. The RADIUS server maintains a log of all the devices connected to the network and it also allows for a way to centrally distribute configuration options (such as timeouts, security policies, etc) through RADIUS options.

The APs were also configured to send SNMP traps to the central management console and to inform of "rogue" APs detected, unsuccessful logins, and other security alert conditions. The network monitoring tools keep traffic information on all the wireless devices in the network to detect any strange network traffic patterns.

The configuration for the APs is centrally managed and replicated and updated to the APs over-the-wire, using a web-based application.

To allow for a simpler setup, desktop security is not centralized but instead each computer behaves like a thin client, with a minimum set of applications, a common login scheme and all the applications being accessed through a web-based interface. The web browser's interface has been heavily customized to restrict configuration changes and to present a cleaner look to the user.

Initially, all the servers, datacenter desktops and wireless network were located on the same network segment; this was deemed not secure and a proposal to create different "network domains" was drafted to UAB, where a central firewall will control the flow of data from one network to the other keeping a separate network for external services, such as Simple Mail Transfer Protocol (SMTP), main servers, IT personnel, and wireless clinics.

5.10 Configuration and Asset Management

RTI worked closely with the local staff on documenting the steps, technologies and services implemented on the network. These documents were placed in an electronic document library to serve as a reference, keeping this information readily available and ensuring the staff can easily understand what has been written and add to it in the future as the network evolves.

Along with the technical documentation, RTI's network specialist created a central repository for configuration files and policies and created documents detailing the regular maintenance and monitoring tasks needed to keep the network running smoothly.

To allow the project to keep control of the hardware belonging to the project, a web-based inventory system was installed; this simple system allows for the tracking of assets by location, the follow-up of service requests and the reporting and alerting functions needed to order consumables and spares parts and is backed by the existing web and database services running on the central servers.

5.11 Local Staff and Staff Training

A key aspect of sustainability of the ZEPRS network is to ensure that there is a strong local technical team able to troubleshoot any problems that arise and to perform routine maintenance. At every step of the installation of the network the local technical team -- ICT Coordinator, User Support Technician and Datacenter Technician -- participated in project activities and learned through on-the-job training; several dedicated training sessions were setup, and a laboratory (able to replicate the server installation at the datacenter) was constructed to allow the technicians to test new tools and practice with new configurations, without risking the stability of the network. An RTI home office network specialist and other project team members supported the local technical team with technical advice and training. The local technical team also attended Linux operating system and Proxim wireless network equipment training. RTI technical experts worked closely with the local technical team to apply the configuration and rollouts for networking equipment and PCs. RTI experts developed, tested and documented procedures which were then carried out by the local technical team with RTI guidance and supervision. This allowed the local technical team to learn by doing and encouraged their sense of ownership and pride.

5.12 Network Reliability

Initial use of the ZEPRS network began with electronic mail (email) as part of basic computer literacy training developed and managed by CIDRZ. By this time each clinic had been equipped with at least one networked PC on a mobile cart. Early network reliability problems were caused by the following:

- Users turning off UPS battery backup systems
- Rodents gnawing through network cables in enclosed mobile PC carts
- Marginal and unreliable wireless network connections between some subscriber units and base stations or relay points
- Equipment damaged due to lightning at network high sites
- Failure of on-site technical support staff to correctly diagnose and correct network problems
- Delays in getting replacement network equipment into Zambia

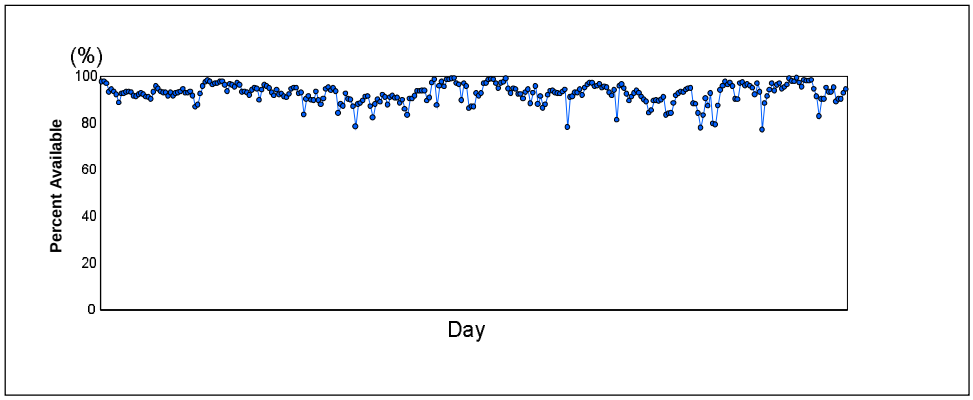
RTI took several actions to deal with these issues as follows:

- Posted signs near network equipment in all facilities, explaining the purpose of the equipment, how and when it should be turned off, and who to contact with any further questions
- Informed and educated clinic personnel during clinic visits and presentations
- Replaced enclosed metal carts with open wire carts, eliminating hiding places for rodents
- Provided clinics with rodent-resistant coating to protect exposed cables
- Updating network firmware at all points and correcting the configuration of network equipment
- Installing the best available lightning suppression equipment on network cables connecting all exterior mounted network equipment
- Installed automatic voltage regulators at all high sites and six clinics where data showed additional voltage regulation was needed.
- Mentoring local technical support staff in problem diagnosis and resolution, and management of day-to-day network operations
- Ensuring an adequate supply of on-site spare network equipment at CIDRZ for rapid replacement

A local rigger hired by the project was essential in installing additional lightening suppression devices at all mast sites.

Exhibit 11, generated by the WUG monitoring system, shows the impact of these efforts. This exhibit shows average overall network availability by day from September 1, 2004 through June 30, 2005 as a percentage of time. Therefore a value of 95 percent on this graph indicates that 95 percent of all monitored network equipment was reachable during that 24 hour period.. Network equipment being monitoring includes: bridges, base stations, repeaters, subscriber units, access points, VoIP equipment, and the Internet gateway. As shown in Exhibit ??, network availability fluctuated, but remained between 90 percent and 99 percent with the exception of a few days when availability dropped into the low 80s. Network availability improved steadily toward the end of this period, reaching an average of 95 percent uptime for the period by the end of June 2005, when RTI completed the transfer of responsibility for managing network operations to CIDRZ. While 95 percent availability is low by developed countries standards, it is a significant achievement in sub-Saharan Africa. In interpreting these figures it is important to understand the reasons why some network equipment was not reachable at various times.

Exhibit 11 Daily Average ZEPRS Network Availability September 1, 2004 - June 30, 2005



No empirical data on power reliability were available from the power utility during the network design phase. Anecdotal information collected by questioning medical personnel in the various clinics suggested that the most extended power outages lasted roughly two (2) hours and occurred during the rainy season in November through February. During this period road flooding near several of the most severely affected clinics could result in clinic closures lasting several days. However the majority of clinics reported no power outages lasting more than an hour.

Investigation by local technical support staff indicated that the extended outages were most likely caused by illegal tapping of electrical transformers near the three problem clinics. RTI provided cost estimates to the UAB and CIDRZ for suitable emergency backup generators. Unfortunately, project funds have not been available to purchase these units.

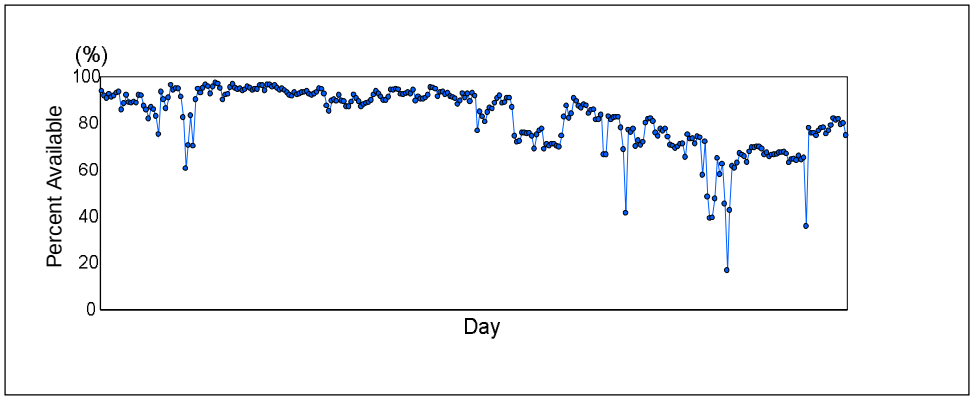
Line-of-site obstructions will be a reoccurring problem. Growing trees and, less frequently, new buildings may obscure what was a clear line-of-site between points on the wireless network. In many cases trees that grow to obstruct the line of site cannot be trimmed or removed because the owner will not permit this. To date the local ZEPRS technical support team has been able to adjust antennas around these obstructions.

Lightning proved to be a particularly serious problem during the November through February rainy season. Lightning suppression equipment had been installed on coaxial cabling at each site to protect mast-mounted wireless antennae. Sites co-located on cellular telephone towers were also protected by substantial earth grounding systems installed by the cellular telephone company. Network equipment was connected to the existing earth grounding system at each high site, but the initial installation did not include lightening suppression devices on twisted pair copper network cables connected to mast-mounted network equipment. Lightening damage to this equipment quickly made it clear that the earth grounding was not sufficient to protect these devices. As mentioned in Section 4.2, RTI installed lightning suppression units manufactured by Transtector (Part Number APLU-TSU) on all copper network cables connecting exterior network equipment. Cable lengths at network high sites proved to exceed limits supported by the Transtector units. RTI replaced units at these sites with units manufactured by Polyphaser (Part Number IX-2H2DC48/W) that were rated for these installations. These installations were managed by the local ZEPRS technical support team and were completed by a skilled local rigger according to specifications provided by RTI.

While these measures reduced equipment loss due to lightning damage, they have not eliminated the problem. In December 2005 a direct lightning strike on the TELECEL 1 tower destroyed cellular telephone equipment as well as CIDRZ wireless network equipment. It is doubtful any measures could be taken to protect against this type of direct strike.

As shown in Exhibit 12, overall average network reliability continued to be good for months after CIDRZ assumed responsibility for the network, but began to decrease rapidly late in 2005 and continuing in early 2006. Remote monitoring data shows most downtime in subscriber units and connected access points and VoIP equipment at several clinics.

Exhibit 12 Daily Average ZE PRS Network Availability July 1, 2005 - April 30, 2006



The most significant technical problems encountered to date are electrical and network reliability. However, the deterioration from an average of 95 percent availability at the end of September 2005 to an average of 80 percent availability at the end of April 2006 is due to a combination of factors. These include extended electrical failures at several clinics and equipment loss due to lightning. Discussions with CIDRZ also indicate that key technical support personnel have been diverted to meet the demands of other projects, and that the technical support team has not been closely managed in recent months. This has been a key factor. Due to demands from other projects the ZEPRS technical support team has been reduced from more than two (2) Full-Time Equivalent (FTE) personnel to only one (1). CIDRZ is aware that the support team is stretched very thin and is working to correct this situation.

6 Electronic Referral Application

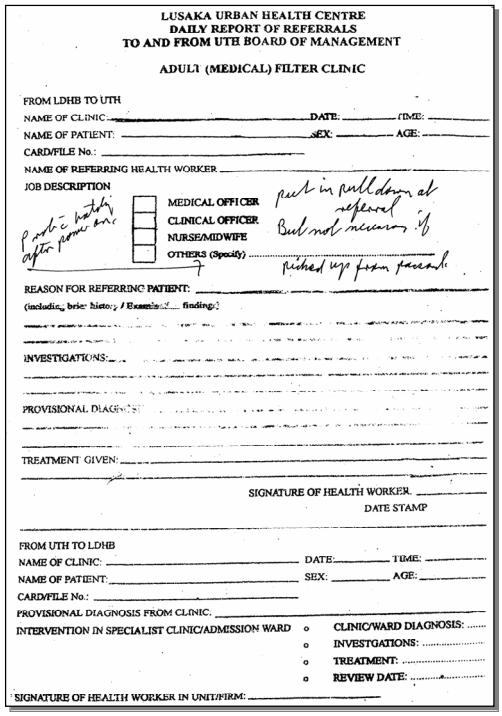
6.1 Description

When the ZEPRS project began, clinics in Lusaka referred patients to the UTH for acute care by voice using short range radio, the majority of clinics having no telephones. There was no system requiring the UTH to notify referring clinics concerning the status of referred patients. Thus patients were often 'lost' in the process and patient care continuity was difficult at best. Exhibit 13 is an example of the hardcopy patient referral form being used by clinics at the beginning of the ZEPRS project. The newly installed ZEPRS network provided a better alternative.

At the beginning of 2003 RTI recommended to the UAB construction of an electric patient referral system that would run over the ZEPRS network. This system would enable medical personnel working in the clinics to refer patients to the UTH for acute care. It would also provide the UTH with critical information concerning the condition of incoming patients. Finally the system would allow clinic midwives and nurses to follow their patients' care at UTH and to learn from outcomes of their treatment. Specifically, the goals of the electronic referral system were as follows:

- To improve outcomes in patients referred to University Teaching Hospital (UTH)
- To monitor and reduce the delay from time-of-referral to time-of-treatment
- To assist UTH in planning and preparing for acute care arrivals
- To improve post-hospitalization care in the clinics by providing more complete and timely information

Exhibit 13 Original Paper Patient Referral Form used by Clinics in Lusaka



LUSAKA URBAN HEALTH CENTRE
DAILY REPORT OF REFERRALS
TO AND FROM UTH BOARD OF MANAGEMENT

ADULT (MEDICAL) FILTER CLINIC

FROM LDHB TO UTH
NAME OF CLINIC: _____ DATE: _____ TIME: _____
NAME OF PATIENT: _____ SEX: _____ AGE: _____
CARD/FILE No.: _____
NAME OF REFERRING HEALTH WORKER _____
JOB DESCRIPTION
☐ MEDICAL OFFICER
☐ CLINICAL OFFICER
☐ NURSE/MIDWIFE
☐ OTHERS (Specify) .....
REASON FOR REFERRING PATIENT: _____
(including brief history / Examination findings)
INVESTIGATIONS: _____
PROVISIONAL DIAGNOSIS: _____
TREATMENT GIVEN: _____
SIGNATURE OF HEALTH WORKER. _____
DATE STAMP

FROM UTH TO LDHB
NAME OF CLINIC: _____ DATE: _____ TIME: _____
NAME OF PATIENT: _____ SEX: _____ AGE: _____
CARD/FILE No.: _____
PROVISIONAL DIAGNOSIS FROM CLINIC: _____
INTERVENTION IN SPECIALIST CLINIC/ADMISSION WARD
- CLINIC/WARD DIAGNOSIS: .....
- INVESTIGATIONS: .....
- TREATMENT: .....
- REVIEW DATE: .....

SIGNATURE OF HEALTH WORKER IN UNIT/FIRM: _____

6.2 Development

Construction of the electronic patient referral system was to be done by a South African contractor and would be done while RTI worked on specification of the complete electronic perinatal medical records system. This strategy had the following major objectives:

- Testing the performance of the South African contractor
- Providing a useful application to test network and datacenter performance
- Providing a practical foundation for training personnel in the clinics and at UTH
- Determining how receptive medical personnel would be to an electronic system
- Developing ownership and support among medical personnel and MOH officials

The electronic patient referral system would be developed as a component of the ZEPRS perinatal records system and would be integrated with the system later.

In late April, 2003 RTI issued the subcontract to Data Matrix, South Africa, for constructing an electronic patient referrals system using the HP scripting language and the MySQL database server. Data matrix proposed a seven-month development timeline.

By October 22, 2003, six months later and after many reviews and revisions, RTI had determined that the performance of Data Matrix on this project was not acceptable and that the resulting software did not meet RTI quality standards. RTI notified Data Matrix on that date

via e-mail. On November 23, 2003, RTI terminated its subcontract with Data Matrix and assumed responsibility for further development of the electronic referral system.

RTI completed development of the web-based perinatal patient referral application in May 2004 after two detailed and intensive rounds of testing by local staff in Lusaka under RTI supervision. The RTI team created a User's Guide, a detailed Test Plan and a Test Execution Guide. During the testing and re-testing process, the RTI team used a web-based bug tracker and an Excel tracking mechanism to detect, fix and re-test bugs. The application, complete with a 72-page User Guide, was the focus of training for medical personnel following an extensive basic training program in computer literacy managed by CIDRZ.

The RTI team launched the perinatal patient referral system on July 22nd and July 23rd 2004, with three clinics, Chawama, George and Chipata, and three areas of UTH, the Neonatal Intensive Care Unit (NICU), the Labor Ward and the Antenatal Clinic. Cha wama was the first clinic to refer a patient using the Referral Application, and sent two patients with the same ambulance to UTH. For general computing support, with a live application in use, RTI created User Support documentation and posted this on all mobile computers, explaining how to diagnose some simple issues and contact technical support. RTI also established a web-based help desk (hosted externally to CIDRZ) used to track referral system issues.

The perinatal patient referral system was rolled out to the remaining clinics and other areas of UTH and was completed by end of October, 2004. The perinatal patient referral system tracks statistics of usage for the 24 clinics and 4 areas of UTH for patient referrals, including their referral status (referred, acknowledged, or disposed). These reports have been used to identify sites where more training is needed. The RTI team participated in the official launch of the perinatal patient referral system in early November, 2004. In October RTI team member Dennis Nkula was interviewed on a Zambian national radio program in Lusaka about the referral application and the ZEPRS project as a whole.

The following section describes the initial launch of the referral system in detail, showing examples of the screens used by medical personnel in clinics and at the UTH.

6.3 Application Launch

The Referral Application launched on Wednesday and Thursday, July 22 and July 23,2004, in Chawama, George, and Chipata clinics, and in the following UTH areas: Labour Ward, Antenatal Clinic (ANC) and NICU. Chawama was the first clinic to refer a patient using the new electronic referral application, sending two patients with the same ambulance to UTH, on July 22nd. Medical staff members participating in this launch of the referral application at Chawama clinic included Lizzie Ntoka Kamuhuza, Jean Mugala NG'oma and Martha Phiri NJovu.

The first two patients to be referred using the new web-based referral application were referred from Chawama Clinic to UTH for the following reasons:

- Intrapartum with foetal distress [2004-07-22 13:45:20]
- Postpartum, Postpartum Hemorrage Anemia [2004-07-22 14:08:41]

UTH NICU medical personnel participating were Charity Mwango and Mumba Kababa. UTH ANC Staff involved were Lestina Phiri, Matilda Jere, Esther Simwanza and Cecilia Tembo.

UTH LABOUR WARD Staff involved were Ketty Njobvu, Doris Ngosa, Hilda Mubita and Pumulo Kabalanyana.

The next patient referred using the referral application was referred from the George Clinic to UTH for the following reason:

- Antepartum Pre-Eclampsia, who when at UTH delivered twins [2004-07-22, 13:57:31 referred, and delivered twins on July 23rd, 17:16 and 17:19]

Medical personnel participating in the launch of the referral application at George clinic were Veronica Zulu, Evelyn Chilufja, Lillian Banda and Pauline Sikazwe.

The next patient, from the Chipata Clinic, to use the live Referral Application was

- Antepartum foetal distress, breech presentation [2004-07-24 22:48:16]

Medical personnel participating in the launch of the referral application at Chipata clinic are Chilco Siameja, Dorcus Kapapa and Manda Kachenjela.

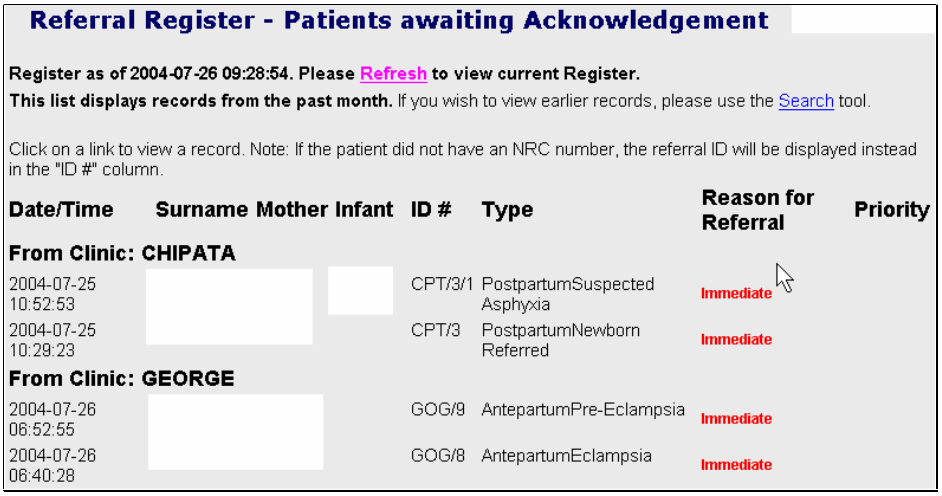
CIDRZ trainers all a significant role in training all referral application users, and helped with the launch on July 22nd and July 23rd to ensure that everything went smoothly.

6.4 Referral Screen Images

This section demonstrates the process of referring patients during the launch of the new application. It includes screen images taken during the roll-out of the referral application. Note that names and any other information that could be used to identify individual patients have been blanked-out in the following screen images to protect patient privacy. In the electronic referral application, authorized users can view all patient information.

Exhibit 14 is the referral register display on Monday, 26 July, 2004. It shows patients referred to UTH from Chipata and George clinics and awaiting acknowledgement from UTH.

Exhibit 14 Summary Referrals Screen, Monday, 26 July 2004, 09:30 AM[6]



Referral Register - Patients awaiting Acknowledgement

Register as of 2004-07-26 09:28:54. Please Refresh to view current Register.
This list displays records from the past month. If you wish to view earlier records, please use the Search tool.

Click on a link to view a record. Note: If the patient did not have an NRC number, the referral ID will be displayed instead in the "ID #" column.

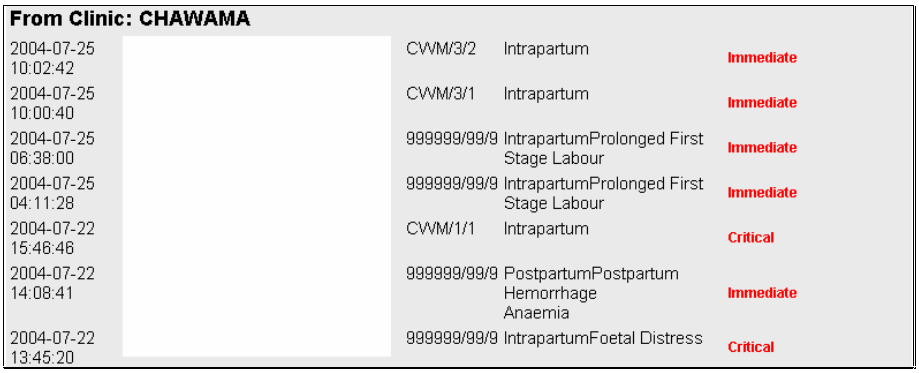
Date/Time	Surname Mother	Infant	ID #	Type	Reason for Referral	Priority
From Clinic: CHIPATA						
2004-07-25 10:52:53			CPT/3/1	PostpartumSuspected Asphyxia	Immediate	
2004-07-25 10:29:23			CPT/3	PostpartumNewborn Referred	Immediate	
From Clinic: GEORGE						
2004-07-26 06:52:55			GOG/9	AntepartumPre-Eclampsia	Immediate	
2004-07-26 06:40:28			GOG/8	AntepartumEclampsia	Immediate	

The first two patients to be referred using the Referral Application were referred by Chawama Clinic to UTH for the following reasons:

- Intrapartum with foetal distress [2004-07-22 13:45:20]
- Postpartum, Postpartum Hemorrage Anemia [2004-07-22 14:08:41]

Exhibit 15 shows the Referral Acknowledgements display at Chawama Clinic on Monday July 26th, 2004. This shows that Intrapartum has been acknowledged, but not yet disposed.

Exhibit 15 Referral acknowledgements for Chawama clinic on Monday July 26th, 2004, at 9:30 AM



From Clinic: CHAWAMA				
2004-07-25 10:02:42		CWM/3/2	Intrapartum	Immediate
2004-07-25 10:00:40		CWM/3/1	Intrapartum	Immediate
2004-07-25 06:38:00		999999/99/9	IntrapartumProlonged First Stage Labour	Immediate
2004-07-25 04:11:28		999999/99/9	IntrapartumProlonged First Stage Labour	Immediate
2004-07-22 15:46:46		CWM/1/1	Intrapartum	Critical
2004-07-22 14:08:41		999999/99/9	PostpartumPostpartum Hemorrhage Anaemia	Immediate
2004-07-22 13:45:20		999999/99/9	IntrapartumFoetal Distress	Critical

[6] Names and any other information that could be used to identify individual patients have been blanked-out on screen images in this document to protect patient privacy. In the electronic referral software application, authorized users can view all patient information.

Exhibit 16 shows the referral patient detail display for Intrapartum. The display shows that this patient delivered an infant at UTH. Exhibit 17 shows entry of birth weight and outcome.

Exhibit 16 Referral Patient Details Display

Exhibit 17 Referral Patient Details Showing Birth Weight and Outcome Entered

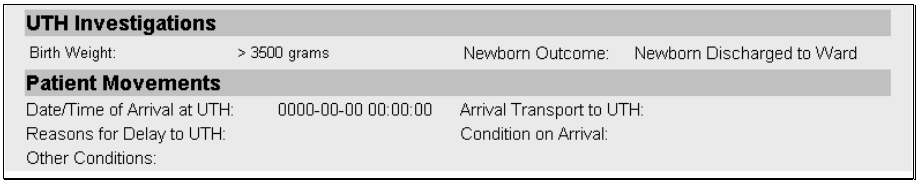
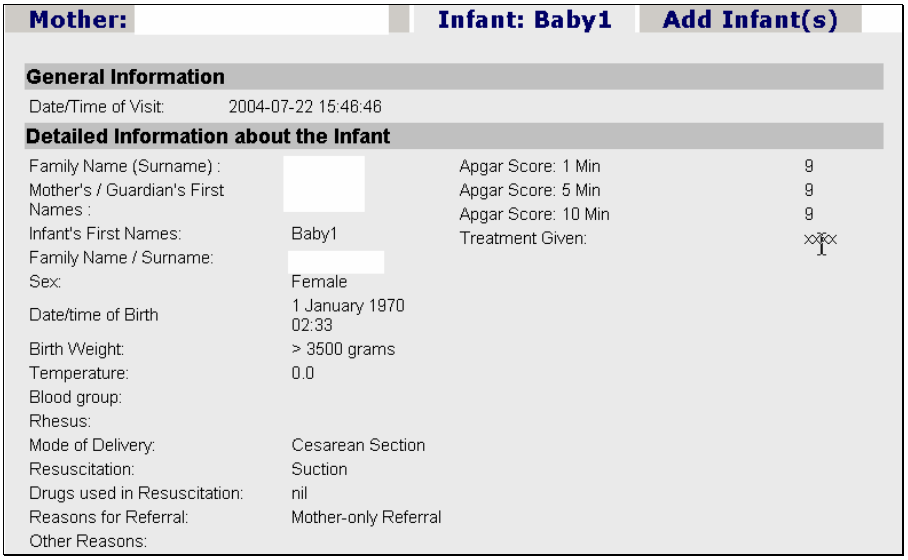


Exhibit 18 shows the intrapartum referral display for the mother, updated with information entered in the UTH delivery ward.

Exhibit 18 Referral Display for Intrapartum Mother



Mother: **Infant: Baby1** **Add Infant(s)**

General Information

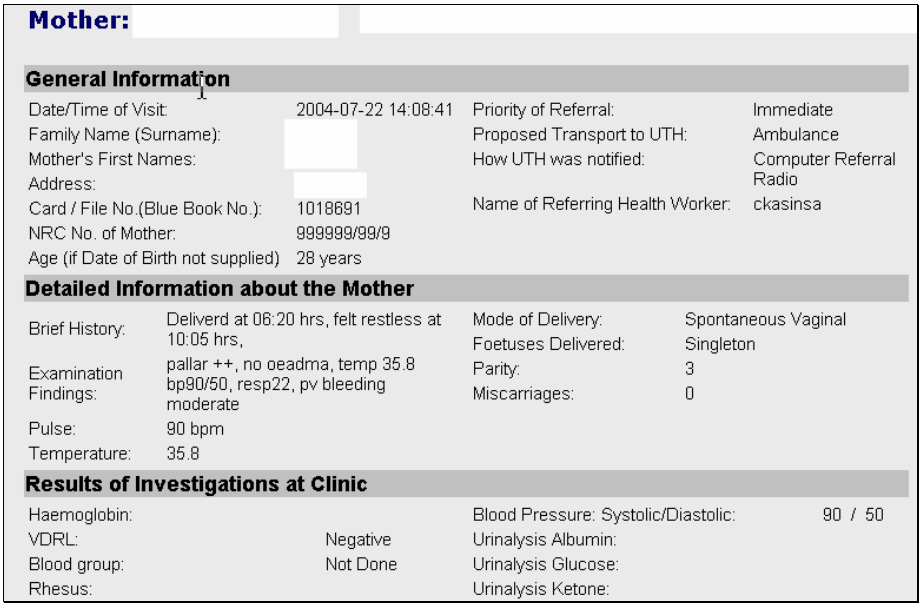
Date/Time of Visit: 2004-07-22 15:46:46

Detailed Information about the Infant

Family Name (Surname) :		Apgar Score: 1 Min	9
Mother's / Guardian's First Names :		Apgar Score: 5 Min	9
		Apgar Score: 10 Min	9
Infant's First Names:	Baby1	Treatment Given:	
Family Name / Surname:			
Sex:	Female		
Date/time of Birth	1 January 1970 02:33		
Birth Weight:	> 3500 grams		
Temperature:	0.0		
Blood group:			
Rhesus:			
Mode of Delivery:	Cesarean Section		
Resuscitation:	Suction		
Drugs used in Resuscitation:	nil		
Reasons for Referral:	Mother-only Referral		
Other Reasons:			

Exhibits 19 and 20 show updated status displays for the postpartum patient. This display shows medical personnel at Chawama clinic that the patient has been acknowledged at UTH, but has not yet been discharged.

Exhibit 19 Referral Display for Postpartum Patient



Mother:

General Information

Date/Time of Visit:	2004-07-22 14:08:41	Priority of Referral:	Immediate
Family Name (Surname):		Proposed Transport to UTH:	Ambulance
Mother's First Names:		How UTH was notified:	Computer Referral Radio
Address:			
Card / File No.(Blue Book No.):	1018691	Name of Referring Health Worker:	ckasinsa
NRC No. of Mother:	999999/99/9		
Age (if Date of Birth not supplied)	28 years		

Detailed Information about the Mother

Brief History:	Deliverd at 06:20 hrs, felt restless at 10:05 hrs,	Mode of Delivery:	Spontaneous Vaginal
		Foetuses Delivered:	Singleton
Examination Findings:	pallar ++, no oeadma, temp 35.8 bp90/50, resp22, pv bleeding moderate	Parity:	3
		Miscarriages:	0
Pulse:	90 bpm		
Temperature:	35.8		

Results of Investigations at Clinic

Haemoglobin:		Blood Pressure: Systolic/Diastolic:	90 / 50
VDRL:	Negative	Urinalysis Albumin:	
Blood group:	Not Done	Urinalysis Glucose:	
Rhesus:		Urinalysis Ketone:	

Exhibit 20 Referral Display for Postpartum Patient Showing Acknowledgement by UT H

Blood sugar:	0		
Other Investigations:			
Reasons for Referral and Treatment			
Reasons for Referral:	Postpartum Hemorrhage Anaemia	Treatment at Clinic:	IV Access
Other Reasons:		Other Treatment	oral fluids: 500mls water, 250mls tea, milk 50mls.
UTH Investigations			
Blood Pressure upon Admittance: Systolic/Diastolic:			
Pulse upon Admittance:	0 bpm		
Temperature upon Admittance:	0.0		
Patient Movements			
Date/Time of Arrival at UTH:	2004-07-22 14:48:31	Arrival Transport to UTH:	Ambulance
Reasons for Delay to UTH:		Condition on Arrival:	Fair
Other Conditions:			

Exhibit 21 shows medical and support personnel in Chawama Clinic as they used the referral application for the first time.

Exhibit 21 Staff in Chawama Clinic Using the Referral Application for the First Time

The next patient was referred from George Clinic with the following conditions:

- Antepartum Pre-Eclampsia [2004-07-22, 13:57:31 referred, and delivered twins on July 23rd, 17:16 and 17:19]

The antepartum patient went to UTH on Thursday, July 22nd, and delivered twins on Friday, July 23rd. The initial referral from George only included the mother. Staff at the UTH labour ward added the two infants to the referral, so medical personnel at George clinic were able to

see that the mother had two infants. Exhibits 22 and 23 show the acknowledgement screen for the mother. Exhibits 24, 25, and 26 show the acknowledgement screens for the two infants.

Exhibit 22 Antepartum Mother Acknowledgement Screen

Mother: | **Infant: b/o twin 1.** | **Infant: b/o twin 2**

Add Infant(s)

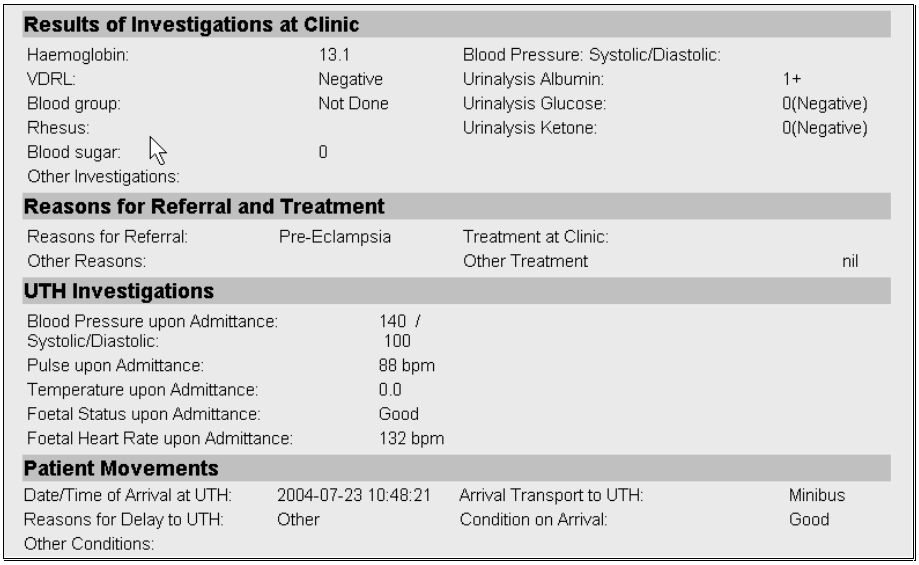
General Information

Date/Time of Visit:	2004-07-22 13:57:31	Priority of Referral:	Immediate
Family Name (Surname):		Proposed Transport to UTH:	Minibus
Mother's First Names:		How UTH was notified:	Computer Referral
Address:	twikatane	Name of Referring Health Worker:	wnsimwanza
Card / File No.(Blue Book No.):	2002242		
NRC No. of Mother:			
Date of Birth/Age	22 September 1978 / 25 years		
Age (if Date of Birth not supplied)	25 years		

Detailed Information about the Mother

Brief History:	Raised B/p-130/90	Parity:	1
Examination Findings:	Hof-40wks	Miscarriages:	0
Pulse:	72 bpm	Gravida:	2
Temperature:	37.0		
Foetal Status:	Good		
Foetal Heart Rate:	136 bpm		

Exhibit 23 Antepartum Mother Acknowledgement Screen (Continued)



Results of Investigations at Clinic

Haemoglobin:	13.1	Blood Pressure: Systolic/Diastolic:	
VDRL:	Negative	Urinalysis Albumin:	1+
Blood group:	Not Done	Urinalysis Glucose:	0(Negative)
Rhesus:		Urinalysis Ketone:	0(Negative)
Blood sugar:	0		
Other Investigations:			

Reasons for Referral and Treatment

Reasons for Referral:	Pre-Eclampsia	Treatment at Clinic:	
Other Reasons:		Other Treatment	nil

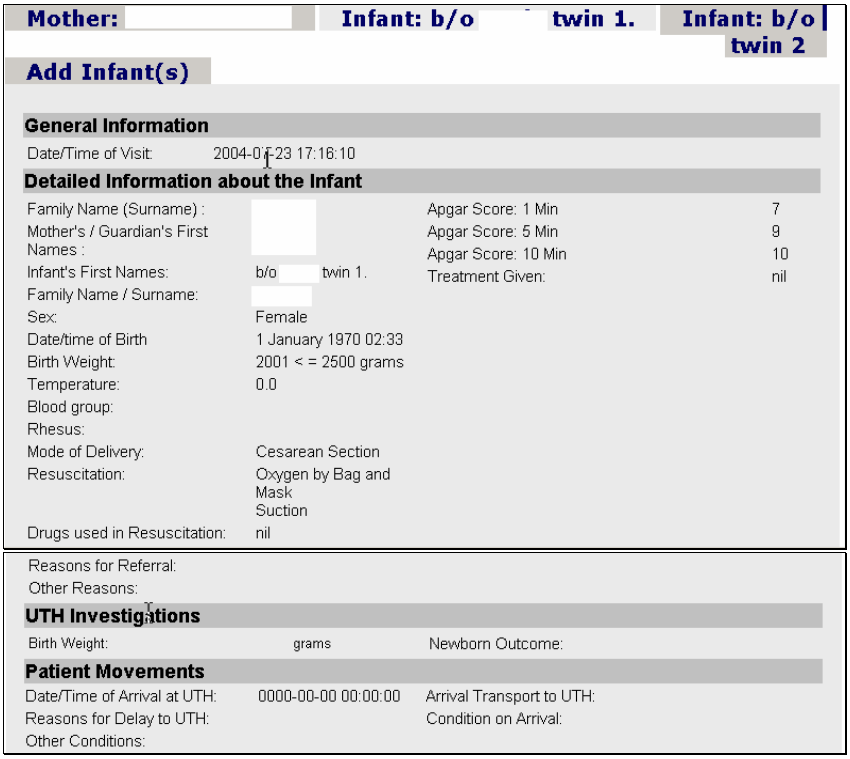
UTH Investigations

Blood Pressure upon Admittance: Systolic/Diastolic:	140 / 100
Pulse upon Admittance:	88 bpm
Temperature upon Admittance:	0.0
Foetal Status upon Admittance:	Good
Foetal Heart Rate upon Admittance:	132 bpm

Patient Movements

Date/Time of Arrival at UTH:	2004-07-23 10:48:21	Arrival Transport to UTH:	Minibus
Reasons for Delay to UTH:	Other	Condition on Arrival:	Good
Other Conditions:			

Exhibit 24 Antepartum First Infant Acknowledgement Screen



Mother: Infant: b/o twin 1. Infant: b/o twin 2

Add Infant(s)

General Information

Date/Time of Visit: 2004-07-23 17:16:10

Detailed Information about the Infant

Family Name (Surname) :		Apgar Score: 1 Min	7
Mother's / Guardian's First Names :		Apgar Score: 5 Min	9
		Apgar Score: 10 Min	10
Infant's First Names:	b/o twin 1.	Treatment Given:	nil
Family Name / Surname:			
Sex:	Female		
Date/time of Birth	1 January 1970 02:33		
Birth Weight:	2001 < = 2500 grams		
Temperature:	0.0		
Blood group:			
Rhesus:			
Mode of Delivery:	Cesarean Section		
Resuscitation:	Oxygen by Bag and Mask Suction		
Drugs used in Resuscitation:	nil		

Reasons for Referral:

Other Reasons:

UTH Investigations

Birth Weight:	grams	Newborn Outcome:	

Patient Movements

Date/Time of Arrival at UTH:	0000-00-00 00:00:00	Arrival Transport to UTH:	
Reasons for Delay to UTH:		Condition on Arrival:	
Other Conditions:			

Exhibit 25 Antepartum Second Infant Acknowledgement Screen

Mother: Infant: b/o twin 1. Infant: b/o twin 2

Add Infant(s)

General Information

Date/Time of Visit: 2004-07-23 17:19:51

Detailed Information about the Infant

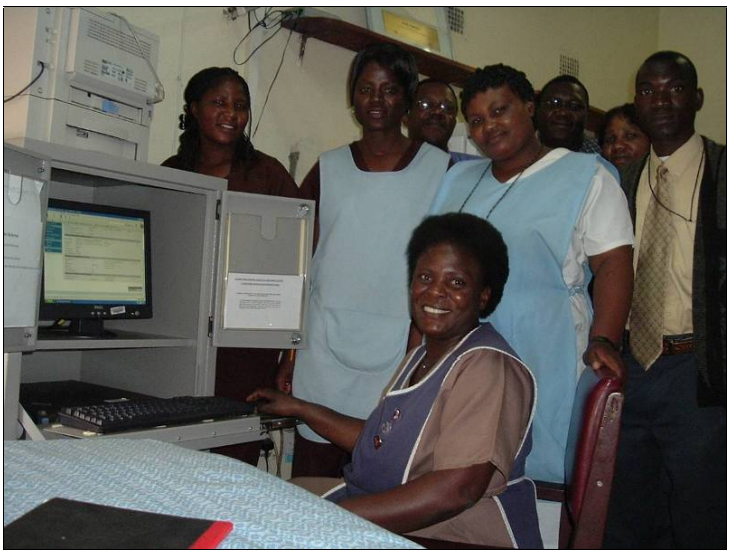
Family Name (Surname) :		Apgar Score: 1 Min	7
Mother's / Guardian's First Names :		Apgar Score: 5 Min	9
		Apgar Score: 10 Min	9
Infant's First Names:	b/o twin 2	Treatment Given:	nil
Family Name / Surname:			
Sex:	Female		
Date/time of Birth	1 January 1970 02:33		
Birth Weight:	1501 < = 2000 grams		
Temperature:	0.0		
Blood group:			
Rhesus:			
Mode of Delivery:	Cesarean Section		
Resuscitation:	Oxygen by Bag and Mask Suction		
Drugs used in Resuscitation:	nil		

Exhibit 26 Antepartum Second Infant Acknowledgement Screen (Continued)

Reasons for Referral:		
Other Reasons:		
UTH Investigations		
Birth Weight:	grams	Newborn Outcome:
Patient Movements		
Date/Time of Arrival at UTH:	0000-00-00 00:00:00	Arrival Transport to UTH:
Reasons for Delay to UTH:		Condition on Arrival:
Other Conditions:		

Exhibit 27 below is a photo of the medical team at George Clinic during the launch of the referral application.

Exhibit 27 Staff who launched the Referral Application at George Clinic

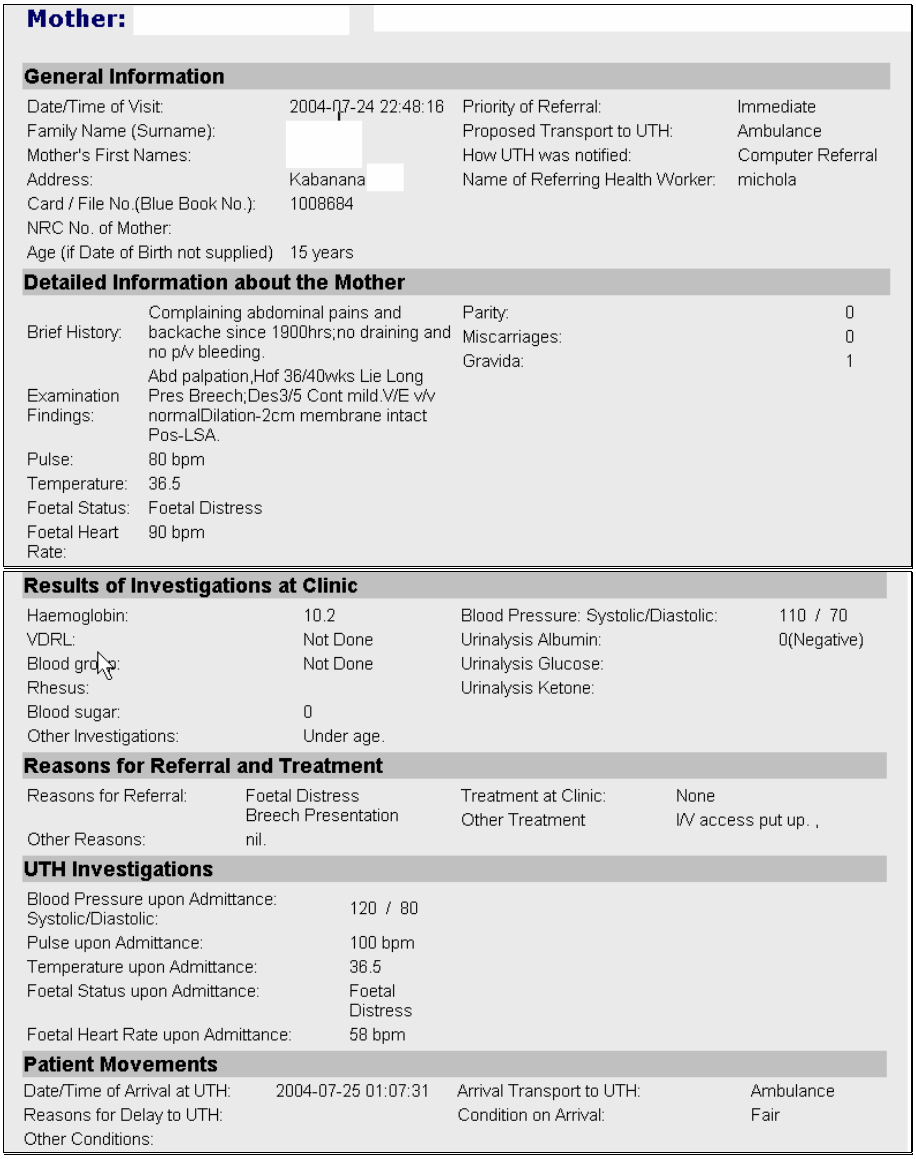


The next patient was referred from Chipata Clinic with the following conditions:

- Antepartum foetal distress, breech presentation [2004-07-24 22:48:16]

The patient was transferred to UTH and was still recovering at the time the following screen displays were captured. Exhibit 28 below shows the antepartum screen indicating that the patient has been acknowledged as received at UTH, but has not yet been disposed.

Exhibit 28 Antepartum Screen Showing Ack nowledged but not yet Disposed



Mother:

General Information

Date/Time of Visit:	2004-07-24 22:48:16	Priority of Referral:	Immediate
Family Name (Surname):		Proposed Transport to UTH:	Ambulance
Mother's First Names:		How UTH was notified:	Computer Referral
Address:	Kabanana	Name of Referring Health Worker:	michola
Card / File No.(Blue Book No.):	1008884		
NRC No. of Mother:			
Age (if Date of Birth not supplied)	15 years		

Detailed Information about the Mother

Brief History:	Complaining abdominal pains and backache since 1900hrs;no draining and no p/v bleeding.	Parity:	0
		Miscarriages:	0
		Gravida:	1
Examination Findings:	Abd palpation,Hof 36/40wks Lie Long Pres Breech;Des3/5 Cont mild.V/E v/v normalDilation-2cm membrane intact Pos-LSA.		
Pulse:	80 bpm		
Temperature:	36.5		
Foetal Status:	Foetal Distress		
Foetal Heart Rate:	90 bpm		

Results of Investigations at Clinic

Haemoglobin:	10.2	Blood Pressure: Systolic/Diastolic:	110 / 70
VDRL:	Not Done	Urinalysis Albumin:	0(Negative)
Blood group:	Not Done	Urinalysis Glucose:	
Rhesus:		Urinalysis Ketone:	
Blood sugar:	0		
Other Investigations:	Under age.		

Reasons for Referral and Treatment

Reasons for Referral:	Foetal Distress Breech Presentation	Treatment at Clinic:	None
		Other Treatment	I/V access put up. ,
Other Reasons:	nil.		

UTH Investigations

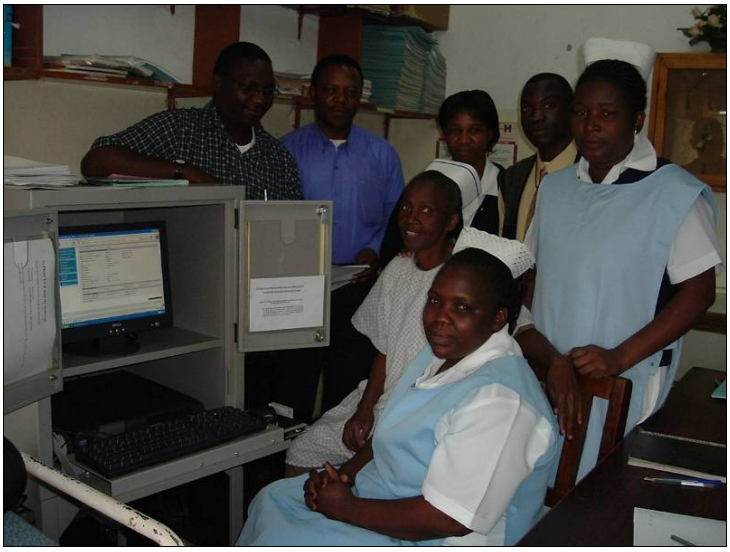
Blood Pressure upon Admittance: Systolic/Diastolic:	120 / 80
Pulse upon Admittance:	100 bpm
Temperature upon Admittance:	36.5
Foetal Status upon Admittance:	Foetal Distress
Foetal Heart Rate upon Admittance:	58 bpm

Patient Movements

Date/Time of Arrival at UTH:	2004-07-25 01:07:31	Arrival Transport to UTH:	Ambulance
Reasons for Delay to UTH:		Condition on Arrival:	Fair
Other Conditions:			

Exhibit 19 below is a photo of the medical team at Chipata Clinic on the day they launched the electronic referral application.

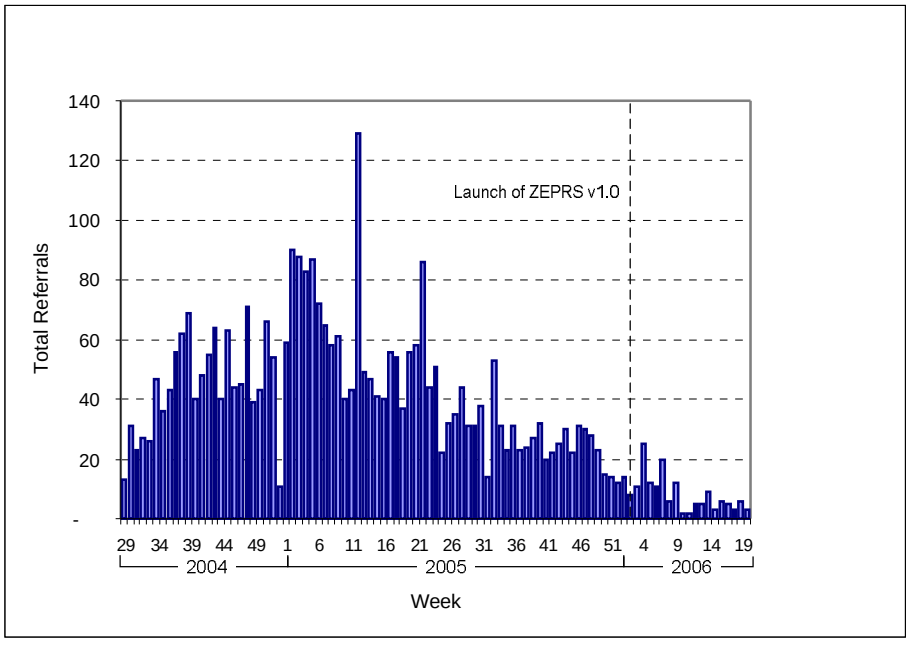
Exhibit 29 Staff who launched the Referral Application at Chipata Clinic



6.5 Usage Statistics

Exhibit 30 shows the total number of patients referred each week using the electronic referral application from initial launch to the introduction of the integrated ZEPRS Version 1.0 perinatal record and patient referral application in February 2006.

Exhibit 30 Total Patients Referred by Week Using the Electronic Patient Referral Application



As shown by Exhibit 30, the roll-out of the application was rapid. This was the result of a coordinated training and roll-out effort and the enthusiastic acceptance of medical personnel. Referrals for the 24 weeks of operation in 2004 averaged 21 referrals per week. Usage reached a peak in the first six weeks of 2005, and then tapered off to an average of approximately 40 patients per week. The average rate for all of 2005 was 45 referrals per week. The number of patients referred using this system began to taper off further beginning at around week 26 of 2005, and much more noticeably in week 52 of 2005. This corresponds with lightening damage to wireless network equipment at the TELECEL 1 high site noted in Chapter 4, as well as the imminent launch of the integrated ZEPRS Version 1.0 application. By the end of week 20 in 2006, the electronic referral application had been used to refer a total of 3,541 patients.

The average rate of referral for the first 20 weeks of 2006 was eight (8) referrals per week, a 19 percent decline in average rate from 2005. The six clinics that converted to using the integrated ZEPRS Version 1.0 application during this period accounted for nearly 28 percent of all referrals in 2005. Declining use of the electronic referral application may be due to a combination of factors, including the declining availability of the ZEPRS wireless network, as discussed in Chapter 4, the introduction of the integrated ZEPRS Version 1.0 application, and turnover of medical personnel. In particular, a staffing shortage at UTH may have had an impact on UTH acknowledgement of referrals and updates of patient status in the system. Clinics may be less interested in entering referral data if UTH does not respond.

7 Electronic Perinatal Record System

7.1 Description

ZEPRS is an electronic medical record (EMR) system designed for public obstetric clinics and UTH in Lusaka, Zambia. RTI is building the ZEPRS application using open-source components and best-of-breed web-based application architecture. This minimizes operating costs, makes it easier to expand usage within Zambia, and increases transferability to other countries. ZEPRS clinicians, nurses, mid-wives and other staff will access the ZEPRS application using a web browser. The ZEPRS application is located on the ZEPRS network, enabling fast access to patient data.

7.1.1 Software Platform

RTI elected to build ZEPRS maximizing the use of free and open source technologies to minimize recurring licensing costs. RTI also took care to select technologies that are not specific to any single operating system. This makes it possible to run the system on several alternate operating systems, giving organizations some flexibility and broadening the applicability of the system. RTI initially considered the user of the LAMP platform (Linux, Apache, MySQL, and PHP). This combination of operation system, Web and application server, database server, and Web application markup language, is the most widely used combination of free and open source technologies. The electronic referral application developed by this project and described in Chapter 5 is built using this combination. This experience convinced RTI that it would be very difficult to implement some features and to provide the performance needed for the electronic perinatal record system. After careful research RTI decided to replace PHP with Java. Java is a more advanced and more powerful programming language than PHP, but can still run on a wide variety of operating systems.

The ZEPRS application uses Java as the software platform for the server component and runs inside the Apache Tomcat servlet container. RTI chose to implement the programming of the ZEPRS application using the Model-View-Controller (MVC) paradigm, a widely adopted approach for separating presentation from data and business logic. Apache Struts is the framework used to implement MVC in the ZEPRS application. Database persistence is maintained using a Java Database Connectivity (JDBC) wrapper (Apache Commons DbUtils) for the main ZEPRS application and Hibernate, an Object Relational Mapping (ORM) framework, for parts of the administration application.

The ZEPRS application functions in a manner similar to many enterprise Content Management systems. Many aspects of the application are configurable by a system administrator using a web browser, such as the creation and management of the following:

- **Forms, fields, and field enumerations**: Authorized users may login to the Administration section of the ZEPRS application and create new forms, add/modify fields to a form, and add/modify enumerations to a field.

- **Simple reports**: systems administrators may query common values using the Report section Query interface. These ad-hoc reports may be useful for previewing data intended for a published standard report.

- **Rules**: Rules may be added to the ZEPRS forms via the Administration section's web interface. Values entered into a form field that has a rule can trigger the creation of a problem[7], which will be displayed in the Problem listing. These problems can prompt the user to refer the patient to UTH, complete a form, or provide information.

This greatly simplifies customization and maintenance in environments with a shortage of skilled software developers, and makes it easier to adapt ZEPRS to new requirements.

7.1.2 Integration with other applications

The ZEPRS application interoperates with other applications on the ZEPRS network. For example, the ZEPRS application queries the mail system database in order to perform user authentication, which makes account management much simpler for the users and administrators, since each authorized user has a single username and password that provides access to all the ZEPRS applications (email, referral, ZEPRS and training applications).

7.1.3 User Interface

The ZEPRS application is designed to enable the user to take the most direct route possible to data. After the user selects a patient, the system helps guide the user to the most relevant form (or stage in their pregnancy, for example routine antenatal visit, labor, etc). After each form submission, the system forwards the user to the next logical form. Menus on the left navigation strip are available if the user needs to take a different path from the system recommended path.

7.1.4 Reports

After consulting with the UAB and Zambian clinicians we selected twenty of the most critical reports to be included in the ZEPRS version 1.0 system:

[7] In this context a problem is a set of conditions concerning the patient that require further action by medical personnel. A Problem Listing on ZEPRS patient record displays alerts care providers to conditions that require follow-up action.

1. Delivery Register
2. Safe Motherhood Register – Antenatal
3. Safe Motherhood Register – Postnatal
4. Integrated VCT Register
5. Maternal Mortality Register
6. Neonatal Mortality Register
7. Birth Record
8. PMTCT Labour Ward Register
9. CBoH Health Centre Self-Assessment HIQ.1
10. Clinic Workload Report
11. Health Centre Service Delivery Aggregation HIA.2
12. Antenatal Monthly Summary Sheet
13. Delivery Summary Sheet
14. LUDHMB Maternal And Neonatal Stats
15. DHMT HIV Control
16. Weekly Maternal Mortality Report
17. Weekly Neonatal Mortality Report
18. CBoH Health Centre Quarterly Self-Assessment HIQ.1
19. LUDHMB Maternal And Neonatal Stats Monthly
20. UTH Obstetrics and Neonatology Statistics

In addition to these reports, the system provides a report on patient record modifications, a simple Query Builder interface for producing ad hoc reports, and the capability to export patient records in XML format.

7.2 Development

Annex A shows significant dates and events along the path toward ZEPRS deployment in late 2005 and early 2006. For simplicity we have included only the most significant recent events.

RTI experience and presence in South Africa suggested that skilled software development firms in that country may be a cost effective and sustainable solution to developing and supporting the software. In 2001 RTI solicited rough cost estimates from software development companies in South Africa for developing the ZEPRS EMR application. Based on a general description of the required functionality and the operating environment, RTI obtained cost estimates from two companies that had previously completed successful projects for RTI South Africa. Total cost estimates were in the range of $160,000. At the end of August 2001, the currency exchange rate was 8.4 South African Rand (ZAR) per US Dollar (USD). By April 2002 the exchange rate had reached 11.4 ZAR/USD. The exchange rate trend was greatly in favor of subcontracting the South African software developer to produce the ZEPRS application, as planned originally.

RTI conducted an initial site assessment in Lusaka in April 2002. Beginning on that date RTI began to develop detailed system requirements and specifications, including the development of a detailed medical record that would serve as the foundation for ZEPRS.

RTI completed the system requirements and specifications for the Electronic Perinatal Patient Records System in the fall of 2003. This effort included representatives of physicians, nurse-midwives, clinic staff, administrative staff, and information technology (IT) staff at the UAB, CIDRZ, LUDHMT, UTH, CBoH, and RTI. In addition, a Medical Record Committee consisting of key medical personnel from the various interested organizations has guided the

creation of a perinatal medical record that will be useful for improving patient care and still meet the various reporting and research needs of the participating organizations. RTI held numerous meetings and conference calls in Zambia and the United States to insure that the medical record was comprehensive, yet efficient for nurse-midwives-doctors entering and maintaining data. We also completed alpha and beta testing of the ZEPRS application, which resulted in updating the medical record to meet local user needs. We also gathered user input in Zambia to ensure the application is suitable for local reporting needs as well as long-term research access. This user input served as the basis for developing the ZEPRS system.

Due to a falling exchange rate, RTI decided it was necessary to expand the pool of bidders to include at least one outside South Africa capable of providing continued support through a South Africa office. In October 2003 RTI distributed a detailed Request for Quotations for ZEPRS development to four selected software development firms, three in South Africa and one based in India, but with a presence in South Africa All four companies submitted bids. Due the falling exchange rate, By November 2003, the exchange rate had dropped to less than 7 ZAR/USD and was continuing to fall rapidly. In early January 2004, the rate dropped to less than 6.5 ZAR/USD, increasing the cost of outsourcing software development to South Africa by 23 percent since August 2001 and by 43 percent since April 2002. In November 2003 through January 2004 RTI answered questions and issued two modifications to the RFQ an effort to further define the scope of work and reduce costs.

On January 12, 2004, RTI completed an analysis of bids from software developers in South Africa for developing the ZEPRS system. Due to significant drop in the ZAR/USD exchange rate, none of the bids were within the available budget. RTI presented the UAB with an analysis showing that RTI could complete the software at a lower cost than any of the bids received. On 14 January 2004 the UAB issued approval to RTI to begin developing the ZEPRS software.

The RTI team (Chris Kelley, Scott Herman-Giddens, Niamh Darcy, Eileen Reynolds) developed the User Interface (UI) specifications and screen flows for the application (from April 2004, to April 2005). RTI reviewed the UI and screen flows with the UAB team and Zambian clinicians. The ZEPRS system was developed iteratively, and with each new build RTI held a review session with Dr. Dwight Rouse and Dr. Francis Nuthalpathy from the UAB and added their suggestions (after discussion) into the next build.

In January, Ms. Darcy traveled to Lusaka to work with the Medical Records Committee, nurses Emelda Kabwe, Ethel Mwenzi, and Dr. Machada of UTH to review the ZEPRS prototype, getting feedback on screen flow and form content. Niamh Darcy and Chris Kelley traveled to Lusaka in April 2005 to finalize the set of detailed specifications to create ZEPRS Version 1.0 (alpha) with Dr. Dwight Rouse, Zambian clinicians, and Dr. Benjamin Chi.

In August 2005, Ms. Darcy traveled to Lusaka to review the ZEPRS version 1.0 (beta) with Dr. Alan Tita of the UAB and with local Lusaka staff. Several review sessions were held with representatives from different areas of UTH and clinics, to test out entering patient blue book data into the ZEPRS system. We also entered data for a live patient who was doing a routine antenatal visit in the UTH Antenatal clinic, as well as entering data for a patient who was in labor in Chipata clinic. Ms. Darcy also developed the ZEPRS System User Manual, with multiple iterations released as the ZEPRS system evolved, which has been used by the Lusaka training team as the main material for their training sessions with users of the ZEPRS System. This User Manual was transitioned to the Lusaka team in December, 2005.

Ms. Darcy worked with six medical students from UTH during 2004-2005 to create a detailed test plan for ZEPRS Version 1.0, as well as working with them to enter in patient test data from existing obstetric blue books (taking care to de-identify patient information to protect privacy). RTI updated the test plan during the year as each build was released and the screen flows and content evolved.

RTI transitioned management of local testing to the UAB during the fall of 2005 in order to ensure that the local UAB team could apply their understanding of software testing, which will be an on-going demand as the ZEPRS application continues to be developed and improved. RTI provided documentation, guidelines, and training to enable testing to be managed by local staff in Lusaka.

RTI pilot tested ZEPRS Version 1.0 (beta) software in clinics from October 2005 to January 2006. Pilot testing included entering a sample of patient records into the application at the UTH and two selected clinics: George and Chipata. Sample patients were taken through all system operations from registration to discharge. Actual patient records entered between 23 November 2005 and 7 December 2005 are the first actual clinical use of the ZEPRS software.

7.3 Application Load Testing

Based on background documents and discussions with the UAB, RTI's original proposal estimated each clinic would modify 50 to 100 patient records per day per clinic, or roughly 1,400 record changes per day for original 23 clinics and UTH. The total number of obstetric cases handled by the system in 1999 was 47,000. RTI estimated that this might increase to perhaps 49,000 in 2002.

RTI estimates the total number of obstetric patients in the system in 2005 to be 55,000. On average there are six (6) visits per year for each obstetric patient. There are currently 24 clinics, 12 of which are delivery clinics. Each delivery clinic has a three-bed delivery ward. There are 16 beds in the UTH labor ward, making it roughly equivalent in patient volume to five delivery clinics. Non-delivery clinics operate for 8 hours per day. Delivery clinics and the UTH labor ward operate for 24 hours per day. These figures produce a rough estimate of 31 patient record transactions per day in each clinic, a little over two (2) transactions per hour in each clinic, and a little over 68 transactions per hour on average for the entire system. These figures are, however, very rough estimates. They assume all clinics operate 365 days per year. Based on direct observation by RTI, at peek times in some clinics, such as a typical Monday at Kalingalinga Clinic, there may be 10 times that number: 300 patients in a day at a single clinic.

In December 2005 RTI conducted load tests of the ZEPRS Version 1.0 (beta) application to test its performance and stability, identify areas where performance could be improved, and determine whether the application was likely to provide adequate response times for users under the anticipated transaction load.

Load tests were conducted using Apache JMeter, a Java desktop application designed to test functional behavior and test the performance of Web applications. Testing was performance on a separate test server, as well as on ZEPRS datacenter servers in Lusaka. RTI created scripts in JMeter to emulate the following basic transactions associated with patient visits:

- Search for patient
- Load patient record
- Insert Routine antenatal visit

Individual transaction scripts and delays between transactions included delays that simulated user response times. Tests were conducted using different delay times to test application performance with users of different skill levels. The transactions of different simulated users were alternated or staggered in time to simulate the typical usage pattern expected for multiple users. Stress testing was done by increasing the number of simulated users until the application encountered a catastrophic failure ("crash"), or until system performance degraded to a level judged by RTI testers to be unacceptable.

As a result of these tests RTI made some adjustments in Structured Query Language (SQL) queries, MySQL configuration settings, and Java Virtual Machine (JVM) settings. After making these and other changes, repeated load stress testing showed that application performance would begin to decrease with increasing load, but that the application would not fail or crash. As the number of concurrent users increased past 40 threads application performance began to decrease.

RTI also developed scripts to generate patient records for testing system capacity and response. These scripts created a variety of test patients to provide a somewhat realistic mix of patient records. Patient records generated included the following:

- Simple patient problem/labour visit
- Patient with partograph
- Patient with newborns
- HIV positive patient w/ newborn
- HIV negative patient w/ newborn
- HIV negative patient w/ newborn; Needs pregnancy conclusion
- HIV negative patient w/ newborn; Pregnancy Concluded
- HIV negative patient w/ stillbirth; Pregnancy Concluded

Each patient included data in the following general areas:

- Patient registration
- Pregnancy dating
- Previous pregnancy
- Safe motherhood
- Three routine antenatal records
- Initial visit
- Problem labour visit

Mothers with infants also had data in the following general areas:

- Problem/labour visit to trigger partograph
- Partograph
- Puerperium (some have it twice)
- Maternal discharge
- Postnatal maternal visit

Randomly, some mothers were HIV positive and some infants had still birth records.

RTI generated 20,000 test patients with completely populated records to determine how the system would perform. This number includes mothers only. It does not include singleton and twin newborn records that were also generated. RTI did not observe any problems in system function or response times for creating and locating records with this number of test patients.

These results are preliminary; our project budget did not include extensive load testing. RTI recommends monitoring server performance statistics closely during system roll-out, and continuing to monitor system performance as the number of transactions and database size increases. At some point it will be necessary to upgrade server hardware in the ZEPRS datacenter.

Three months after the initial launch of the ZEPRS Version 1.0 application RTI has not detected any performance or load concerns with the application or datacenter servers. At the time of this report ZEPRS is being used in 10 clinics. There are 5,000 patient records in the system. The transaction rate during the day is 15 patient transactions per hour: roughly half of our theoretical estimate. RTI load testing indicates that the performance of data center servers and response times in clinics should be monitored closely during the roll-out period for some time after to determine whether it is necessary to add server capacity to maintain adequate performance.

7.4 Application Launch

In January 2006, Dr. Perry Killam arrived at CIDRZ from the UAB to help launch the ZEPRS v1.0 application in clinics and at the UTH. Chris Kelley continues to work closely with Dr. Killam, the primary UAB contact in Lusaka, on updates and bug-fixes to the application as it is deployed in more Lusaka clinics. Regular use of ZEPRS for antenatal care was initiated February 1, 2006 at Chipata Clinic, and February 22, 2006 at Matero Reference Clinic. By March 9, 2006 approximately one thousand patient records were being managed using ZEPRS in three clinics and two units of the UTH. Nine clinics and two departments at UTH are now using ZEPRS v1.0. Exhibit 65 shows the total number of clinics using ZEPRS v1.0 by month. Labor wards at four clinics are now using the system. A total of 3933 new antenatal patient records and 4675 total visits have been entered into the system. As shown in Exhibit 65, the number of new patients and repeat patient visits entered into the system is increasing each month. The roll-out of the application is on schedule with two to three new clinics being added each month.

Throughout this period RTI continued to make adjustments, to correct problems as they are encountered in the field, and to add high priority enhancements. Users are contributing actively, providing comments and requests that have already resulted in some adjustments. This indicates that providers are engaged, have seen positive responses to their input, and developing a sense of ownership of the system.

There are encouraging signs that ZEPRS is beginning to achieve one its major objectives: improving the quality of perinatal care significantly in 24 participating clinics of the Lusaka Urban District. Dr. Killiam observed that nurses in Chipata Clinic felt remorseful about not testing women for HIV and promised to do better, and that nurses at Matero Main Clinic are making changes to ensure that all Rapid Plasma Reagin (RPR) positive women are given penicillin. Patient data and patient care prompts in ZEPRS is affecting provider behavior and improving the quality of care.

As described in Section 4.12, network availability was high from September 2004, when RTI began collecting availability data, through the end of 2005. Beginning in early 2006 network availability began to deteriorate, reaching an average of 80 percent at the end of April 2006. The causes, as discussed in Section 4.12, are not entirely technical and can be corrected. The record of network availability prior to this period demonstrates that it is possible to achieve consistently overall availability of 95 percent and higher. However, even with this record we can be certain that at times, in some clinics, the network will not be available. When the network is not available clinics must still have access to critical patient information and must be able to record important new information regarding patient status and treatment.

RTI has made several adjustments to enable clinics to continue operating through extended network outages. RTI added the ability to print patient record summary cards. Each facility is equipped with at least one laser printer connected to the network wireless network via a wireless print server. An updated patient record summary card can be printed and given to each patient during each visit. This card, which contains critical patient information, effectively replaces the original hardcopy obstetric "blue books." This provides essential information to care providers, and can be used to collect new information until it can be entered into the system. While this is useful, it is of limited use, and is essentially a low-tech version of using smartcards for portable patient records. Much more useful would be a system that enabled disconnected facilities to continue using ZEPRS to enter, retrieve, and update patient records, and that would synchronize all off-line additions and updates with the central database when connectivity is restored. Progress in this area is described briefly in the following section.

7.5 Adding Offline Capability

Recently RTI developed the capability to store patient records locally at clinic installations. This is done using an existing PC as a server. Other PCs in the clinics access and update patient records stored in this local network database by using this local "clinic" server rather than servers in the ZEPRS datacenter. When network connectivity is available records in this database are synchronized with the central ZEPRS database. This enables clinics to continue operating through network outages, while still maintaining a centralized database that permits patient records to be shared among facilities, and permits cross sectional and longitudinal analysis of patient records from all clinics. It also maintains the electronic patient referral system. This capability is being tested at the time of this report.

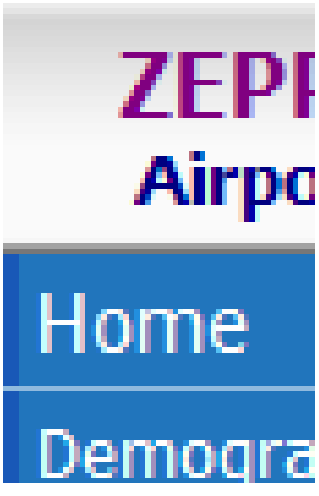
7.6 ZEPRS Screen Images

The following section contains screen images of the ZEPRS Version 1.0 application. This section is not intended to replace the comprehensive ZEPRS user manual, which is available separately. It is intended to give the reader an overall view of the application. Note that names and any other information on these screen images that could be used to identify individual patients have been blanked-out in this document to protect patient privacy. In the ZEPRS software application, authorized medical personnel and registrars can view all patient demographic information, but registrars cannot view medical information.

7.6.1 Site navigat

Exhibit 3
Users ma

Exhibit 31
ZEPRS Na



7.6.2 Patient Search on Home P age

Users can search for patients using a variety of criteria, including a firstv name, family name, ZEPRS assigned identification code (ID), national NRC identification number, or the username of the health worker who last modified the patient's record. Search results display all patients matching the search criteria, and include sufficient information to disti nguish among patients with identical names. Exhibit 32 shows the results of a patient search on the ZEPRS home page. Exhibit 33 shows how links to matching mother and related infant records are displayed in the search results list.

Exhibit 32 Patient Search on Home Page [8]

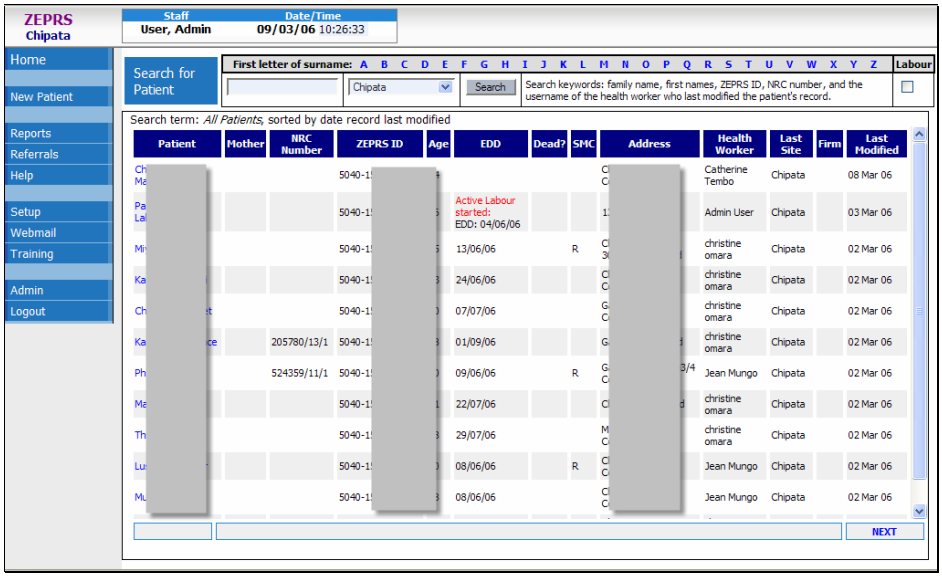


Exhibit 33 Search Results Provide Links to both Mother and Infant Records

Patient	Mother	NRC Number	ZEPRS ID
Patient2476, Baby1	Patient2476 , Labour2393		5040-152-00418-8

7.6.3 Patient Registration

The Patient Registration form collects basic demographic information about the patient . This includes extensive information that can be used for patient identification. This is necessary for patient follow-up and to distinguish among patients with identical names, and also to note any religious issues that might impact patient care. Exhibit s 34 and 35 show the patient registration form displays.

[8] Names and any other information on these screen images that could be used to identify individual patients have been blanked-out in this document to protect patient privacy. In the ZEPRS software application, authorized medical personnel and registrars can view all patient demographic information, but registrars cannot view medical information.

Exhibit 34 Patient Registration and Identification Form

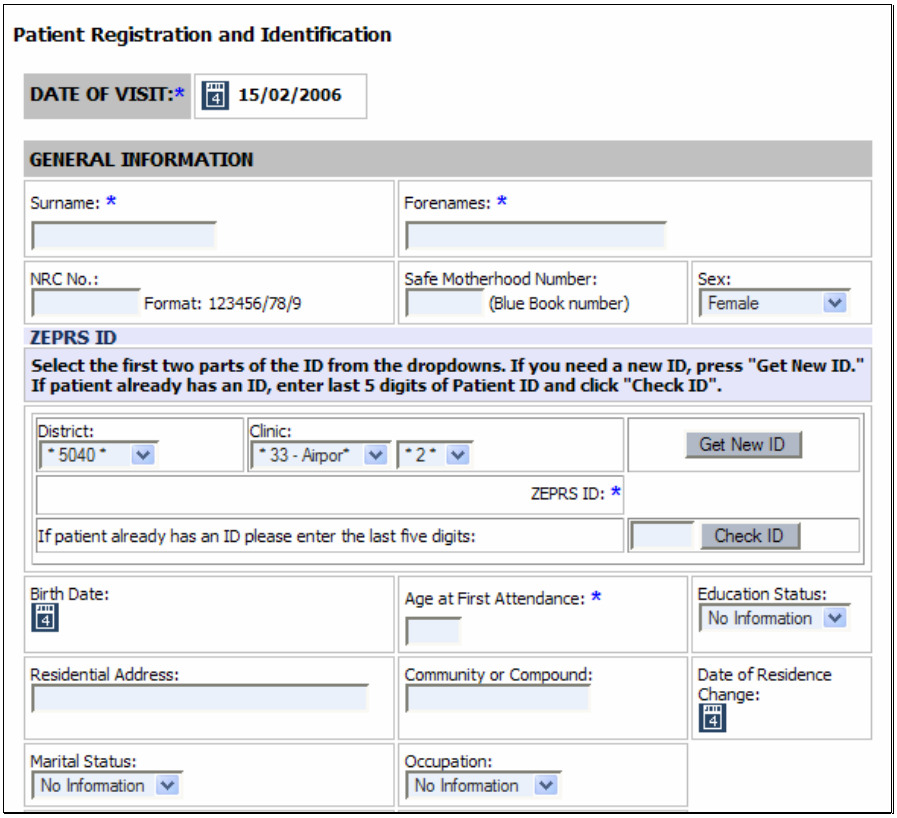
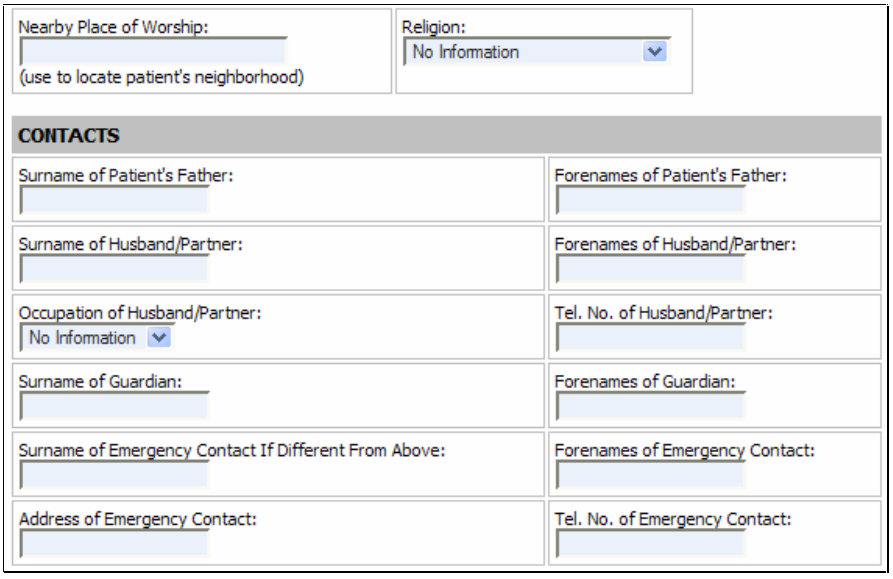


Exhibit 35 Additional Information for Patient Identification



7.6.4 Assigning a Unique Patie nt Identifier

ZEPRS assigns a unique identification codes (ZEPRS ID) to each patient based on the Lusaka District ID requirements. Exhibits 36 and 37 show the assignment of a new unique ZEPRS ID to a new patient.

Exhibit 36 Selecting Components of the Unique Patient Identifier

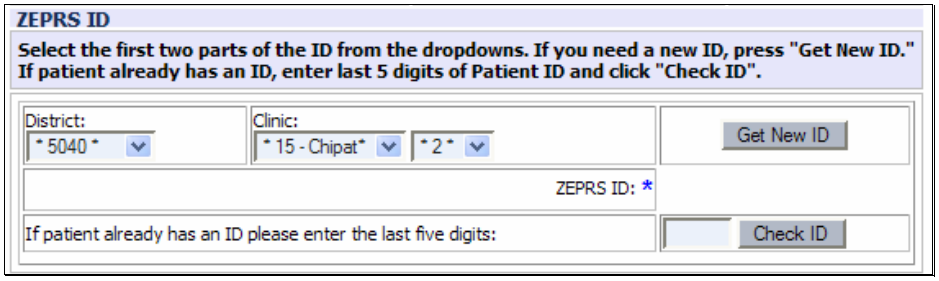
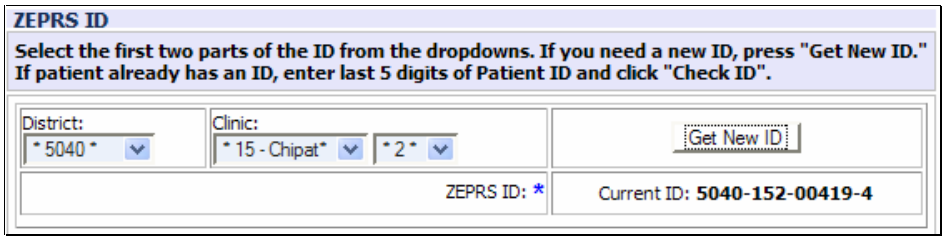


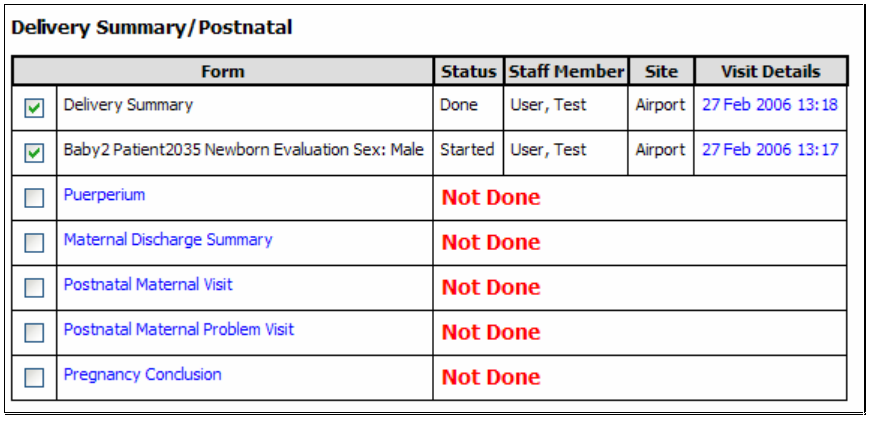
Exhibit 37 Generating a New Patient Identifier



7.6.5 Task Lists

Access to forms and records are presented in a task list format. The system helps the user identify which forms need to be completed, depending on the stage of the pregnancy. Exhibit 38 shows an example task list display.

Exhibit 38 Delivery Summary/Postnatal Task List Display



7.6.6 Patient History

Patient history displays provide access to all historical information concerning patient condition, treatment, and outcomes. Exhibit 39 shows a typical patient history display that includes a task list in the center of the screen, and a problem list on the right. The problem list alerts care providers to conditions that require further follow up or patient referral.

Exhibit 39 Patient History Displays Showing the Task List and Problem List

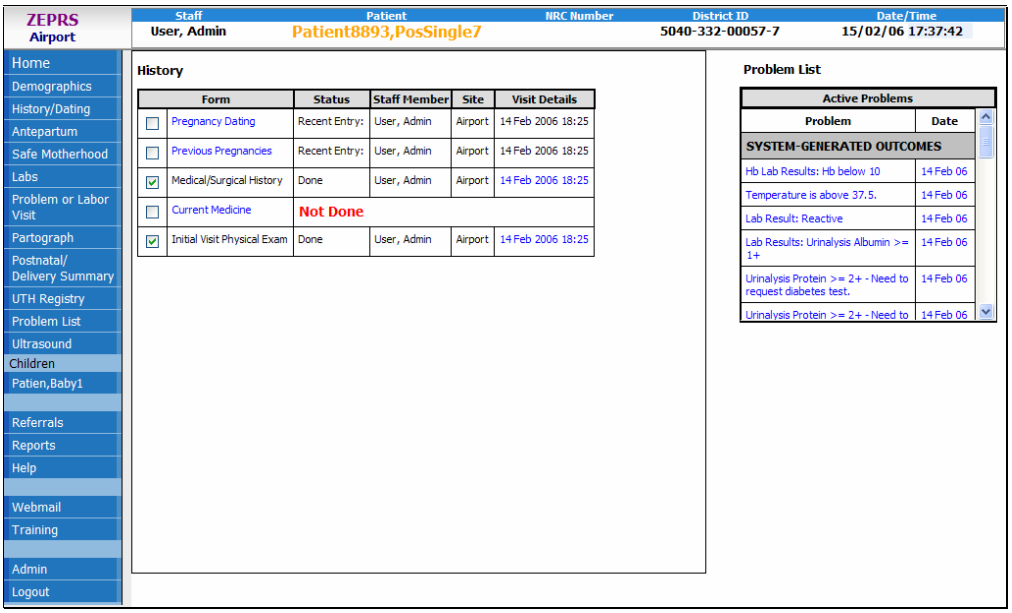
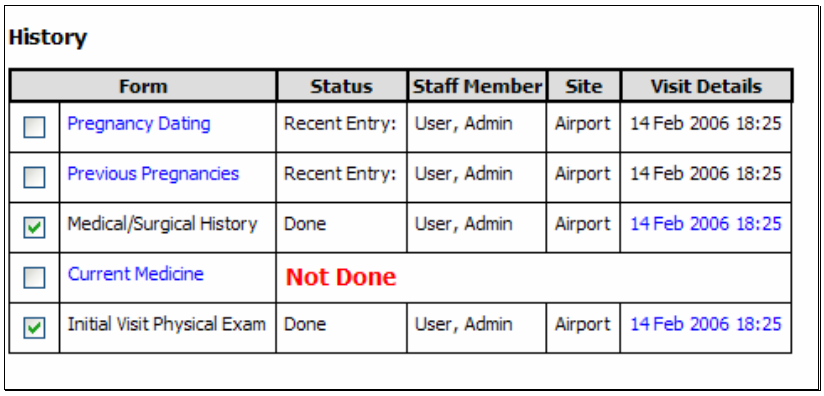


Exhibit 40 is a close-up view of a patient history display. This display helps care givers to keep track of which forms have been completed and which forms have not been completed.

Exhibit 40 Patient History Task List Display



7.6.7 Previous Pregnancies

Detailed information about previous pregnancies is available through the patient history display. Each pregnancy added into ZEPRS shows up as a previous pregnancy in this list. Exhibit 41 shows a new blank form ready to receive information about a previous pregnancy.

Exhibit 41 Display of Detailed Information About Previous Pregnancies

Year of Delivery	1987	Not Recorded
Month of Delivery	8	--
Place of Delivery	Clinic	--
Place of Delivery, Other, describe	test value6363	
Pregnancy Course	Full Term	--
Outcome of Pregnancy	Alive	--
If Died Before 5 Years, Cause	Pneumonia	--
Other Cause of Death: Describe	test value6363	
If Died < 5 Yrs, baby HIV tested?	No	Yes No N/A
If tested, result of test	Positive	--
Mode of Delivery	Spontaneous Vaginal	--
Type of Labor	Induced	--
Indication for C/S Forceps/Vacuum	Foetal Distress	--
Duration of Labor (hours)	2	
Postpartum Infection	None	--
Num. Fetuses this pregnancy	Singleton	--
Birth Weight Infant 1 (KG (x.xx))	2.0	
Sex Infant 1	Female	Sex Infant 1: Female Male
Birth Weight Infant 2 (KG (x.xx))	5.0	
Sex Infant 2	Female	Sex Infant 2: Female Male
Birth Weight Infant 3 (KG (x.xx))	5.0	
Sex Infant 3	Female	Sex Infant 3: Female Male
Eclampsia	No	Yes No N/A
PPH	No	Yes No N/A
APH	No	Yes No N/A
Comments	test value6363	
If more pregnancies click "Add". If no more pregnancies click "Done".		Password: Done Add

7.6.8 Pregnancy Dating

Users may evaluate Estimated Gestational Age (EGA) based on three methods, (1) LMP, (2) Uterus Size, and (3) EGA from Ultrasound, and may choose which method to use for estimating the EGA and thus EDD for a patient. Exhibit 42 is an example of a pregnancy dating form.

Exhibit 42 Estimation of Gestational Age Using Several Methods

Date of Visit	Method	EGA	EDD	Dating Method by
09/03/2006 Chipata, User, Admin	Reliability of LMP: Certain LMP (calc.): 2005-12-05 LMP (widget): 2005-12-05 Uterus: 11.0 weeks Ultrasound: 12, 3/7 weeks	13, 3/7	2006-09-11	LMP
09/03/2006	Reliability of LMP: Certain LMP: 2006 January 5	9	12/10/2006	◉ LMP ○ Uterine size ○ Ultrasound EGA: 9 EDD: 12/10/2006
	Uterus size in weeks: --			
	EGA from Ultrasound Results: --			
	Quickening: weeks			
Password: Submit				

7.6.9 Routine Antenatal Visit

Exhibit 43 shows the form used to record information during a routine antenatal visit. A clinician makes entry to this chart on every Antenatal visit, for each pregnancy.

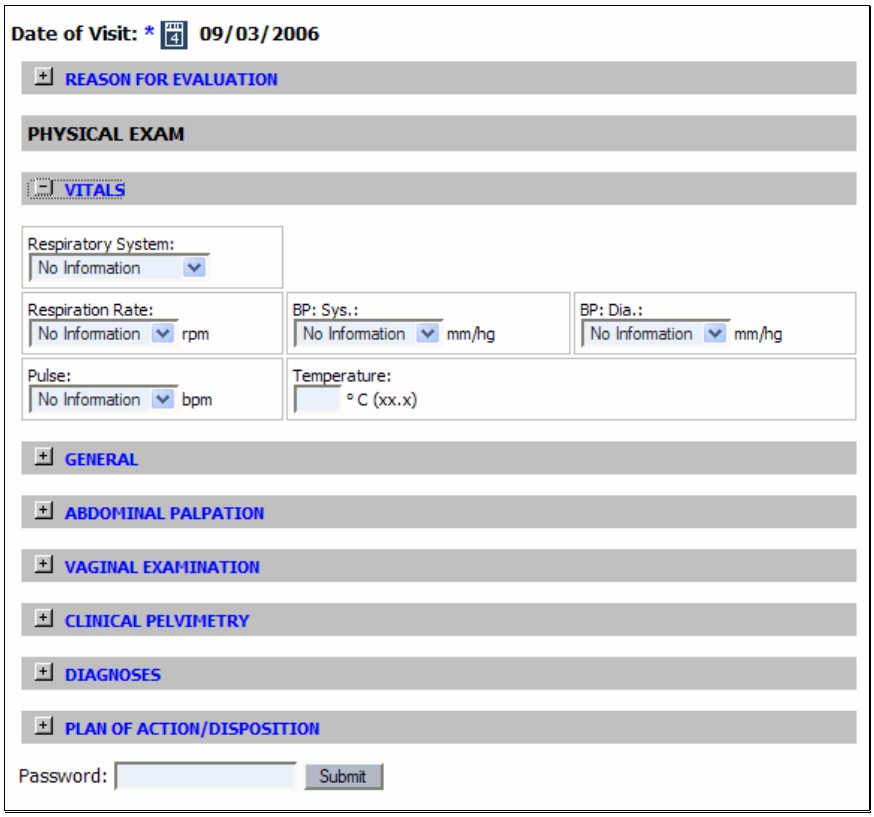
Exhibit 43 Routine Antenatal Visit Display

Date	01/02/2006	09/03/2006
Site	Chipata	
Staff	User, Admin	
EGA	13, 3/7	13, 3/7
Fundal Ht. (cm)	15	
Lie	Longitudinal	--
Pres.	Cephalic	--
Engaged	Yes	--
Oedema	1+	--
FHR (bpm)	120 - 160	--
FH Rhythm	Reg.	--
BP: Sys. (mm/hg)	160	No Information
BP: Dia. (mm/hg)	80	No Information
Weight (KG (xxx.xx))	56.6	
Ace.	0 (-)	--
Alb.	1+	--
Glu.	1+	--
Folate	Yes	Folate: ○ Yes ○ No ○ N/A
Iron	Yes	Iron: ○ Yes ○ No ○ N/A
Malaria SP	SP1	--
Next Appt.		Date:
Problem?		☐
		Password: Done

7.6.10 Problem or Labor Visit

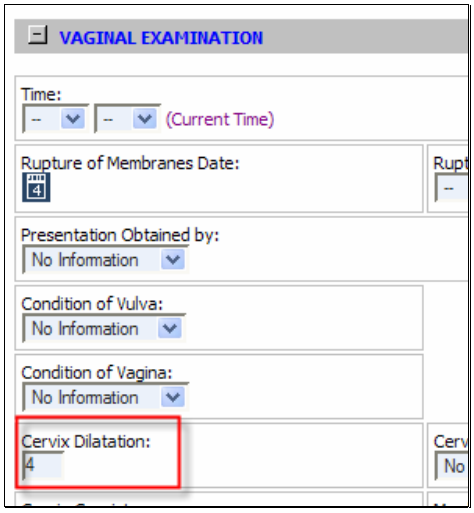
If the patient is experiencing a problem during antepartum or intrapartum that the clinician wishes to note, they have the option of filling out the problem or labor visit form. Exhibit 44 shows an example. The clinician must complete this form in order to dispose the patient to labor. Sections of this form may be expanded or collapsed as needed. In the following screenshot, the "Vitals" section is expanded.

Exhibit 44 Problem/Labor Visit Form



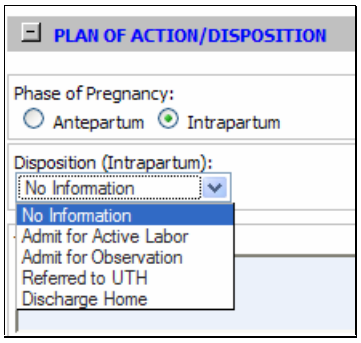
The system will admit the patient to labor if the Cervix Dilatation is greater than or equal to four (4) centimeters (cm). Exhibit 45 highlights the Cervical Dilatation field.

Exhibit 45 Vaginal Examination Detail on the Problem/Labour Visit Form



The plan of action/disposition section of the problem/labor visit form allows a user to indicate the disposition action taken with the patient. Exhibit 46 shows an example of this section of the Problem/Labor Visit form.

Exhibit 46 Plan of Action/Disposition Detail on the Problem/Labor Vi sit Form



7.6.11 Observations for Latent Phase of 1st Stage of Labour

Even if the user chooses "Admit to Active Labor," the system forwards the user to the "Observations for Latent Phase of 1st Stage of Labour" form if Cervix Dilatation is less than four (4) centimeters (cm.) Exhibit 47 shows an example of observations recorded during the latent phase of 1st stage labor. The Cervix Dilation field has been highlighted.

Exhibit 47 Observations for Latent Phase of 1st Stage of Labour Fo rm

Date	09/03/2006	09/03/2006
Site	Chipata	
Staff	User, Admin	
Time	11:06:29	11 07 (Current Time)
FHR (bpm)	120 - 160	120 - 160
Pulse (bpm)	100 < 110	120 < 130
BP: Sys. (mm/hg)	170	170
BP: Dia. (mm/hg)	70	60
Temperature (° C (xx.x))	37.0	
Urinalysis		--
Alb.		--
Glu.		--
Ace.		--
Contractions	Mild	Moderate
Contraction Freq. Per 10 Minutes (cnt. in 10 mins)	2	4
Cervix Dilatation	3	4
Remarks		
Disposition	Continue Observations	Admit Active labour
Priority of Referral		--
Transport		--
		Password: Done

7.6.12 Partograph

Once the patient has reached cervix dilatation >=4, the system forwards the user to the Partograph. The Partograph is based on the paper chart endorsed by the WHO for labor management. The clinician may click directly on the chart to enter data – the chart automatically updates. Exhibit 48 is an example partograph display. Exhibit 49 is a larger view of the cervix/decent plot area of the display. Exhibit 50 is a larger view showing the use of a drop-down list field to enter data into the partograph display.

Exhibit 48 Partograph Display

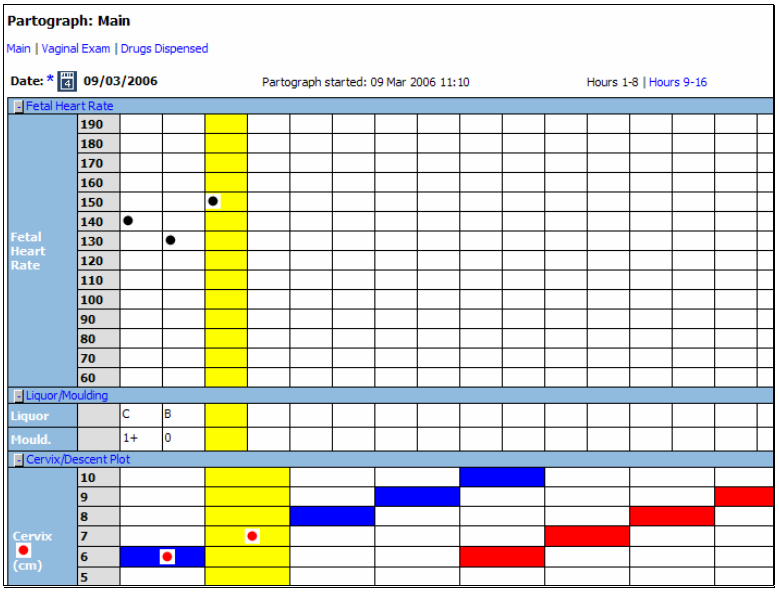


Exhibit 49 Detail of the Cervix/Descent Plot

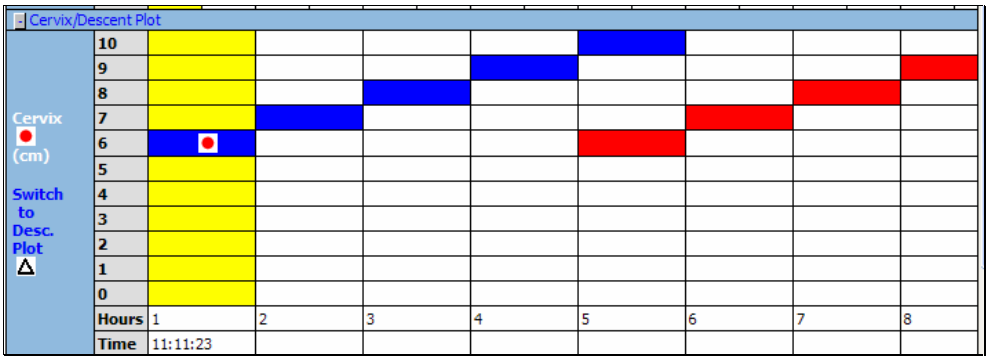
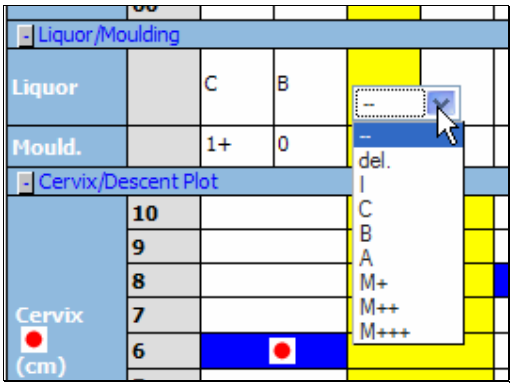
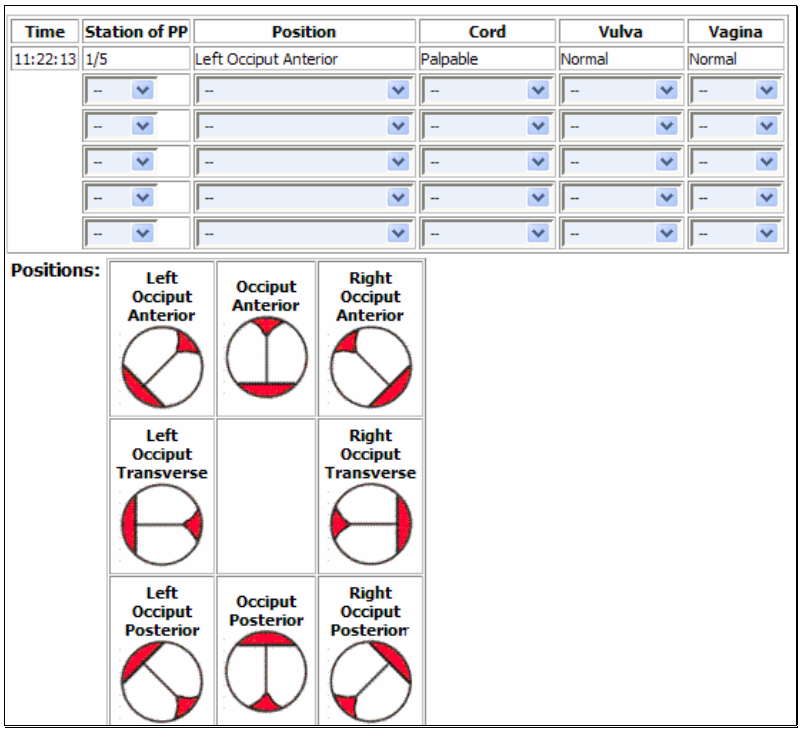


Exhibit 50 Detail Showing Data Entry using the Drop -Down Field on the Partograph Display



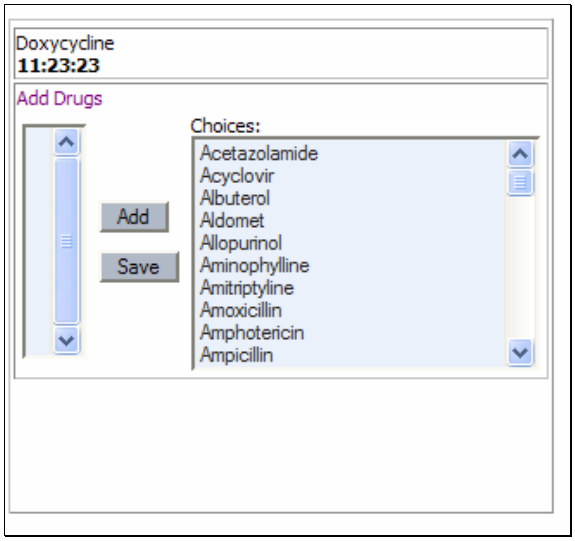
The Partograph chart has a link to another chart for recording the vaginal exam during the labor process, as shown in Exhibit 51.

Exhibit 51 Detail of the Vaginal Exam Display



Drugs dispensed during labor may be recorded while in filling in the Partograph, as shown in Exhibit 52 This drug list reflects current drugs dispensed in Lusaka.

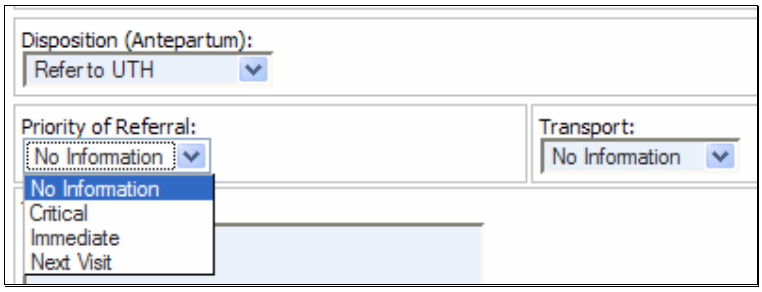
Exhibit 52 Detail Showing Drugs Dispensed during Labor being Recorded While in The Partograph Display



7.6.13 Referrals

Electronic referral capability has now been integrated into the ZEPRS application. This replaces the Electronic Patient Referral Application deployed in May 2004. Clinicians may refer patients to UTH from many of the forms by selecting a dropdow n, as shown in Exhibit 53

Exhibit 53 Patient Disposition Form Showing Referral



When the form is submitted, this record appears on the Referrals page, which is available from a link on the left navigation strip. The active referrals display is shown in Exhibit 54

Exhibit 54 The Active Referrals Display

Active Referrals

To admit a patient, click the "Admit" link under the Admission Date column.

Click the link under the "Referral Date" column to view the patient visit that triggered the referral.

Only active referrals appear on this list. To query a patient's referral status, use the Search tool on the Home page to find a specific patient. A patient's referrals - active and disposed - appear in the UTH Registry section on the left navigation strip.

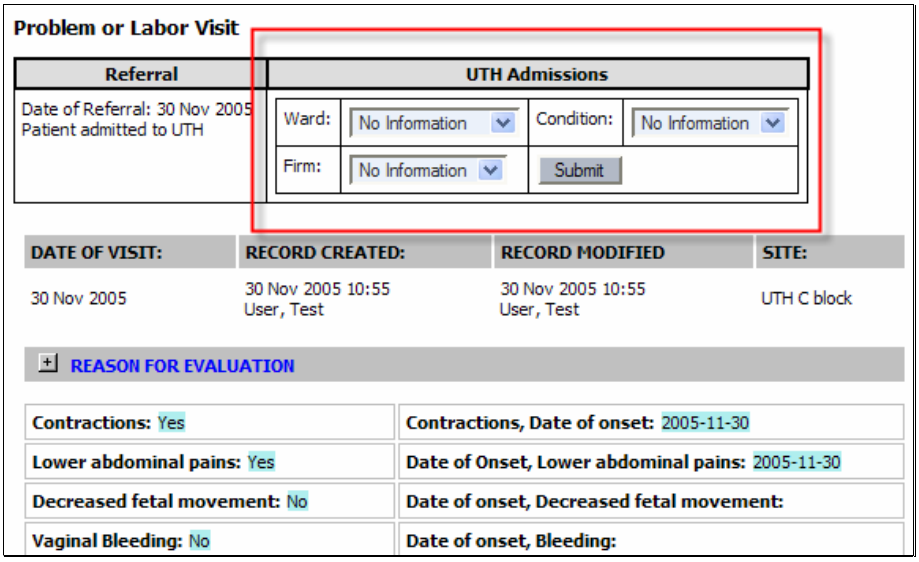
Patient	Referral Date	Reason	Clinic	Priority	Transport	Admission Date	Condition	Ward/Firm
[redacted]	02 Mar 2006	Patient admitted to UTH: True Labour , Other: in first stage of labour	UTH B block			Admit		
[redacted]	02 Mar 2006	Patient admitted to UTH: True Labour , Other: in first stage of labour	UTH B block			09 Mar 2006	Fair	Antenatal Firm A
[redacted]	02 Mar 2006	Observations for Latent Phase/Labour Referral:	UTH B block	Immediate	Ambulance	Admit		

Clinicians at UTH who are responsible for admitting patients may click on the "Admit" link in the list to admit the patient, as shown in Exhibit 55.

Exhibit 55 Detail Showing the Admission of a Patient from the Active Referrals Display

Clicking "Admit" displays a small form attached to the record that triggered the referral, as shown in Exhibit 56

Exhibit 56 Detail Showing the Admission of a Patient Referred to the UTH

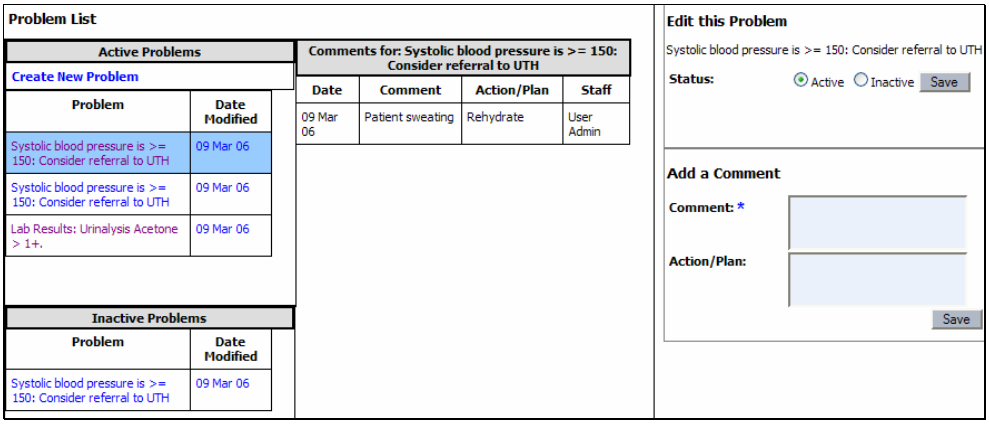


Submitting this small form admits the patient for UTH care.

7.6.14 Problem List

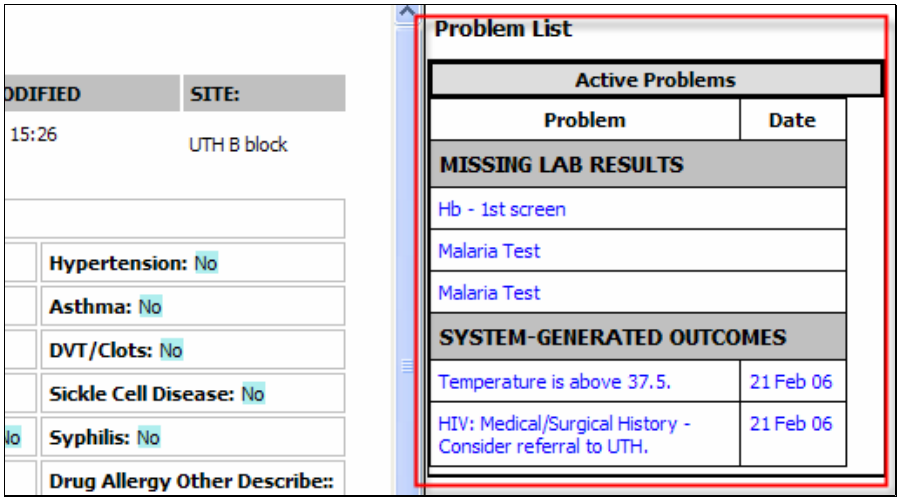
During the course of the pregnancy, system-generated problems, as well as problems manually entered by the clinicians, may be viewed and commented upon in the Problem List, as shown in Exhibit 57.

Exhibit 57 A Detailed Problem List Display



Problems are also displayed on the right side of each form, record, and task list, as shown in Exhibit 58.

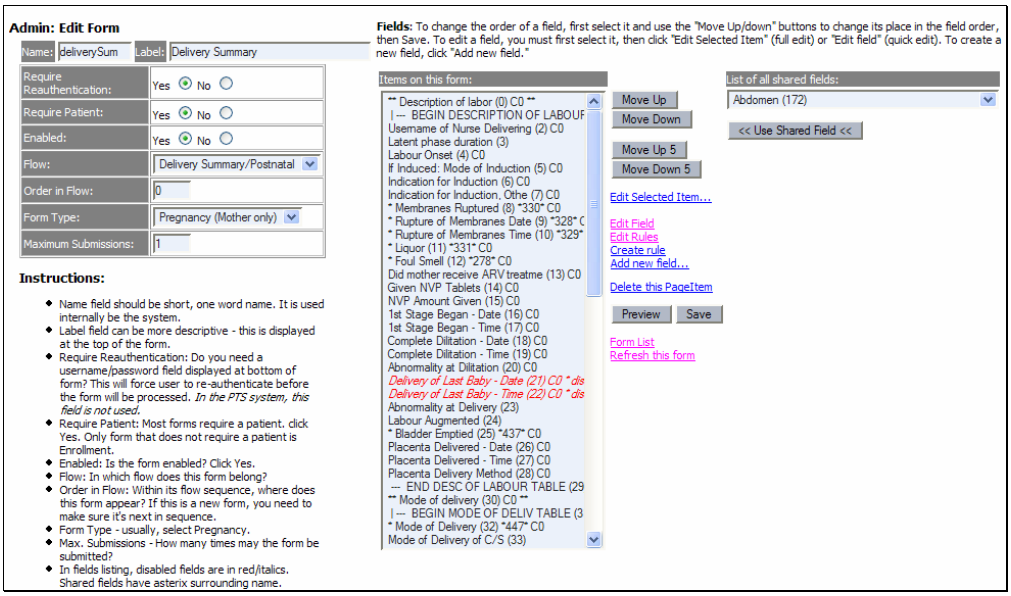
Exhibit 58 The Summary Problem List Display Included on Many Forms



7.6.15 Administration

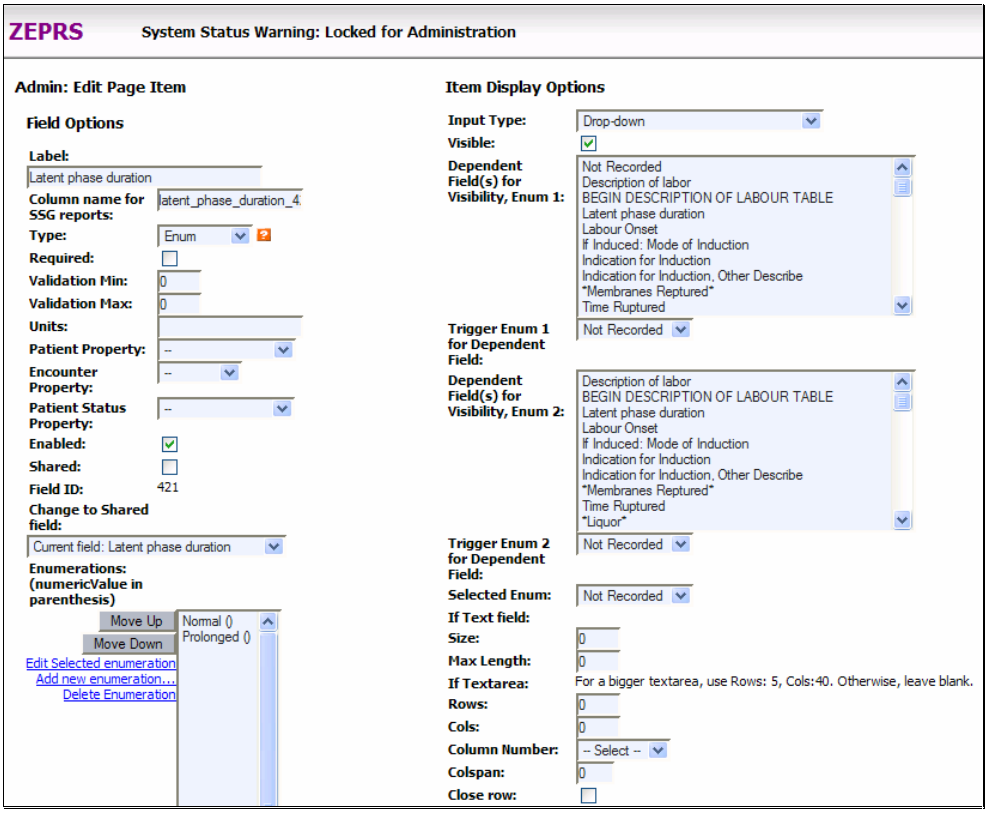
Authorized users can change forms, fields, and data handling rules in ZEPRS without changing the underlying programming code. Administrative functions enable authorized users to create and manage forms, and to determine which fields appear on each form, as shown in Exhibit 59.

Exhibit 59 Administrative Functions Enable Authorized Users to Choose Which Fields A ppear on Each Form



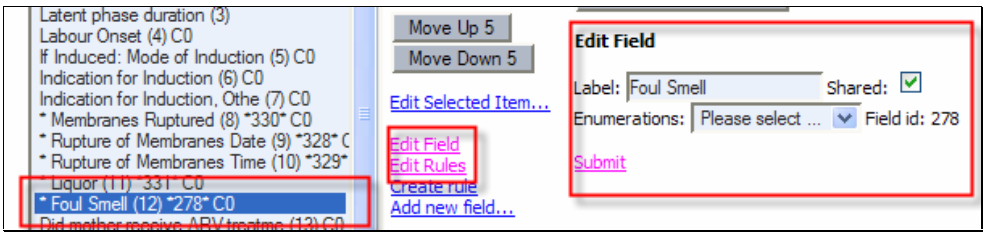
As shown in Exhibit 60, the Edit Page Item display provides access to a comprehensive set of attributes for each field, including field dependencies.

Exhibit 60 Editing field Attributes and Dependencies usin g the Edit Page Item Display



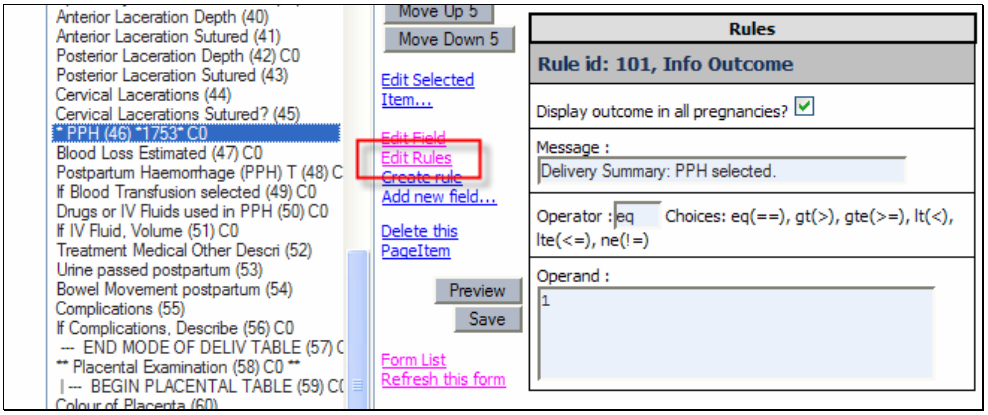
For quick edits, authorized users may use the "Edit field" or "Edit Rules" link on the Edit Form display to perform edits of common field elements. As shown in Exhibit 61, a small form appears to the right of the field. This enables the user to process many field changes while on the Edit Form page.

Exhibit 61 Using the Edit Field Link on the Edit Form Display to Edit Field Elements



As shown in Exhibit 62, authorized users may also add and edit ru les that trigger actions based on the values entered in selected form fields.

Exhibit 62 Using the Edit Rules Link from the Edit Form Display to Edit Processing Rules for Field Values



8 Operating Costs and Sustainability

RTI submitted a comprehensive estimate of ZEPRS operating costs to the UAB and CIDRZ In July 2004. This report estimates the operational costs for the voice and data network installed as part of the ZEPRS project. RTI considered several factors, such as equipment depreciation rates, obsolescence, expected useful life of the installed equipment, consumables, and software licensing costs. The prorated salaries of the staff directly or indirectly related to the system's operation were also included to allow for a global maintenance figure. This section summarizes the main findings of that report.

Exhibit 63 summarizes the estimated costs for the major components. Salaries and yearly provisions for end-of-useful-life hardware replacements are the two highest expenditures for the maintenance of this network. Salaries include staff directly tasked with the supervision and technical support of this network as well as the prorated salary of the IT Director at CIDRZ.

Exhibit 63 Estimated Annual Op erating Costs

Item	Base	Item Total
Salaries	Year	$105,400
HW Replacements (failures)	Year	$37,343
HW Replacements (amortization)	Year	$105,443
Consumables	Year	$6,945
Software licenses	Year	$7,225
Other Costs	Year	$1,500
	Total	$263,856

Salaries include a full-time support staff of five persons, including an IT Director, an IT Manager, and three support technicians. In addition, salary costs include the cost of a part-time rigger, who is responsible for making replacements and repairs on masts as needed.

Hardware costs include all networking and computing equipment, including PCs and printers. These costs include the costs of anticipated failures as well as depreciation costs necessary to fund the scheduled replacement of equipment as it reaches the end of its useful life.

The cost of consumables supplies includes all magnetic and optical removable storage media, as well as paper and toner cartridges used by the printers.

As shown in Exhibit 64, annual software licensing costs are low. Annual software costs could be lowered further by substituting free and open-source software for some of the commercial products listed in Exhibit 64, and by forgoing paid support for updates to the Red Hat Linux operating system distribution. However, for the ZEPRS project RTI elected to reduce risks somewhat by paying for Linux operating system support, and by using carefully selected commercial products in key high risk areas, such as server backup. Current commercial anti-virus protection at multiple points proved to be critical in protecting the network from computer virus attacks that could destroy network performance.

Exhibit 64 Annual Software Licensing Costs

Component / Description	License Cost	Required Licenses / Year	Yearly Licensing Costs
Annual SonicWALL Firewall Support [8x5] for SonicWALL PRO 100 (2x)	$250	1	$250
SonicWALL Network Anti-Virus 50-user 1 Year Subscription (2x)	$1,300	1	$1,300
McAfee VirusScan (Distribute by SonicWall)	$20	140	$2,800
RedHat	$180	3	$540
Server backup software - Arkeia Annual maintenance contract	$1,300	1	$1,300
Server Antivirus – F-Secure	$345	3	$1,035
AEGIS Radius Server (There are no annual costs for AEGIS)	$2,000	0	$0
		Total	$7,225

9 Current Status and Conclusions

9.1 Current Status

As of this report RTI has completed the following:

- Designed and installed a wireless network interconnecting 24 clinics and the UTH
- Upgraded the electrical service at all clinics
- Inspected and renovated existing radio masts at all clinics
- Designed and installed connections to provide wireless network connectivity in multiple buildings at delivery clinics
- Designed and installed a fiber-optic and wireless network connecting different wards and units at UTH
- Designed, installed, and configured the CIDRZ data-center

- Installed Voice over Internet Protocol (VoIP) to provide voice communications to clinics and selected areas of the UTH
- Installed PCs on mobile carts in clinics, selected areas of UTH, and the Lusaka District Office
- Installed battery backup systems to provide a minimum of four (4) hours battery backup time at all points in the network including client PCs
- Installed lightning suppression for all exterior mounted network devices
- Developed and documented standard operating procedures for all routine network support operations
- Developed an automatic network status monitoring and alert system
- Mentored and managed local technical support staff
- Designed a new electronic medical record in close collaboration with Zambian and UAB physicians
- Designed, developed, tested, and launched a Web-based patient referral system
- Modified and launched a Web-based email system
- Helped to create four training centers (two at clinics and two at UTH)
- Produced user manuals and helped design and manage user training for more than 800 medical personnel
- Provided essential clinical practice guides in electronic form on each ZEPRS PC
- Developed, tested, and launched the ZEPRS Version 1.0 Web-based Electronic Medical Record (EMR) system with integrated electronic referral system and patient care alerts

The ZEPRS wireless backbone network has been in operation since March 2003. The complete ZEPRS wireless network, including connections at delivery clinics and the hospital network at the UTH, has been in operation since March 2004. By the end of July 2005 network uptime averaged 95 percent availability. RTI handed network operations over to CIDRZ on 1 June 2005. For several months following the handover network uptime continued to at around 95% availability. The direct lightning strike at the TELECEL 1 tower on the 22nd of December 2005 destroyed network and cellular telephone equipment. Since then network reliability has declined and now hovers at around 80 percent availability. A few pieces of equipment have failed and have not been repaired or replaced.

The electronic patient referral system was launched in July 2004 through October 2004 and was used successfully in production from until January 2005, when ZEPRS Version 1.0 was launched with integrated electronic referral capability. While operating as a separate application the electronic patient referral system achieved all its objectives. Medical personnel in the clinics and learned to use the system quickly and became enthusiastic users. Users at UTH were less enthusiastic regarding their responsibility to acknowledge referred patients when they arrived by entering data into the system. The referral system has been incorporated into standard training for medical personnel. The system demonstrated the value and the functionality of ZEPRS wireless network and laid the groundwork for the ZEPRS network operations, user training, user acceptance, and user ownership. As is the nature of most software applications, requirements became increasingly complex and eventually far exceeded the information managed using the original paper referral form. All 24 clinics used the electronic referral system for more than a year before it was incorporated into the main ZEPRS application.

The ZEPRS v1.0 integrated EMR and referral system was released officially by RTI on November 21, 2005. Nine clinics and two departments at UTH are now using ZEPRS v1.0. Exhibit 65 shows the total number of clinics using ZEPRS v1.0 by month. Labor wards at four clinics are now using the system. A total of 3933 new antenatal patient records and 4675 total visits have been entered into the system. As shown in Exhibit 65, the number of new patients and repeat patient visits entered into the system is increasing each month. The roll-out of the application is on schedule with two to three new clinics being added each month. Early evidence is very encouraging and indicates that the system is already helping to improve the quality of patient care. Feedback from users and rapid response in the form of adjustments is helping to build user ownership of the application.

Exhibit 65 Total Clinics using ZEPRS v1.0 by Month in 2006

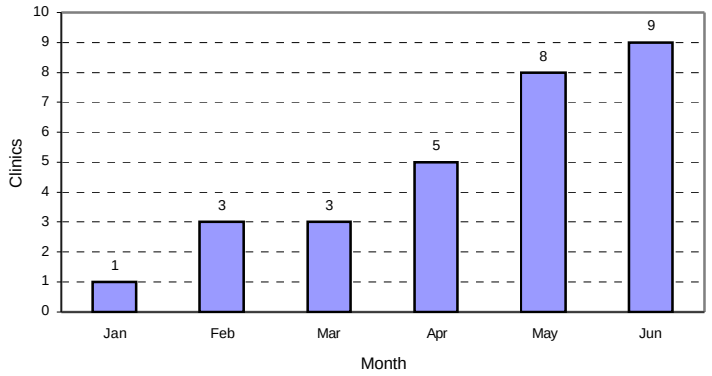
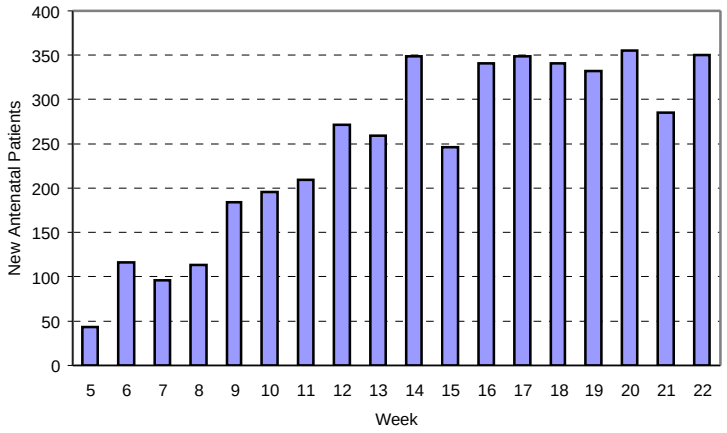


Exhibit 66 Number of New Antenatal Patients by Week in 2006



Prolonged electrical outages at a few clinics, network damage due to lightening, and a stretched technical support team pose challenges, but progress to date has been very encouraging. RTI added the capability to print patient records summary cards that can be used for reference and recordkeeping during extended electrical outages. Recently RTI developed capability that enables ZEPRS users to continue using the system during network outages. This feature

caches data off-line and resynchronizes with central databases when network connectivity is restored. This new capability is being tested now in Kalingalinga Clinic.

9.2 Challenges and Adjustments

No project is without challenges, and ZEPRS has presented many. Some of these are discussed in more detail below.

9.2.1 Selection of Network Backbone Technology

RTI originally proposed the use of 802.11b 2.4 GHz wireless technology for all network links. This technology nominally provides up to 11 Mb per second and bandwidth. At the time of our proposal, this technology was in common use at many sites in Africa. During the wireless site survey and design phase, RTI became concerned that limitations of this technology could jeopardize the project if used for the network backbone. Specifically, actual transmission speeds link speeds were projected to be 4.6Mbps or less over many links, and analysis of spectrum usage in Lusaka showed congestion in the 2.4 GHz band. These concerns caused us to recommend more expensive equipment operating in the 5.8 GHz band and using a proprietary wireless protocol. This equipment would provide much higher speed and more secure backbone links.

At that time, the Communications Authority of Zambia (CAZ) had no formal policy with respect to the use of this frequency band. RTI worked closely with CIDRZ and the Zambia Central Board of Health (CBoH) to get clear agreement from CAZ for free and unlicensed use of this frequency band. CAZ agreed to permit the unlicensed use of this frequency band specifically to the CBoH for ZEPRS since this is a nonprofit application for public benefit.

Selection of 5.8 GHz wireless technology for the network backbone more than doubled network costs and increased operating costs due to the higher cost of replacing equipment. In retrospect we believe this was the correct decision. Despite increasing loads, performance has been good, and apart from lightning damage, equipment reliability has also been good. Selecting this technology eliminated the risk of inadequate bandwidth and eliminated concerns about the security of subscriber and backbone links. In new applications however, RTI would consider piloting lower-cost solutions and examining the cost-effectiveness of newer 802.16 "WiMax" technologies.

9.2.2 Connecting Delivery Clinics and Networking the UTH

At the time RTI developed his proposal for the UAB, RTI did not have the opportunity to conduct a site assessment in Lusaka. After the award of the contract to RTI, site surveys identified several significant issues. First, delivery clinics included multiple buildings that would need to be interconnected to provide network access in each building. Second, while work had begun to install a network at the UTH, this work was not progressing and was not likely to be completed in time to be used by ZEPRS. An analysis of operations also revealed that many departments and wards at the UTH would require network connectivity. It became clear that the project would need to install network access in all buildings at delivery clinics as well as a very comprehensive network interconnecting buildings at the UTH. Finally, the original site survey questioned whether adequate line of site existed to connect State Lodge Clinic to the wireless network. It became clear that a new, higher, tower would be needed to provide good connectivity to this clinic, and that repeater equipment would need to be installed on a Zambia National Broadcasting Corp. (ZNBC) tower to reach this clinic.

Connecting additional buildings at delivery clinics cost just over $25,000. It cost just over $40,500 to install a combined fiber-optic and wireless network at the UTH. Installing a new tower at State Lodge Clinic and repeater equipment on the ZNBC tower cost roughly $9,300. The project also equipped CIDRZ with nearly $37,000 worth of spare network equipment for rapid on-site replacement. The total cost of these additions to the network was nearly $133,300.

9.2.3 Installing VoIP Capability

The UAB asked RTI about the feasibility of installing VoIP capability in all clinics and the UTH, as well as connecting this capability to the public telephone network. This would, for the first time give clinics voice communication capability with each other and with the UTH with the ease of telephone communications. RTI presented the UAB with an analysis of costs and an analysis of the impact on ZEPRS network bandwidth. RTI argued against installing this capability on the basis of cost, since there were still many cost unknowns concerning the development of the main ZEPRS EMR application. However, at the request of the UAB RTI proceeded to add this to the contract modification for Communications Solutions at a total cost of just over $6,000.

In retrospect, VoIP capability has been very valuable in enabling voice communications between clinics and the UTH, and between clinics and the datacenter at CIDRZ. It has proven very cost-effective. While it depends on ZEPRS network reliability, VoIP has provided voice communications where none existed before. Impact on network bandwidth usage has been negligible. In the future RTI would consider other VoIP solutions, including integrated solutions offered in some wireless networking equipment and free solutions such as Skype.

9.2.4 PCs and PC Carts

RTI's initial site assessment in April 2002 identified two important factors concerning the installation of computers and clinics. First, space in clinics was limited; they had not been designed to provide room for computers. Second, computers should be mobile so they can be placed where needed as clinic operations change, and placed in a secure area when not in use. RTI, the UAB, and CIDRZ considered many alternatives, including tablet computers, laptop computers, thin clients, and industry-standard PCs. RTI submitted an analysis of advantages, disadvantages, and costs to the UAB. RTI recommended considering the use of laptop computers to reduce space and to eliminate the need for an external UPS battery backup system for each computer. CIDRZ was concerned about the usability of laptops and their attractiveness to thieves. At CIDRZ request RTI proceeded to purchase and install industry-standard desktop PCs on mobile carts.

In retrospect RTI believes that industry-standard PCs are more sustainable. Replacement PCs and UPS battery backup units are readily available on the local market, and costs for these units continue to be below the cost of comparable laptop computers. Desktop PCs also provide a full-size keyboard and mouse and can be repaired more easily by local technicians.

CIDRZ originally worked with the South African manufacturer to custom-design manufacturer enclosed metal carts for the PCs. These were well designed, well manufactured, and provided a securing closure for the PCs when not in use. However, they proved to be expensive for the project to purchase in quantity, and the enclosed carts provided an ideal place for rodents to breed and gnaw on network cables. RTI proceeded to purchase and deploy much less expensive wire carts. These eliminated the rodent problem and have proven to be a good and secure choice.

9.2.5 Electronic Referral Application

As planned originally, the Referral Application is now an integrated part of the ZEPRS medical record system, with reports available to track each patient's referral status and history, as well as combined reports with multiple patients in different locations. Historical referral data prior to January 2006 has not been transferred from the original separate web-based referral application to the ZEPRS medical record database.

The poor performance of the original software subcontractor was surprising and disappointing. RTI previously had very positive experience with the same subcontractor on other RTI projects. After assuming responsibility for continued development, RTI found requirements for the application becoming increasingly complex. In retrospect the referral application began to resemble the electronic perinatal record system and could have served as the foundation rather than as a peripheral component. However, while development therefore took seven months longer than expected, the referral system accomplished all its original objectiv es. Specifically:

- It tested the performance of the South African contractor
- It provided a useful application to test network and datacenter performance
- It provided a practical foundation for training personnel in the clinics and at UTH
- It demonstrated that medical personnel were very receptive to and capable of using an electronic system
- It helped to develop ownership and support among medical personnel and CBoH officials

9.2.6 Currency Exchange Rate

RTI's original cost proposal assumed the use of South African subcontractors for software development. At the time of the proposal RTI obtained cost estimates from two separate South African software developers that have worked with RTI on other projects. By the time RTI had completed detailed requirements and specifications for the software, currency exchange rates had increased the cost of outsourcing in South Africa by roughly 43 percent. It had become less expensive for RTI to develop the software internally then to outsource this work.

In retrospect developing the software internally enabled RTI to develop much tighter loops for clarifying customer requirements and testing the software. This became increasingly important as customer requirements changed.

9.2.7 ART/PTS

In April 2004, at the urgent request of the UAB and CIDRZ, RTI used the ZEPRS software architecture to develop the Antiretroviral Therapy Patient Tracking System (ART/PTS) for use by CIDRZ in clinics providing ART services. This work has been complementary to the work done for ZEPRS as the software platform. ART/PTS also uses the ZEPRS network. The development of ART/PTS presented a serious resource constraint. During 2004-2005 RTI had to dedicate considerable time to producing the ART/PTS application to meet UAB/CIDRZ needs and to transfer technical capacity for continued development to CIDRZ in Lusaka. The development of the ART/PTS application resulted in a considerable delay in developing the ZEPRS application.

We believe collaboration between RTI, the UAB, and CIDRZ to create ART/PTS has made a significant contribution to efforts to combat HIV/AIDS through CIDRZ ground-breaking ART

program in Zambia. In its first nine months Lusaka HIV Care and Treatment Program enrolled 10,951 patients, 6,726 of them started on anti-retroviral therapy. All patients were entered into the ART/PTS system. A total of 1.3 million data elements were collected over 105,000 patient visits using this system.

RTI experience building on ZEPRS software architecture to create ART/PTS also benefited ZEPRS. RTI worked closely with an expatriate consultant and a Zambian software developer in Lusaka to transfer further development of the ART/PTS application to Lusaka. By February 2005 this effort succeeded in enabling CIDRZ to assume full responsibility for further ART/PTS development to support CIDRZ ART programs, while freeing RTI's lead software developer to concentrate on ZEPRS.

9.2.8 Determining System Requirements

RTI began gathering requirements for the system during its initial site visit in April 2002. During that visit RTI began the work of developing detailed technical specifications for the electronic medical record to be managed by the ZEPRS application. RTI consulted existing paper record-keeping systems, including obstetric "blue books," infant growth and development and immunization cards, and registers at clinics and relevant wards at UTH. RTI led several workshops in Lusaka to help define the requirements of the system with input from key local stake holders, including physicians and other medical personnel. RTI consulted closely with physicians at the UTH and conducted multiple reviews of the draft medical record specifications. UAB physicians also had input into the medical record specifications. RTI continued to revise the medical record specification based on input from the medical team until June 14, 2004. During subsequent User Interface and beta testing sessions, the medical record continued to be updated until October, 2005 when it was transferred to CIDRZ.

RTI demonstrated a rough prototype application in early January 2004, and began development in earnest in February 2004. Beginning in February 2004, RTI provided the UAB advisory team with a series of detailed software design documents to review, including screen flows and screen layouts in May and June of 2004. The advisory team did not react to these documents, and did not begin providing substantial feedback on the application until they could finally see it in operation. It became clear to RTI that the medical advisory team would not be able to describe what they wanted until they saw a working prototype.

RTI made every effort to hold monthly design review sessions with the UAB team. Beginning in June 2004, RTI made every effort to hold weekly to bi-weekly design review sessions with the UAB advisory team led by Dr. Dwight Rouse. These sessions concentrated on reviews of the working prototype. RTI worked hard to adapt the software based on the recommendations and requests of UAB and Zambian clinicians. We believe that this has greatly improved the quality of the medical records system.

After the UAB's review of the ZEPRS Beta version in late July 2005 RTI re-evaluated funding and schedule requirements for completion of the software and transition to the UAB, and with UAB understanding proposed a contract extension until September 2006 to allow for additional ZEPRS system requirements to be defined, developed, tested, and rolled-out to all clinics and UTH areas involved in the ZEPRS Version 1.0 system.

In retrospect RTI believes software development could have started much earlier in the process, in parallel with work towards defining the medical record. The ZEPRS application could have been built incrementally on the foundation of the electronic referral application,

engaging the combined Zambian and the UAB advisory team in reviewing an evolutionary series of increasingly functional modules at a much earlier date. This incremental and parallel process of developing requirements and successive working prototypes could have helped the medical advisory team to visualize the application and define their requirements more quickly.

9.2.9 Network Reliability

While the selected network equipment has proven to be reliable, extended electrical outages at some clinics and lightning damage at some high sites during the rainy season have continued to be problems. While RTI provided for four hours of battery backup at all points, electrical outages at some clinics proved to be much longer than indicated by information collected during our design assessment. In retrospect the budget should have provided for an emergency backup generator for each clinic. RTI also assumed that the network subcontractor had installed lightning suppression devices on all tables to all external network equipment. This proved not to be the case. After RTI installed the best available lightning suppression devices, equipment loss due to lightning decreased significantly. However, the direct lightning strike at the TELECEL 1 site in December of 2005 demonstrates that even the best equipment cannot protect against a direct strike.

In response, RTI added the capability to print patient record summary cards for reference and recordkeeping during network outages. RTI is currently testing enhancements that enable ZEPRS users to continue using the system during network outages. This feature caches data off-line and resynchronizes with central databases when network connectivity is restored.

9.3 Conclusions

Simplification, standardization, and strengthening local technical and management capacity are keys to developing reliable and sustainable IT infrastructure. RTI has demonstrated that it is possible to achieve 95 percent average availability for the wireless network, but this is sustainable only with strong local technical support and adequate local supplies of replacement spares. It is clear that any information system designed to operate over such a network must be capable of operating without network connectivity during network outages, and capable of synchronizing with central databases when network conductivity is restored. Users must also understand procedures for continuing operation during network outages.

The information system must also be designed to operate for short periods with no electricity. Even if generators are provided to all sites, there will be periods when there is no electricity from the grid and no functioning generator. It is essential to be able to print patient summary cards that can be used for reference and for record-keeping during extended electrical outages. Whiles ZEPRS remains an “electronic first” medical record application, it is not a paperless application.

The training of local medical personnel is best done by local medical personnel. RTI and CIDRZ observed a distinct improvement in results when and user training was conducted by experienced local medical personnel rather than by local IT technical support personnel.

The strong positive reception and rapid acceptance of the electronic referral application by Zambian medical personnel in the clinics was a surprise. The use of computer technology was not a significant barrier when medical personnel could clearly see the value of the application to their work.

Developing such an application is best done by developing a successive series of prototypes in close collaboration with users and subject matter experts. Technical requirements and designs can be developed while producing successive prototypes. In contrast to a long requirements specification and design phase, followed by software development, this rapid prototyping approach is more appropriate when users and subject matter experts need help in defining a system that will meet their needs, and when users are more likely to respond to visual examples than engineering specifications. Engineering specifications are essential to document the work, to reveal inconsistencies and incoherence, and to ensure that all members of the technical team are following the same set of requirements, specifications, and designs. They may not be useful in clarifying requirements and communicating the proposed solution to users and subject matter experts.

It is critical to involve users and subject matter experts early and often in developing and reviewing a successive series of working prototypes. No requirements gathering process in such a complex environment can discover all critical requirements. Users and subject matter experts often do not know what is possible and what they want until they see it. Involving users and subject matter experts early and often in development builds ownership and helps the system converge more quickly on an acceptable solution.

It is possible to develop and operate a networked EMR system in sub-Saharan Africa. Such a system can be nearly paperless and can operate over a wireless network. If components are selected carefully, and local technical and management capacity is strengthened through long-term mentoring, it is possible to sustain the supporting technology. Use of free and open-source software components can reduce software licensing costs significantly. The most significant operating costs will be salaries for local technical support personnel, and emergency and planned replacement of computer and network equipment. It may not be possible to sustain these costs without some financial support from research grants and international donor programs.

We are less than halfway through the complete roll-out of ZEPRS v1.0, but early signs are very encouraging. The evidence indicates that when EMR system data are used carefully in collaboration with care providers to monitor the quality of treatment, care providers respond, and the quality of care improves. This monitoring and coaching role is likely to prove essential in maximizing the impact of the system.

9.3.1 Transfer to Other Countries

The ZEPRS network involves many different sites, networking and security equipment, servers and employs a group of people for its maintenance. All this is necessary to distribute the ZEPRS applications, ancillary services and other services (not related to the project) that benefit from a high-speed network that now reaches places that previously were lacking even basic phone service.

Is this a replicable installation? Can this configuration be used in a project that requires an application like ZEPRS but that cannot afford the complexity of this network? Yes. There are some aspects of this network that would allow it to be used in different scenarios with minor alterations, “rightsizing” its components to suit each particular scenario.

The network design for ZEPRS can easily be replaced by a scaled-down implementation that deals with a reduced number of sites. The networking equipment can be replaced with other models, brands, or even frequencies if the uptime or traffic congestion in the selected band

allows. The multiple-server approach can be easily reduced by consolidating multiple services in a single server; this will require a careful load planning and testing but will allow for a simpler setup.

All applications used in the ZEPRS network are based on open standards. Most of them use open source technologies or can be easily replaced by equivalent software released as open source, thus lowering the initial setup costs. Since there are no client computer requirements other than the ability to run a web browser, there is nothing that would prevent choosi ng freely between different architectures and operating systems, or customizing the client to each installation.

The open source software architecture RTI developed for ZEPRS is extensible; it may be customized for different applications and two different environments easily. The ZEPRS architecture is flexible enough to accommodate adding new fields, forms and reports without changes in the underlying software code. This makes it possible to adapt ZEPRS efficiently to clinical environments in countries other than Zambia. Use of open source software components eliminates the need to pay recurring software licensing fees.

In 2004 ZEPRS provided the foundation for the Antiretroviral Therapy Patient Tracking System (ART/PTS) for managing antiretroviral treatment (ART) for HIV/AIDS patients. RTI worked with the UAB and CIDRZ to develop ART/PTS. This software has since become an integral component of CIDRZ ground-breaking ART treatment program in Zambia.

ART/PTS is a web-based application that operates on stand-alone or networked computers. The system tracks patient data, including lab tests, patient adherence, appointment schedules, compliance with treatment protocols, and general antiretroviral (ARV) statistics, and also produces PEPFAR standard indicator reports. ART/PTS has proven to be a vital tool in improving ART clinical care by helping to schedule and track patient visits and by providing immediate access to key program indicators.

The use of the ZEPRS architecture to produce ART/PTS demonstrates its flexi bility. ZEPRS can be adapted easily to the needs of other health care systems and, in fact can be used as the foundation for applications not related to health care.

Annex A: ZEPRS Development Timeline

Date	Event
Aug 2001	RTI submits original proposal t o the UAB
Jan 1, 2002	Beginning of RTI contract with the UAB to develop ZEPRS
Apr 2002	Initial RTI site assessment in Lusaka
Jun 2002	RTI contracts Communications Solutions to complete a detailed site survey of all 24 clinics and the UTH.
Jul 2002	Communication Solutions completes detailed site survey and equipment specifications for the ZEPRS wireless network.
Nov 2002	RTI contracts Communications Solutions to install the ZEPRS wireless network.
Mar 2003	Communications Solutions completes installati on of the core ZEPRS wireless network.
Apr 2003	RTI completes several revisions of the revisions medical record specification. RTI contracts Data Matrix of South Africa to develop an electronic patient referral system to run over those ZEPRS network
Jul 2003	RTI contracts Communications Solutions to install Voice over Internet Protocol (VoIP) equipment providing voice communications among all 24 clinics and the UTH.
Aug – Sept 2003	RTI works with Communications Solutions to design a hospital network for the UTH, to extend network connections to multiple buildings at delivery clinics, to add VoIP capability to all network sites, and to equip CIDRZ with the supply of spare network equipment.
23 Sep 2003	RTI subcontracts Communications Solutions to install network at the UTH, connect multiple buildings at delivery clinics, construct a new communications tower at State Lodge Clinic, add VoIP capability at all sites, and provide a supply of network spare equipment to CIDRZ.
13 Oct 2003	RTI completes detailed Request For Quotations (RFQ) containing complete specifications to be issued to selected software development firms in South Africa.
Oct 2003	RTI submits *Zambia Electronic Perinatal Record System (ZEPRS) RFQ* to several selected software development firm s in South Africa.
13 Nov 2003	RTI completes third round of questions and answers with potential bidders for the software development RFQ.
23 Nov 2003	RTI terminates its subcontract with Data Matrix of South Africa, and assumes responsibility for complet ing the electronic patient referral system
1 Dec 2003	RTI notifies bidders of changes to RFQ made to reduce software development costs.
16 Dec 2003	RTI releases a second addendum to the RFQ.
Jan 2004	RTI notifies bidders of changes to RFQ made to reduce software development costs. RTI team tests Referral application and corrects bugs.
5 Jan 2004	First demonstration of ZEPRS application based on medical record specification developed by Senior System Integrator Scott Herman -Giddens in consultation with Z ambian and UAB medical personnel
7 Jan 2004	Chris Kelley Lusaka trip - meets w/ Dr. Phiri on referral app changes, also works on server infrastructure; 7 Jan – 14 Jan.

Date	Event
12 Jan 2004	RTI completes analysis of bids for software development and determines t hat due to changes in Rand/USD exchange rate, no offer is close enough to the original estimated cost. RTI develops estimate for the cost of developing the software in -house.
14 Jan 2004	The UAB (Dr. Robert Goldenberg) issue approval to RTI to begin devel opment of the ZEPRS application.
9 Feb 2004	Chris Kelley installs ZEPRS team collaboration site; notifies Harmony, Dennis, Francis, Noel, and RTI team members. The purpose of this project site was to help us keep track of major deliverables in this project, especially during the early stages of development.
13 Feb 2004	RTI completes detailed screen flow logic diagrams (wireframes) for entire ZEPRS application.
Feb-Mar 2004	Lead Software Developer Chris Kelley and Consultant Dave Peckham design and devel op core ZEPRS architecture. During this period Kelley and Peckham have three telephone conferences each week with Scott Herman-Giddens. Kelley continues work on referral app updates.
23 Feb 2004	Chris Kelley trip to Lusaka – hand over management of data c enter to Pablo Destefanis. Feb 23 - 25
12 Mar 2004	Scott Herman-Giddens completes a review document of the live ZEPRS demonstration application.
29 Mar 2004	UAB Meeting teleconference – Scott and Chris report on ZEPRS software development
12 Apr 2004	Niamh Darcy completes and shares user interface design process and guidelines with RTI team.
16 Apr 2004	Chris Kelley completes new build of the Referral application
20 Apr 2004	Niamh Darcy, Eileen Reynolds, and Chris Kelley review outline ZEPRS user inter face organization and schedules review meeting the next day with Harmony Fusco, UAB Project Manager.
22 Apr 2004	RTI revises ZEPRS user interface outline, develops User Interface (UI) specifications and screen flows
28 Apr 2004	RTI completes matrix of us er security roles and access levels to various ZEPRS functions.
Early May 2004	Niamh Darcy, Scott Herman -Giddens, and Eileen Reynolds review and adjust ZEPRS screen flow specifications.
Early May 2004	RTI completes web -based patient referral system.
May 2004	Chris Kelley works three intensive weeks on ART/PTS 1.0. Trip 1 – May 4 – 6 – ZEPRS trip; met w/ Jeff Stringer about PTS Trip 2 – May 12 – June 1 – Code and complete PTS 1.0 application – installed at Kalingalinga – "3 hours sleep in 48 hours" It is important to note that from this point, Chris Kelley is both developing ZEPRS app and supporting ART app.
10 May 2004	RTI revises medical record application
11 May 2004	Scott Herman-Giddens provides written feedback to Chris Kelley on Referral applic ation.
17 May 2004	RTI defines and documents the types of testing to be preformed on the ZEPRS application.
28 May 2004	RTI records detailed feedback on review of ZEPRS application
5 Jun 2004	RTI completes detailed user interface screen flows for ZEPRS application.
5 Jun 2004	RTI revises medical record specification.
7 Jun 2004	RTI team reviews the ZEPRS application.
10 Jun 2004	RTI updates ZEPRS site map diagrams.
10 Jun 2003	RTI revises medical record specification.
11 Jun 2004	Dr. Rouse reviews the ZEPRS application. RTI records detailed review notes with changes and additions.
11 Jun 2004	RTI team completes revision to medical record specification.
24 Jun 2004	Niamh Darcy meets (teleconference) with Dr. Mary Ngoma and two medical students in L usaka to explore options for executing the ZEPRS test plan.
2 Jul 2004	Dr. Rouse reviews ZEPRS application with RTI team.
6 Jul 2004	Niamh Darcy submits detailed review of updated ZEPRS application with Chris Kelley.
14 Jul 2004	Dr. Rouse reviews the ZE PRS application with Niamh Darcy and Chris Kelley.
14 Jul 2004	RTI revises medical record specification.
15 Jul 2004	Dr. Rouse transmits UAB OCC record forms to Scott Herman -Giddens.
19 Jul 2004	Niamh Darcy trip to Lusaka July 19 – 26, 2004 – Referral a pp launch/ ZEPRS work
22 Jul 2004	Referral application is launched in production in three clinics.
Aug 2004	Consultant Thomas Hubschman begins work on ART/PTS application. Chris Kelley provides software support, but begins to have more time for ZEPRS dev elopment.

Date	Event
	RTI conducts comprehensive beta testing of ZEPRS.
4 Aug 2004	RTI team completes Edit and LMP/EGA rules
8 Aug 2004	RTI completes detailed ZEPRS test plan.
26 Aug 2004	RTI team reviews ZEPRS application with Dr. Rouse, Dr. Stringer, and Zambian consultant nurses (Ethyl, Imeldah, Charity, Elizabeth)
Aug – Sep 2005	RTI conducts comprehensive beta testing. RTI develops ZEPRS Version 1.0 in close collaboration with the UAB and CIDRZ team members in Lusaka.
8 Sep 2004	Chris Kelley completes detaile d analysis of ZEPRS user interface with respect to design and comments from Dr. Rouse and other members of the UAB team. Chris also completes a detailed ZEPRS user interface guide.
21 Sep 2004	Chris Kelley meets w/ Dwight and Francis in Birmingham
13 Oct 2004	Dr. Rouse review screenshots of initANC, followupANC, and Labour
1 Nov 2004	Scott Herman-Giddens reviews ZEPRS user interface with Niamh Darcy.
18 Nov 2004	Official launch of Referral application for all clinics.
12 Dec 2004 – 2 Jan 2005	Chris Kel ley works on ART/PTS 2.0
2-14 Jan 2005	Chris Kelley works in Lusaka with Tom Hubschman to deploy ART/PTS 2.0.
2-13 Jan 2005	RTI team reviews ZEPRS application with Dr. Rouse, Dr. Stringer, Dr. Chomba and other UTH doctors and Zambian consultant nurses (Ethyl, Imeldah, Charity, Elizabeth)
17-22 Apr 2005	Dr. Dwight Rouse, Chris Kelley and Niamh Darcy review ZEPRS in Lusaka with nurses.
19 May 2005	RTI produces draft ZEPRS User Guide.
July 2005	RTI finalizes and reviews ZEPRS beta version with the UAB .
Aug – Sep 2005	RTI conducts comprehensive beta testing RTI develops ZEPRS Version 1.0 (beta) in close collaboration with the UAB and CIDRZ team members in Lusaka.
Oct 2005	Pilot testing of ZEPRS Version 1`.0 (beta) in a selected clinics and UTH. This i ncluded tests using data from a sample of obstetric blue books and live patient data entry for selected patients. Bug fixes completed and deployed to these locations. Patient records entered at UTH, George, and Chipata.
21 Nov 2005	ZEPRS Version 1.0 (v1. 0) released by RTI
Dec 2005 – Jan 2006	Actual “live” patient records entered between 23 November 2005 and 7 December 2005 are the first clinical use of ZEPRS. v1.0.
Feb 2006	Regular use of ZEPRS v1.0. for antenatal care was initiated 1 February 2006 at C hipata Clinic and 22 February 2006 at Matero Reference Clinic.
9 Mar 2006	Three (3) clinics and two (2) blocks (B and C) at UTH are using ZEPRS v1.0. Approximately 1,000 patient records are being managed using the ZEPRS system.
14 June 2006	Nine (9) clinics and two (2) blocks at UTH are using ZEPRS v1.0. Labor wards at four (4) sites are using ZEPRS v1.0. 3,933 new antenatal patients and 4,675 visits have been entered into the system.

Annex B: ZEPRS Core Project Team Members

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