Uganda Health Information Network, Phase-IV

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Cost Effectiveness Assessment of Uganda Health Information Network

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Executive Summary

Health care, especially in the developed world, is characterized by a rapidly increasing use of information technology in patient care, improving documentation, coding and billing, and management. The rise of Health Information Technology worldwide is increasing efficiency of health service delivery, reducing medical errors, improving quality of care, and providing better information for patients and physicians. In Uganda, the Health Ministry Information System (HMIS) is responsible for this enormous undertaking. The system has been entirely dependent on a manual system of transmission and management of health information and data. The Uganda Health Information Network (UHIN) implemented by AED-SATELLIFE, Ministry of Health, Uganda Chartered HealthNet and College of Health Sciences of Makerere University has piloted an electronic system using a wireless network and handheld computers (or PDAs, Personal Digital Assistants) in 5 out of the current 91 districts. Seven years into this project, more than 174 remote facilities that have no Internet access are able to send and receive regular transmissions of needed information and accurate, actionable data.

UHIN project partners implemented the UHIN phase IV project component through funding from the International Development Research Centre, Canada (IDRC) which aimed to support the expansion of the network to additional healthcare workers over a two-year period (November 2007 – October 2009).

Rationale and relevance of the study

The initial benefits revealed by the UHIN pilot in enhancing quick response to outbreaks of epidemics and others gave policy makers the basis for suggesting the electronic HMIS as a viable option. However, more information on the costs and outcomes was required to provide a firm foundation for its adoption. This study served the purpose of conducting a comparative study on the cost-effectiveness of the Paper-based HMIS vis-à-vis the UHIN solution for HMIS in order to better inform policy of the most appropriate HMIS for higher quality and reliable health data in Uganda.

The main objective of the study

The overall objective of the cost effectiveness study was to test the hypothesis that using PDAs for data collection and reporting via the UHIN costs less than the traditional paper-based method yielding the benefit of higher quality data in rural districts of Uganda.

Data collection approach

The primary units for data collection for this task were the districts, health sub-districts, health centres at Level IIIs and IIs (see details in section 1.1). The empirical data were collected during a period of two weeks from a total of 30 health facilities in the two districts of Mbale (20) and Lyantonde (10). The data collection methods consisted of interviews, document review analysis and observation.

Theoretical framework/Methodology

The study used a Cost Effective Analysis (CEA) to compare the two HMIS, that is, the Paper-based HMIS vis-à-vis the UHIN solution for HMIS. This involved estimating the cost per form of the paper-based health information system sent from the lower health centers to the districts and comparing this with the cost involved in sending the same information electronically via PDAs. The study also employed the Cost Utility Analysis (CUA) to measure perceptions of the effectiveness of the health information systems (paper-based and computer based). In this case the health utility index (HUI) was used to rate each system. After obtaining the utility index, the cost-utility ratio of each of the health information systems under comparison was computed.

The study adopted the ingredients method which heavily relies on the view that every intervention uses ingredients that have costs. The total costs were thus the sum of recurrent costs plus capital costs. Recurrent costs consisted of: salaries and benefits; office supplies; transport costs; water; electricity and communications; while capital costs consist: buildings; equipment; vehicles; and training costs.

The cost effectiveness ratio

The estimation of the cost effectiveness of the different HMIS systems was done by summing all the costs and using the ingredients associated with a specific form collected at district level, divided by the total number of forms successfully filled out at district health office level.

Results

1. The occupations that had the largest representation in the survey were nurses and records assistants, although other professionals also perform tasks associated with HMIS activities.
2. Regarding registration of forms, both HMIS performed this task and there was no significant difference among staff between the two HMISs.
3. The UHIN solution for HMIS skipped the data aggregation task since this was automatically done electronically. The aggregation costs were thus automatically eliminated by the UHIN solution for HMIS.
4. The survey clearly showed that the Paper-based HMIS required more person hours to conduct the registration, aggregation and data entry than the UHIN solution for HMIS. Under the UHIN solution for HMIS, personnel were free to perform other tasks and responsibilities. Where registration, aggregation and data entry under the Paper-based HMIS took a total of 268 hours for all six forms in all the health facilities visited, the UHIN solution for HMIS took 32 hours to complete the same tasks.
5. The UHIN solution for HMIS automatically aggregated data and generated reports–this not only reduced incidence of errors, but also lessened the processing and response time.
6. Although the creation and conversion of forms into a database is an expensive exercise, once completed the forms can be "recycled." In the long run this would cut costs since the same forms can be used for many years as compared to the paper system where every entry has a cost implication.
7. The study demonstrated that office supply costs were a major component of the Paper-based HMIS compared to the UHIN solution for HMIS. The forms must be printed and distributed to the health facilities—both tasks were entirely absent

under the UHIN solution for HMIS. On average, office supplies cost UGX 19,320 for the paper HMIS. Facilities using the UHIN solution for HMIS needed just UGX 7,023 on average to cover office supplies—just 36 percent of the cost for facilities using the paper system.

8. It is evident that transport plays a major role in increasing the costs of the Paper based HMIS. To transport one form "f" from the health facility to the districts costs UGX 14,640, while the UHIN solution for HMIS does not incur this cost
9. The study revealed that the UHIN solution for HMIS had higher capital costs compared to the Paper HMIS. This was because initializing the operation of the UHIN solution for HMIS required a substantial initial capital equipment to cover the electronic components. The UHIN solution for HMIS had a higher unit annual capital cost (UGX 31,932) compared to the Paper HMIS (UGX 17,844). The capital cost per form for the Paper HMIS was 56 percent that of the PDA HMIS.
10. It cost UGX 8,672 per PDA individual form "f" compared to UGX 11,263 per Paper individual form "f" for the miscellaneous costs like water and electricity. This is 77 percent of the costs.
11. The capital equipment, (the server, AAPs, computers, the PDAs among others) once acquired, serve for some time (3 to 7 years) before they are replaced.
12. When we computed comparative proportions, it was observed that for the tasks performed at the health facility, it took only 30 % of the costs of the Paper based HMIS to process one UHIN solution for HMIS H033B form, 48 percent of the H105 form, 78 percent of the H055B form, 42 percent of the H108 form, 86 percent of the H106 form and 274 percent of the H107 form.
13. All the Cost Effective Ratios (CER) for the PDA HMIS were lower than those for the Paper-based HMIS demonstrating that the former was more cost effective than the latter. The UHIN solution for HMIS CERs ranged between 72 percent and 88 percent of those of the Paper-based HMIS. The study revealed that the costs of running the UHIN solution for HMIS were about three quarters of the costs for the Paper HMIS. Therefore, the HMIS can save as much as a quarter of its running expenses by switching from the Paper based to the UHIN solution for

HMIS. *Therefore, the use of UHIN solution for HMIS for data gathering and reporting provided 25 percent cost savings compared to Paper-based HMIS. In this case, if policy makers look at costs without considering other factors, the UHIN solution for HMIS is superior to the Paper based HMIS.*

14. The results of the sensitivity analysis further enhanced the grounds for considering the UHIN solution for HMIS as a more viable option, especially with its ability to handle shocks like epidemics or population influxes. The UHIN solution for HMIS exhibited lower change in Incremental cost Effectiveness Ratio (ICER) indices compared to the Paper HMIS. A 50 percent increase in the number of forms collected led to a disproportionate change in the total cost for each type of form. The change in total cost was less than 37 percent for the Paper based HMIS and less than 23 percent for the UHIN solution for HMIS.
15. The results of the health utility index generated from the qualitative data clearly demonstrated the preference of the UHIN solution for HMIS over the Paper based HMIS. The overall average health utility index for the Paper based HMIS is 0.39 and the one for the UHIN solution for HMIS is 0.57, indicating that the stakeholders viewed the UHIN solution for HMIS to be superior when compared to the paper based system for all 9 system attributes.
16. The Cost Utility Ratios show that the use of UHIN solution for HMIS yielded greater utility (benefits) than that derived from the Paper-based health information system.
17. In addition to data collection and transmissions, the UHIN solution for HMIS offers a wider range of services that can greatly improve health service delivery, which should be put into consideration when looking at its benefits.

In conclusion, the UHIN solution for HMIS emerged as a superior system for transmitting data when compared to the Paper based HMIS as it provided cost savings of up to 25 percent. This arose especially from absence of transport, printing and office supply costs. There were other benefits also such as Continuing Medical Education, which were conducted through the UHIN solution for HMIS and not only improved the services provided by health workers but also reduced the costs of providing CME.

Therefore, taking running costs without considering establishment costs, and bearing in mind other factors such as CME, the UHIN solution for HMIS is superior to the Paper based HMIS and should be considered for implementation in all health districts in Uganda.

Recommendations

1. Particularly to enhance the performance of personnel for the UHIN solution for HMIS, the training of health professionals at all levels should include hands on computer training.
2. For policy purposes, UHIN solution for HMIS is recommended as a superior option as it minimised cost, reduced errors and decreased the reporting time. It is thus prudent to consider the UHIN solution for HMIS for scaling up and rolling to more districts.
3. Other benefits from the UHIN solution for HMIS, such as Continuing Medical Education, which would likely accrue over time, bolster the recommendation to adopt it.
4. The solution for HMIS demonstrated that it is the best option for handling shocks. Its CER illustrated that it is more cost effective than Paper based HMIS. Therefore, as the superior option, it should be scaled up and rolled out.
5. A comparative study of start-up costs for both HMIS is crucial to establish what would be needed financially to get them started, especially countrywide. Doing this in addition to the running costs of the present study would enhance policy makers' ability to make the most informed decisions on which system is the best in the long run.

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Note: This report was reviewed by Frederic B. Jennings Jr., Ph.D. Fred Jennings has a B.A. in economics (magna cum laude) from Harvard College (1968) and an M.A. and Ph.D. in economics from Stanford University (1980 and 1985) and currently works for his own economic consulting company called EconoLogistics in Ipswich, MA.

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List of acronyms and abbreviations

AAP	African Access Points
ART	Anti Retroviral Therapy
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
CER	Cost Effectiveness Ratio
CUA	Cost Utility Analysis
GPRS	General packet radio service
GSM	Global System for Mobile Communications
HCT	HIV Counselling and Testing
HMIS	Health Ministry Information System
HUI	Health Utility Index
ICER	Incremental Cost Effectiveness Ratio
IDRC	International Development Research Centre, Canada
IDRS	Integrated Disease Response Surveillance
IPD	Inpatient Department
IT	Information Technology
MOH	Ministry of Health
OPD	Out Patient Department
PDA	Personal Digital Assistant
PMTCT	Prevention of Mother To Child Transmission
QALYS	Quality of Life Years
UHIN	Uganda Health Information Network
UNEPI	Uganda National E
WAP	Wireless access Point
WTP	Willingness To Pay

1.0 Background

Health care especially in the developed world is characterized by a rapidly increasing use of information technology in patient care, increasing documentation, coding and billing, and management. The rise of Health Information Technology worldwide is increasing the efficiency of health service delivery, reducing medical errors, improving quality of care, and providing better information for patients and physicians. The overall goal of the information management function is to obtain, manage, and use information to improve health care and medical services' performance, governance and management and support processes. Shorbaji (2001) has outlined a number of benefits of the application of information technology in health care: There are quantitative benefits (financial) attributable to the use of a particular technology, such as the use of electronic data interchange technology to transmit surveillance data in real time. There are qualitative benefits which are directly and indirectly attributed to the improved technology but are difficult to quantify. The benefits are best measured by the impact of the technology on the performance of a system, for example more accurate data, faster transfer, wider accessibility etc. One can exploit the strategic benefits which offer prospective improvements to the health care organization and can be used as a basis for planning. In Uganda, the Health Ministry Information System (HMIS) is responsible for this important undertaking. The system has been entirely dependent on a manual system of transmission and management of health information and data. The Uganda Health Information Network (UHIN) jointly implemented by AED-SATELLIFE, Ministry of Health, Uganda Chartered HealthNet (UCH), and the College of Health Sciences of Makerere University has piloted an electronic system (in 5 out of the current 91 districts[1]) of collecting and transmitting health information and data for the purposes of transforming the HMIS from a purely hard copy system to an electronic system with the aim of reaping the benefits thereof.

[1] The number of districts in Uganda has since increased

The Uganda Health Information Network (UHIN) is a joint project of the AED-SATELLIFE Center for Health Information and Technology; Uganda Chartered HealthNet, the Makerere University College of Health Sciences, and Connectivity Africa, an initiative of the International Development Research Center (IDRC) of Canada. The main objective of UHIN is to help improve healthcare service delivery to the Ugandan population by improving health workers' access to health and medical information and by supporting data collection and analysis through the use of small, mobile computing devices interfaced with the local GSM/GPRS cellular telephone network via Wireless Access Points (WAPs) (called African Access Points or AAP). This incorporated a new, previously untried element: digital networking of geographically dispersed handheld computers (also known as "Personal Digital Assistants" or "PDAs") via the existing local GSM/GPRS cellular telephone network to support the two-way transmission of information and data. Five years into this project, over 174 remote facilities that have no Internet access are able to send and receive regular transmissions of needed information and accurate, actionable data.

UHIN commenced as a pilot study in Rakai and Mbale districts to test the viability of using handheld computers, wireless access points and the GSM/GPRS network to establish a robust and easily adaptable information communications network. To date a total of 700 handheld computers[1] provided by the project are now in use by frontline health workers in the 174 health centres in Rakai, Lyantonde, Mbale, Manafwa, and Bududa districts[2] serving more than 1 million people.

UHIN project partners are currently implementing the UHIN phase IV project component through IDRC funding which aims to support the expansion of the network to additional healthcare workers over a two and half year period (November 2007 – April 2009). Phase IV has seen additional Health Management Information System (HMIS) forms and registers made available for use on PDAs. The usefulness of the network will be enhanced through its application to the collection and reporting of data related to the

[1] PDAs and smart-phones
[2] Mbale district was later divided into Mbale, Manafwa and Bududa, and Rakai was divided into Rakai and Lyantinde. This is part of the process of creating more districts under the local government set up.

Integrated Disease Surveillance and Response (IDSR) efforts. All IDSR forms have been formatted for use with PDAs. UHIN partners conducted two studies to assess cost-effectiveness of UHIN for HMIS data collection and transmission vis-à-vis paper-based approaches by hiring independent consultants. The first study conducted in 2004 revealed that UHIN yielded economic benefits to the health sector–each unit of spending in UHIN provided about 24 percent more goods and services than the same unit in the traditional manual data collection and transmission approaches.

A second study conducted in 2007, aimed at identifying and comparing the costs of accessing, sharing, and communicating information between health care providers, managers, and policymakers using this technology versus paper-based approaches for the overall goal of improving the quality of the health of the people of Uganda. The resulting report revealed that the cost-benefit ratio of using UHIN for HMIS data collection/transmission and delivery of continuing medical education (CME) vis-à-vis paper-based approaches was 1.05. However, this study left a number of questions unanswered with regard to a comparative analysis of the Cost Effectiveness of using the electronic or the paper HMIS for data collection and transmission. The current study has addressed this gap.

1.1 The Uganda National Health system

The National Health system is comprised of institutions, structures and actors who serve to achieve and sustain good health. In totality, it includes the public sector services of the army, police and prisons; and the private health delivery system consisting of the private not for profit organizations, private health practitioners, and the communities. The system has 3,257 health units in total, with 2,301 (70 %) owned by the government, 676 (21 %) units run by NGOs and 279 (9 %) units exclusively owned by the private sector (MoH, 2008).

The hierarchical structure is organized in such a way that at the top are the National Referral hospitals that are meant to care for the 30 million-plus Ugandans, followed by the Regional Referral hospitals that are each the designated care facilities for 2 million

Ugandans. The next in line are the district health services that take care of about 0.5 million people. Below the district are the Health Sub-districts. Health-sub districts are hospitals in which care for 0.5 million people. Below this level are Health Center IIIs based at the sub-county level, each caring for about 20,000 people. Next is the Health Center II caring for about 5,000 people. Theoretically, the last level is the Health Center I caring for 1,000 people but rarely are these operational. Operationally in Uganda, there are four levels of health facilities: Hospitals are 112 (3%); Health center IVs are 162 (5 %), Health Center IIIs are 956 (29 %) and Health Center IIs are 2,026 (62 %) in number.

1.2 Description of the paper-based versus the PDA HMIS in Uganda

The design of the HMIS draws on different levels of the health system for purposes of planning and management. The system uses a number of tools including the patient care registers which are the primary source of data collection. These include the Outpatient department (OPD) registers, the antenatal registers and PMTCT, Family Planning, HIV counseling and testing (HCT), Anti-Retroviral Therapy (ART) and Postnatal registers. The Inpatient department (IPD) data collection tools include the Inpatient register (for all wards such as Pediatrics, female and male wards). The registers are then transcribed to the database, which is the source of data for compilation of other reports at higher levels. Overall there are over 36 different instruments[1] used for recording and transmitting data/information within the HMIS. The reports are designed to move from Health Center II to the Health Sub-District, District and at each level feedback is provided to complete the communication. The data is finally transmitted to the National level. The reports are shared on a regular basis for different purposes. On a weekly basis, it is mainly reportable diseases that are handled. The OPD and IPD attendances, maternity, Uganda National Extended Programme for Immunization coverage and Family Planning uptake forms collect data on a monthly basis. The data collected on a quarterly and annual basis consists mainly of totals from the weekly and monthly forms and tallies of items like buildings. Thus, these instruments are used at different levels of the health system. Data collected at Health Center IIs and IIIs are sent to either the Health Sub District or directly to the District Records office on a weekly and monthly basis. Much of the data sent to the

[1] Used synonymously with forms, reports and registers

MoH is captured on Forms 105 (outpatients) and 108 (inpatients), which are summaries of over 20 forms and registers. Although a number of districts have set their own deadlines for submitting the data to the MoH Resource Center, it is a requirement by the latter that this is done by the 28th day of the following month.

Table 1: Activities involved in data collection and reporting on the PDA and on paper[1]:

Control Group – Forms in paper	**Study Group – Forms on PDA**
Health Centre	**Health Centre**
Manual data entry in each of the 7 daily registers	Convert 7 paper registers into electronic format for the PDA
	Electronic completion of each of the 7 daily registers
	Create HMIS Reporter database at district level and configure server
	Automatic electronic transmission of daily registers to district directly into HMIS Reporter database
Manual aggregation into weekly form	
Manual aggregation into monthly form	
Transport weekly aggregated form to District	
Transport monthly aggregated form to District	
	Airtime for data transmission on cellular network
	User support provided by district and UHIN staff
District	**District**
Make paper copies of blank daily ,weekly and monthly forms	
Transport forms to health centres	
Manual data entry of health centre monthly aggregated data into computer to generate HMIS 105, 033B, and 033C	Automatic electronic aggregation of daily registers from health centre to generate monthly HMIS 105, 033B, and 033C
	Trained staff to manage HMIS Reporter database
Transport monthly reports to MoH	Electronic transmission of monthly reports to MoH
Phone calls to remind health centres to send forms, correct errors, etc.	
Storage of blank paper forms	
Ministry of Health	**Ministry of Health**
Manual entry of monthly data from districts into MoH HMIS computer system	Electronic aggregation of monthly reports from districts to generate MoH national reports
Storage of completed reports from districts	Staff to manage database at MoH

1 The forms/reports are defined and described in Table 2

The electronic data transmission system primarily uses the same structure as that of the hard copy system except that it is faster, user friendly and more convenient. Table 1 shows the different activities involved in both the electronic and hard copy systems of information and data transmission.

HMIS is broadly categorized into two layers: the primary and the secondary. Each of these layers has tools that collect data for reporting and also for other uses at the place of collection or by any other interested persons. In practice, primary data sources feed the secondary data tools. The primary data tools are used to collect data directly from the patient during consultation, and they are categorized according to the departments - Out Patient Department (OPD) and In Patient Department (IPD). Each of these departments has its own tools. In summary, primary data tools include: registers for both OPD and IPD, Medical forms (for example MF5 for Outpatients), Treatment sheets or admission forms for Inpatients, Referral notes used by both in OPD and IPD, and Laboratory test request forms. The primary and secondary data collection tools are given in Table 2. All these lead to generation of secondary data whose outputs include Forms, Tables, Charts, Graphs, Health bulletins and Tally sheets.

Table 2: List of forms used for data collection at primary and secondary layers[1]

Primary tool (converted to PDA format			**Secondary tool (periodical aggregate)**
Outpatient department			
1	Outpatient Department Registers (OPD)		Health Unit monthly report - (HMIS 105) District monthly report (HMIS 123) Health Unit & district weekly report - (HMIS 033b) Health Unit monthly report - (HMIS 055b) for laboratory (reported separate)
2	Laboratory registers		
3	Antenatal registers, PMTCT are combined (ANC, PMTCT)		
4	Family planning registers (FP)		
5	HIV counselling and testing Register (HCT)		
6	Anti-Retroviral Therapy (ART)		
7	Postnatal register		
In Patient Department			
1	Inpatient register (for all wards e.g., Paediatrics ward, female, Male ward etc)		Heal Unit inpatient monthly report (HMIS 108) District in patient monthly report (HMIS 124)
2	Theatre register		
3	X-ray register		
4	Ward census form.		

[1] The forms are used by both the electronic and the paper based HMIS

1.3 Rationale and relevance of the study

The use of electronic systems in managing and enhancing health care services is no longer a debatable option; rather, the efforts are being geared towards how implementation can best be accomplished for optimal results. To this end, physicians and other health professionals are rapidly adopting the use of PDAs for various applications in the health care sectors in industrialized country settings. Given the initial benefits revealed by the pilot (UHIN) in enhancing quick response to outbreaks of epidemics and others, policy makers have strong evidence suggesting the electronic HMIS as a viable option. However, more information on the costs and outcomes was required to provide a firm foundation for its adoption. An empirical study comparing the two HMIS was conducted to provide evidence-based information on the cost-effectiveness of the paper-based information system vis-à-vis the PDAs to better inform policy of the most appropriate HMIS for higher quality and reliable health data in Uganda.

1.4 The main objective of the study

The overall objective of the cost effectiveness is to test the hypothesis that using UHIN solution for HMIS for data collection and reporting via the UHIN costs less than the traditional Paper-based HMIS yielding the benefit of higher quality data in rural districts of Uganda**.**

2.0 Literature review

This section reviews the literature on the use of electronic information systems in the health care systems and goes further to look at gaps identified in the paper-based HMIS in Uganda. In addition, it identifies the policy lapses in adopting the electronic HMIS in Uganda, which this study sought to address.

Cheah and Abidi (2002) argue that the healthcare environment is generally perceived as being ‘data rich’ and yet ‘information poor’. This stems from the fact that much of the data collected has not been fully exploited due to the inadequacy of data and information management systems being in place. Much of the data and information generated is never processed and used. A joint effort of healthcare professionals and knowledge and data

management experts is thus necessary to fully exploit the data generated for improving health care provision.

The delivery of health services is increasingly becoming a function of the level of information possessed by health workers. Wang *et al.* (2003) asserts that electronic medical record systems improve the quality of patient care and decreases medical errors. It does provide substantial benefits to physicians, clinics and health care organizations. Cheah and Abidi (2002) argue that the role of information technology in healthcare is well established and its practice a time-honoured tradition. There is growing demand from the healthcare systems to emphasise transformation of vast quantities of health care data and information into usable decision-quality knowledge. This position negates some critical aspects of the differences between countries with the capacity to transform vast quantities of data into usable information and those that do not possess such capabilities to do so. This is what is referred to as the digital divide. The digital divide is the persistent disparity between the rich and poor nations which determines the position of a health care system on the continuum. While well-advanced nations have in place Information Technology (IT) systems that foster the tapping of information for health care, poor nations characterised by rudimentary IT systems and lack of infrastructure in the sparse rural areas struggle to effectively and efficiently provide health services.

Wang *et al.* (2003) performed a cost-benefit study to analyse the effects of electronic medical record systems in ambulatory primary care settings from the perspective of the health care organization in the United States of America. Their results reveal that benefits accrue primarily from savings in drug expenditures, improved utilisation of radiology tests, better capture of charges, and decreased billing errors. They thus conclude that implementation of an electronic record system in primary care can result in a positive financial return on investment to the health care organizations.

Baumgart (2005) assesses the usefulness and impact of the use of PDAs among health professionals in the developed world, particularly the United States of America. Although the study explores the different uses of the PDA ranging from training of

medical students to research, it is evident that well designed studies are still required to demonstrate the full potential for improvement that these devices can bring to bear on the quality of care, saving patients' lives and ultimately reducing health care expenses.

Research Studies on UHIN

Since the implementation of the UHIN project, a number of studies have been carried out although only one study attempted to conduct a Cost Effectiveness Analysis (CEA). A UHIN (2004a)[1] report identified the problems associated with the paper based HMIS which make it difficult to provide good health care services:

- Inaccurate and incomplete knowledge arising from inaccurate and incomplete data;
- Non-reporting by a large number of the health units;
- Poor quality data at the point of collection, further compounded by transcription errors at the different levels of receipt;
- Delays in transferring data due to paper and transport challenges; and
- Poor aggregation of data through the manual processes.

This report thus identifies the challenges associated with the paper-based HMIS, suggesting that a better alternative is needed and in this case the PDA based HMIS is a good alternative. A more comprehensive cost effectiveness study by UHIN (2004b) was conducted on the PDA data capture and transmission. The study revealed that over the short period of 8 months for which the PDA project was in place, it was cost effective to the magnitude of 0.242, offering 24.2 % more benefit per unit of spending.

A preliminary study by UHIN (2006) to assess the impact of access to health information on health outcomes in the districts where the project has been operating showed that there was improved clinical care of patients with malaria and diarrhoea by health workers. It also revealed an increased use of literature including national treatment guidelines by health workers along with an increase in health worker and client satisfaction with

1 This was a report detailing the immediate observed outcomes of the UHIN pilot project

services provided. This study recommended further investigation to fully determine the impact of the intervention.

Another study by UHIN (2007), aimed at identifying and documenting best practices and lessons learnt from the UHIN project, was conducted to provide evidence for those who have the intention of replicating and scaling up the use of PDAs in similar settings. The study revealed that apart from collecting and transmitting data, the electronic system had other important roles with potential for expanding and replicating. These include enhancing the Continuing Medical Education programme, improving the information systems for health unit management, improving the safety of blood due to the improved records system, using the PDAs for collecting survey data and enhancing nutrition programmes for children. This study was however not based on the cost analysis methodology; rather it was a documentation study.

Ultimately a more thorough and comprehensive study based on relevant and well designed methodology was necessary and the present study has responded to this need.

3.0 Theoretical framework

There is a growing body of literature in economic evaluation of health care systems (Drummond *et al*, 1986; Adams *et al*, 1992; Gerard, 1992; Donaldson and Shackley 1997). The literature consists of studies conducted by a wider range of researchers including economists, medical researchers, clinicians and IT specialists. In some cases these studies have been multidisciplinary in nature. Drummond *et al.* (2005) have reviewed this body of literature. Accordingly, the writers have come up with concepts such as Cost Effectiveness Analysis (CEA), Cost Benefit Analysis (CBA) and Cost Utility Analysis (CUA) to describe the studies. What is crucial to their operational definitions are the methodological approaches employed. After critical analysis of these concepts, this paper adopts two approaches based on their strengths and weaknesses with the intent of each augmenting the other. It is rationalised that a combination of the two

(CEA and CUA) improves the results of the study. The CBA was dropped owing to envisaged data limitations.

3.1 Cost analysis

This form of analysis only looks at costs and ignores the consequences/outcomes of the interventions. The approach presents a partial form of economic appraisal which does not show the accompanying consequences of the costs. Lowson *et. al.,* (1981) conducted such a study on the comparative costs of three methods of providing long-term oxygen therapy in the home, where oxygen cylinders, liquid oxygen and the oxygen concentrator (a machine that extracts oxygen from the air) were compared. Their argument for using cost analysis was that the relative effectiveness of the three methods was not a contentious issue. Its status as a "partial approach" does not negate the relevance of cost analysis in economic evaluation studies. In this particular example, the point of interest was not effectiveness but the cost of using the three methods to arrive at the intended known consequence. The present UHIN study went beyond this level of analysis since the purpose was to examine both the costs and consequences of the competing/complementing interventions. This approach was therefore dropped as a method.

3.2 Cost Effectiveness Analysis (CEA)

Cost Effectiveness Analysis refers to the economic analysis of an intervention (UCSF, 2002). Cost Effectiveness Analysis was invented by mathematicians and linear programmers as a handy tool to ease allocation of resources and make prudent decisions where market and price signals fail (Detsky and Laupacis, 2007). CEA was used to guide efficient resource allocations to government investment projects that have the characteristics of public good. It is a method of comparing the cost and effectiveness of two or more alternatives and involves assignment of values to outcomes (United States Department of Veterans Affairs, 2006). It is also defined as the comparison of the relative expenditure (costs) and outcomes (effects) associated with two or more courses of action. Therefore CEA not only analyses the comparative costs but goes ahead to value the consequences that arise out of the costs. This is done in monetary terms in order to make

them commensurate with the costs. In this case it is possible to assess whether the beneficial consequences of the intervention/programme justify the costs.

$$CER = \frac{C}{E} \quad ;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{1}$$

Where:

CER = Cost-effectiveness ratio;

C = Total costs of the intervention; and

E = effects produced (e.g. number of forms submitted)

For example, if US $ 2000 is used to treat 10 patients the CER is 200 which can then be compared with another method that treats say 20 patients in which case the CER is 100. The smaller the CER, the more cost effective the alternative is. The basic principle of a CEA is that all consequences of decisions should be identified, measured, and valued. Cost effectiveness analysis provides a formal framework for comparing the relationship between the health and economic consequences of different health**c**are interventions. At its core is the measurement of the incremental costs and effects that result from choosing one strategic option over another. It is typically expressed as an Incremental Cost-Effectiveness Ratio (ICER), the ratio of change in costs to change in effects (Wikipedia, 2006). In the health system, the application of a CEA is to help the decision/policy makers determine the patterns of resource allocation across an established number of competing options to maximize health outcomes from a limited budget (Drummond *et al*, 2005). When we consider the case of the HMIS in Uganda at present, there is an element of two competing health information systems, that is, the paper-based and the PDA electronic system. The incremental cost-effectiveness analysis has a high potential to inform decision/policy makers on which of the two options is better.

In this ICER measure, the net change in health outcomes associated with a particular strategy (compared with an alternative) is included in the denominator, typically expressed as quality adjusted life years (QALYs), and the net change in cost**s** or resource use with a particular strategy (compared with an alternative) is included in the numerator.

The ICER for a strategy is calculated in reference to the next most effective option, excluding strategies that are dominated (those with higher cost**s** and lower benefits than other options) or weakly dominated (those with higher incremental cost-effectiveness ratios than more effective options). In this case, ICER is specified as:

$$ICER = \frac{C_2 - C_1}{E_2 - E_1} = \frac{\Delta C}{\Delta E}; \qquad \textbf{2}$$

Where:

ICER = Incremental cost-effectiveness ratio;

ΔC =*change in costs between programme 1 and 2;*

ΔE = *change in effects between programme 1 and 2. It is worthy noting that the alternative interventions are ranked according to their effectiveness on the basis of securing maximum effect rather than considering costs.*

In spite of the usefulness of the CEA there are shortcomings that have been reported (Phillips and Thompson, 2001; Hutubessy *et. al*, 2003). Although CEA can help us decide from a number of alternatives which are the best interventions, it fails to make comparisons across different programmes with different outcome effects. Secondly, the quality of cost-effectiveness analysis is highly dependent on the quality of effectiveness data used and most importantly, in most settings especially developing countries, it is difficult to find accurate data. There are elements that are difficult to capture such as equity, externalities and other non-monetary benefits. In spite of these shortcomings, CEA remained a handy tool which this study adopted to implement the analytical aspects. Although there are superior analytical methods when using Cost Benefit Analysis (CBA), there are more serious data limitations than what is likely to be experienced using CEA.

3.3 Cost Utility Analysis (CUA)

CUA analyzes the consequences of interventions/programmes that are adjusted by health state preference scores or utility weights. The states of health associated with the outcomes are valued relative to one another. The approach focuses attention particularly on the quality of the health outcome produced by or forgone by health programmes or treatments. CUA is thus broader in analytical scope than CEA. The current UHIN study

will adopt CUA as part of the analytical methods with a sole purpose of handling perceptions of the health workers/providers regarding the two HMIS.

3.4 Cost Benefit Analysis (CBA)

Cost Benefit Analysis values the consequences of programmes in monetary terms in order to make them commensurate with the costs. In this way the analysis can make a direct comparison of the programme's incremental cost with its incremental consequences. CBA is broad and makes effort to ascertain whether the beneficial consequences of an intervention justify the costs. Wang *et. al.,* (2003) estimated the net financial benefits and costs of implementing electronic medical record systems in primary care. They established that the net benefits of using an electronic medical record for a 5 year period result from savings in drug expenditures, improved utilization of radiography tests, better capture of charges, and decreased billing errors. In spite of this level of depth in analysis the CBA is oftentimes plagued by measurement problems where the range of benefits valued in monetary terms is fairly limited. For this reason and data limitation, Drummond *et. al.,* (2005) have thus concluded that while in theory it is a broad form of evaluation, in practice many of the CBA studies published to date are more restrictive than CEA and are limited to a comparison of those costs and consequences that can easily be expressed in money terms. Zarnke *et. al.,* (1997) in a study found that 60% of studies claiming to be CBA were actually cost comparisons where no attempt had been made to value benefits in monetary terms. The limitation of conducting a CBA in this study arose from the inability to place a monetary value on some of the benefits.

4.0 METHODOLOGY

This section maps out the methodology used to conduct the cost-effectiveness study. It presents the analytical methods, the data collection approach, the quantitative and qualitative methods.

4.1. Analytical methods

The study used a CEA to compare the two HMIS, that is, the Paper-based HMIS and the UHIN solution for HMIS. Estimates were made of the costs per form of the paper-based health information system from the lower health centers to the districts and compared this with the cost involved in sending the same information electronically via PDAs. The CEA included a measure of effectiveness that we compared across the two health information systems, namely, the total number of HMIS monthly form returns received by district headquarters from the associated health facilities and the accompanying unit cost per form.

The study employed the CUA to measure perceptions of the effectiveness of the health information systems (paper-based vs computer based). In this case we used the health utility index (HUI) popularised by Drummond *et al*.(2005), who attributed the work to Dolan *et al.* (1995); Dolan and Roberts (2002); Furlong *et al.* (2001) and Horsman *et al*. (2003). In this study, HUI was used to measure and compare perceived gains that result from the use of each HMIS (paper-based and computer based). After a summation of all the scales selected, the system produced a single utility value for the state of each health information system. The standard scale adopted for the information system was rated on average as one (for good) or zero (bad). After obtaining the utility index, the cost-utility ratio of each of the health information systems under comparison was computed by dividing the total incurred costs of HMIS by the respective value of utility index. The lower the cost-utility value, the better the HMIS.

Our UHIN study produced two ratios that were used to measure the cost effectiveness of the HMIS systems, namely the cost effectiveness ratio and the health information utility

index. The two ratios should clearly reveal which of the two HMIS system is the best and offers more benefits for health care.

4.1.1 Data collection approach

The primary units for data collection for this task consisted of the health system described in section 1.1. Basically this contains the Ministry of Health Resource Center, the districts, health sub-districts and Health centre III and II. Particular focus was on units at and below the district level. The empirical data were collected during a period of two weeks from a total of 30 health facilities as shown in Table A1 in the Appendix, located in two districts of Mbale and Lyantonde. Ten health facilities were sampled from Lyantonde and 20 from Mbale. These two districts represent the UHIN project districts where the electronic HMIS has been piloted alongside the paper based HMIS.

The data collection methods consisted of interviews, document review analysis and observation.

- For the daily registers we collected data on the time it takes to complete each of the 7 daily registers in paper and PDA.
- For the weekly registers we collected data on the time it takes to aggregate each of the 7 daily registers into the weekly form paper and PDA
- For the monthly, we measured the actual time taken to aggregate each of the weekly forms into the monthly form in paper.

Since the qualitative data required for the analysis runs across different implementers (health workers) and policy makers, a cross section of these were interviewed. These included district officials including Records Office officials, Director of District Health Services, other decision-makers and practitioners, managers and supervisors.

To collect the needed data described earlier in Table 2 on page 10, structured questionnaires were administered to the selected sample of 30 health facilities and each District Directorate of Health Services (Lyantonde and Mbale). A total of 6

questionnaires were administered per district. For details of these, please see Appendix A3.

4.2. Quantitative methods

The estimation method adopted in this section drew a lot from the work of Nhampossa (2008) who developed a methodology for a similar study in Mozambique. The study adopted the ingredients method which heavily relies on the view that every intervention uses ingredients that have costs. In this case an initial description of the intervention in terms of resources required to produce the various outputs was produced. The total costs of the items are expressed as the sum of each ingredient. We then annualise all cost items with the corresponding conversion factors. The total costs are thus the sum of recurrent costs plus capital costs. Recurrent costs consist of: salaries and benefits; office supplies; transport costs; water; electricity and communications; while capital costs (details in section 2.4.5) consist of: buildings; equipments; vehicles; and training costs. The costs may vary depending on whether this is a Paper-based HMIS or the UHIN solution for HMIS therefore all the costs are disaggregated by the corresponding HMIS forms. There may be cases where the costs are shared in which case the corresponding cost shares are weighted. Below is the presentation of the estimation of the costs.

4.2.1. Personnel costs

The estimation of the salary (wage) for personnel who perform the actual filling out and transcribing the paper forms and PDA forms is given by the following specification:

$$W_f = \sum_i^n \alpha_f T_f w_j \text{ ……..……..} \mathbf{3}$$

Where;

i =*1, 2…n (health units at district level)*

j =*activity (e.g., filling out paper versus PDA forms)*

α_f = *share of weekly/monthly HMIS forms "f" on total forms filled out/aggregated at health facility/district health office;*

T_f = *time required to fill out/aggregate/transcribe a particular HMIS form "f";*

w_j = *average salary per hour of the health personnel responsible for filling out or transcribing the HMIS form "f" at the health unit/district health office.*

W_f = *Total wage bill of filling out or transcribing form "f".*

4.2.2. Office supply costs

Health units incur costs in the process of providing health care services to the public. Estimation of office general equipment costs considered supplies like stationery, paper, pens, form, binders, register books, etc. Note that the office supplies are specifically for the HMIS unit and not for the entire health facility. These data were retrieved from records of expenditure at health facility/district health. The costs were then estimated for each aggregated HMIS form using the following estimation specification.

$$GOE_f = \sum_i^n \alpha_f OE_k \quad \text{……..4}$$

Where;

i =1, 2…n *(health units at district level);*

k =*office equipment;*

α_f =*share of weekly/monthly HMIS forms "f" on total forms filled out/aggregated at health facility/district health office;*

GOE_f =*Total annual office equipment costs per form "f";*

OE_k = *annual cost of office equipment "k".*

4.2.3. Transport Operation Costs

The estimation of transport costs entirely depended on what means was used. The alternatives included vehicles, motor-cycles, bicycles, public means or even walking depending on the location. This variation implied that care had to be taken to specify all the modes of transport used. Operations took care of maintenance costs including expenditures on gasoline, oil, and repairs and servicing in addition to costs arising from other means of transport. We reviewed and examined expenditure from records/document from the district/health facility to estimate travel costs per month and per form "*f*", using the following speciation.

$$TC_f = \sum_i^n \alpha_f (GAS_i + OIL_i + SP_i + O_i + ...O_n) \text{ ……..} \mathbf{5}$$

Where:

i =1, 2…n (health units at district level)

TC_f =total costs of transport operation per form "f"

α_f = share of aggregated weekly/monthly HMIS forms "f" on total forms filled out/aggregated in a period (month or year) at health facility/district health office

GAS_i =total costs of gasoline [e.g. (km travelled per month/km per litre) x cost per litre)]

OIL_i =total costs of oil (e.g. 15 % x annual expenditure on gasoline)

SP_i =total spare parts cost (e.g. 24 % x purchase price of vehicle)

$O_i + ...O_n$ =other expenses arising from other modes of transport

4.2.4. Miscellaneous Costs

There are other material costs that are incurred either directly or indirectly by either HMIS. These materials include supply costs like water, electricity, gas, telephone and others that we term miscellaneous in the study. We adopted a monthly rate to capture the expenses. However, due to fluctuations depending on the season of the year it was prudent to obtain acceptable averages for a reasonable period of about 6 months. These data were traced in the records existing before the study was conducted. The following specification was used to capture miscellaneous costs of material and supplies.

$$MSC_f = \sum_i^n \alpha_f (WATER_i + ELECT_i + PHONE_i + OMSC_i .....OMSC_n) \qquad \mathbf{6}$$

Where;

i =1, 2…n (health units at district level)

MSC_f =total miscellaneous and supply costs per form "f"

α_f = share of aggregated weekly/monthly forms "f" on total forms filled out/aggregated in a period (month or year) at health facility/district health office;

$WATER_i$ = *average costs in water for at least six months prior to the survey;*

$ELECT_i$ =*average electricity costs for the last six months prior to the survey;*

$PHONE_i$ =*average telephone costs for the last six months prior to the survey.*

$OMSC_i$.....$OMSC_n$ =*other miscellaneous items*

4.2.5. Estimation of Annual Capital Costs

Drummond *et al.* (2005) defines capital costs as expenses of capital assets required by the programme which are generally equipment, buildings and land. They are used beyond a period of one year. Unlike operational costs they represent investment at a single point, often at the beginning of a programme. Except for land one common characteristic of capital assets is that they depreciate/wear over time. The commonest method of measuring and valuing capital assets in an economic evaluation is to annualize the initial capital outlay over the useful life of the asset (see for example Richardson and Gafni, 1983). In this way, we captured both the depreciation and the opportunity cost of the capital costs. Therefore we computed the annual cost of the capital good corresponding to the year of study. Following from Janowitz and Bratt (1994), three steps are taken to estimate the annual capital costs of capital assets (buildings, equipment, vehicles, training and start-up costs):

- We first estimated the replacement cost of the item which is the current cost of purchasing the item.
- With the help of expert knowledge we estimated the useful life of the good[1]
- We estimated the discount rate to take care of the opportunity cost of capital. In annualizing all capital costs we assumed a discount rate of 18%[2].

The annual cost of capital good "*k*" at health facility "*i*" was estimated by the following specification (ibid):

[1] These were obtained from professional sources and compared with respondents estimates and they were in agreement.
[2] This is the rate that would prevail if transactions costs arising from risks were eliminated in lending

$$ACC_k^i = RC_k^i \div \frac{\left[(1+r)^n - 1\right]}{\left[r(1+r)^n\right]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{7}$$

Where

ACC =Annual Cost of Capital

RC =Replacement cost of the item

n =life expectancy of the item (in years)

r =the discount rate

k =capital good

i =health facility (1, 2…n).

This gives us the annual cost of individual capital assets. We then estimate the annual capital costs per form "f" aggregated at district level in the following specification.

$$TACC_f = \sum_{i=1}^{n}\sum_{k=1}^{m}\alpha_f ACC_k^i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{8}$$

Where:

With i=health unit; and k=capital good

$TACC_f$ *=total annual capital costs per form "f" at district health office level*

α_f *= share of forms "f" on total forms filled out in a period of a year at district health office*

ACC_k^i *=Annual capital cost of good item "k" at health unit "i" in the district.*

4.2.6. Cost-effectiveness ratio

Estimating the cost effectiveness of the different HMIS systems proceeded with summation of all the costs and using the ingredients presented in *equation 1* to obtain the desired ratio. This was done by taking the sum of all ingredients associated with a specific form aggregated at district level, divided by the total number of forms successfully filled out at district health office level. The ratio computed gives the estimate of the associated cost of the HMIS by aggregated form and by district level. This procedure is mathematically specified as:

$$CER_f^d = \frac{\sum_d (W_f + GOE_f + TC_f + MSC_f + TACC_f)}{TF_f^d} = \frac{TC_f^d}{TF_f^d} \quad \textbf{.....9}$$

Where:

"f"= form;

"d"=district directorate of health;

W_f *=salary costs;*

GOE_f *=general office supplies;*

TC_f *=transport costs;*

MSC_f *=miscellaneous material costs;*

$TACC_f$ *=total annual capital costs;*

TC_f^d *=total costs per form "f" from the district "d" to the MoH headquarters;*

TF_f^d *=total number of HMIS form returns received by the MoH from the District health offices or total number of monthly HMIS form returns submitted by 28th of next month to MoH from the District health office.*

4.2.7. Sensitivity Analysis

The computation of the CER, although a very commendable tool to compare programmes for intervention, has been plagued by lack of robustness of the parameters estimated especially when subjected to shock. To investigate the degree of robustness of the CER parameter estimates in case of unexpected changes in terms of the parameters, we conduct a sensitivity analysis. There are instances when epidemics break out making the work of filling forms more expensive. We may want to establish which of the two HMIS has less marginal costs as result of this shock. We may want to establish the economies of scale arising from the two systems. In Uganda the UHIN solution for HMIS is likely to be scaled up and this kind of analysis is thus crucial. The sensitivity analysis is done by performing the incremental costs analysis to measure change in costs and effects from the district health office to MoH headquarters, and in respect to all aggregated HMIS forms. It is the difference between costs divided by the difference in outcomes. The

mathematical specification for this kind of analysis (ICER) which measures the difference in costs between interventions is shown in *equation 10*.

$$ICER^{d}_{f1,2} = \frac{TC^{d}_{f2} - TC^{d}_{f1}}{TF^{d}_{f2} - TF^{d}_{f1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

We then rank the alternative interventions according to their effectiveness basing this on the maximum effect rather than considering costs. When we find that an ICER for a certain aggregated form "f2" against "f1" is negative this implies that we shift from filling out "f1" to "f2". There is thus reduction in costs per form filled out due to the improvement in HMIS services.

The effects or marginal cost, which is the extra cost of producing one extra unit of output (form) due to an unexpected increase in the number of forms completed, can be done by conducting simulations. This gives the potential change in cost ingredients as a result of an increase in total forms. This is specified as shown in *equation 11*.

$$\frac{\partial CER^{d}_{f}}{\partial TF^{d}_{f}} = \frac{\sum_{d} (\Delta W_f + \Delta GOE_f + \Delta TC_f + \Delta MSC_f + \Delta TACC_f)}{\Delta TF^{d}_{f}} \qquad 11$$

Results of declining marginal cost imply less sensitivity of the total costs of a specific form. It is preferred that this ratio is low since the higher it is the more sensitive it is thus more expensive when exposed to shocks.

4.3 Qualitative analysis and indicators

This section presents the methods that we used for the qualitative assessment of the health information system. It draws a lot from the work done by several writers (for example Dolan *et al.*, 1995; Routh and Khouda, 1999; Torrance *et al.*, 1996a; Feeny *et al.*, 2002). The approach estimates a health information system state (condition) index taking into account the system attributes and the corresponding multiplicative factors. At its core is the reliance on the perspective of the respondents[1] about the system(s) being analysed. Although there is an element of subjectivity, the fact that a wide range of

[1] The respondents are deemed to have interacted with the system(s) and thus have sufficient experience to give qualified perspectives.

respondents were included increased the chances of introducing mitigating biases. Note that the approach was adjusted to suit the study being conducted. Drummond *et al.* (2005) acknowledge the complexity of measuring preferences for health outcomes and suggests an alternative that is very attractive and widely used. This is the pre-recorded multi-attribute health status classification system. This study adopted the Health Utilities Index (HUI) because it uses multi-attribute utility theory for the estimation of the utility formula. The multi-attribute multiplicative utility theory is represented by the following functional specification found in (Drummond *et al.*, (2005).

$$u(x) = (1/k)\left[\prod_{j=1}^{n}(1+kk_j u_j(x_j)) - 1\right] \qquad \textbf{13}$$

Where;

$u(x)$ = the utility for health state x, represented by an n-element vector

k and k_j =are model parameters

j =Attribute

$\prod$ = multiplicative sign

In fitting the multiplicative model, if the measured k_j sums to 1, then $k=0$. The attributes adopted in this study were proposed by Nhampossa (2008) and were used in conducting a CEA of the Mozambique HMIS. The attributes have a strong bearing on determining the health status of the health information system (paper versus PDAs) and these include:

- The accuracy of the data
- Timeliness and vertical integration
- Completeness and reliability
- Degree of conflict with usual activities
- Supervision
- Prestige
- Motivation
- Need for training for better skills
- The degree of safety of retrieval of information

Each attribute was operationalized to corresponding multiplicative factors that serve to explain the possible health status of the attribute. The multiplicative factors measure the weight with which the attribute impacts the utility index being computed. A higher utility score level implies greater perceived benefits of using a particular HMIS system at the health unit or district level.

To demonstrate how we computed the HUI comparisons for the Paper-based HMIS and the UHIN solution for HMIS, we adopted Torrance *et al.*' (1996) computation of the utility scores in the following formula:

$$U = 1.25\,(b_1 \times b_2 \times b_3 \times b_4 \times b_5 \times b_6 \times b_7 \times b_8 \times b_9) - 0.25 \quad \ldots\ldots\ldots\ldots\ldots 14$$

Where;

U= the health utility index

b_i =the multiplicative factor measuring the weight of the level chosen

0.25=the model error of U

The final outcome of this computation is a single utility value for each health information system state on the standard scale where HMIS state is rated as one (for good) and as zero (for bad), and is based on the nine-attributes. We take the perceived utilities deriving from the use of either HMIS based on nine health information state attributes and compare the HUI outcomes as follows.

Table 3: A sample of the computation of the HUI for both HMIS

	PAPER-BASED HMIS		**PDAs HMIS**	
Attribute	**Level**	**Multiplicative factors**	**Level**	**Multiplicative factors**
1: Accuracy of the data	2	0.95	1	1
2: Timeliness	3	0.86	1	1
3: Completeness and reliability	2	0.95	1	1
4: Degree of conflict	2	0.95	3	0.86
5: Supervision	3	0.85	3	0.86
6: Prestige	3	0.86	1	1
7:Motivation	2	0.95	1	1
8: Need for training for skills	2	0.95	3	0.86
9: The degree of safety &retrieval	3	0.95	1	1
		0.462123		0.636056

Therefore following from equation 14:

For the paper based HMIS; U=*1.25* (0.462123) - *0.25* =0.32765
For the PDA based HMIS; U=*1.25* (0.636056) - *0.25* =0.54507

The theory of the budget constraint in economics calls for allocation of resources to maximize utility or minimize cost. With limited resources to be allocated among legitimate competing options, the Ministry of Health has an incentive to choose the best alternatives among competing options. Given a hypothetical budget of Uganda shillings 2 billion to be allocated for either of the HMIS; we use the cost-utility analysis to compute the corresponding measures of effectiveness that can guide the decision on which option to take.

$$CUR = \frac{Costs}{Utility} \quad \text{……..15}$$

Where,

CUR=Cost-utility ratio;

Costs=Total costs; and

Utility=Perceived utility given (the paper based and the PDAs HUIs)

Therefore, applying this formula we compute the cost utility ratio as follows:

$$CUR_{PDA} = \frac{Costs}{Utility_{PDA}} = \frac{2{,}000{,}000{,}000}{0.54507} = Shs3.67bn$$

$$CUR_{PAPER} = \frac{Costs}{Utility_{PAPER}} = \frac{2{,}000{,}000{,}000}{0.32765} = shs6.1bn$$

This hypothetical example shows that the use of PDAs yields greater utility (benefits) than those derived from the paper-based health information system as shown by the CUR. The PDA system would use just over half of the money to achieve what the paper systems would achieve. Note that these ratios, although useful, depend on perceptions that suffer from lack of statistical significance and therefore may not be heavily relied on in the presence of strong biases among respondents. For that reason this study adopted more than one methodology to conduct the CEA so that the results could be to corroborated.

5.0 RESULTS

5.1 Introduction

This chapter presents the results of the survey according to the structure presented in the methodology. We first present the descriptive statistics of the study area and units where the survey was conducted, and then the characteristics of respondents. This is followed by the patterns of the use of the PDAs in the respective health facilities. Because it is important to understand who uses the PDAs in the health facilities, we present the general composition of the users and their characteristics. A comparison of the personnel who perform tasks on the Paper HMIS is made. This characterization is useful for policy in regard to remuneration and assignment of tasks in health units. The presentation of results ends with the cost indices arising from the Cost Effectiveness Analysis and Cost Utility Analysis. We finally present a synthesized summary containing the implications of findings and recommendations, and propose more research work regarding establishment of start up costs for both HMIS if rolling and scaling is to be done.

5.1.1 Description of the area of study

The survey was conducted in two of the five UHIN project implementing districts (Mbale and Lyantonde). Data were collected using PDAs in November 2009 in a two week period. Since Mbale has more health facilities than Lyantonde (as shown in Table A1 in the Appendix), we visited 20 health units in Mbale and 10 units in Lyantonde. The data from one unit in Lyantonde were poor; therefore we used data from 9 units. The study involved 4 health sub-districts. In Mbale district, the Health Sub-districts included Bungokho North, Bungokho South and Kabula, while in Lyantonde it was the Municipality Health Sub-district. Of the total sample of health facilities, 43 percent were Health Center IIs, 47 percent were Health Center IIIs, 3 percent were Health Center IVs, and 7 percent Hospitals. A total of 15 sub-counties were represented in the study. Mbale had the following 10 sub-counties: Budwale; Bungokho; Busiu; Industrial Division; Lukhonge; Municipality; Mutoto; Nakaloke; Northern Division and Wanale Division.

Lyantonde had the following 5 sub-counties: Kasagama; Kinuuka; Lyantonde Rural; Lyantonde trading center; and Mpumudde.

5.1.2 Characteristics of respondents

Occupation: The categories of occupations include clinical officers, nurses, HMIS officers, records assistants, laboratory technicians and vaccinators. The majority of these were working as Officers in-charge of the health facilities. The occupations that had the largest representation include nurses and records assistants.

Age: The average age of the respondents was 32 years with the majority between 22 years and 35 years. There were a few respondents between 40 and 55 years. This information is very crucial when planning training modules for health workers. Older personnel will have more work experience but their lack of familiarity with the technology may require more on-going training and support. The younger the average age of the workers in Uganda's health facilities suggests a dynamic group willing and able to obtain and use new skill sets, including those needed to operate a new HMIS.
Younger workers in the health facilities in the study were more comfortable and less intimidated by the technology resulting in a short learning curve.

Education: The majority of respondents had completed secondary education and had a Uganda Advanced Certificate of Education (40 percent with 12 years of education) or a Uganda Certificate of Education (23 percent with 10 years of education). Those who had acquired university education were 37 percent. This demonstrates that personnel have the requisite basic education for the tasks they perform.

Duration of work at the station: The respondents had worked at their respective stations for an average period of 3 years implying that they had interacted with the PDA HMIS for a reasonable amount of time. Those with the least time had worked at the health facilities for a period of 6 months to 1 year.

Acquaintance with the PDA and Paper HMIS by respondents: Respondents were asked to identify the HMIS system(s) they used in their respective health facilities. Whereas 47 percent used both, 53 percent utilised only the Paper-based HMIS. The latter group, however, expressed knowledge of both systems and had at different times used the UHIN solution for HMIS for data collection and registration. Of those who used the Paper-based HMIS, the majority of respondents (66.3 percent) were engaged in aggregation (compiling/summarizing/tallying data), 30 percent entered data into the register, and 3.3 percent filed the data. This implies that the respondents were conversant with both HMIS and thus, their responses were due to hands-on acquired knowledge and experience.

Respondents used the PDAs in a variety of ways: 51 percent for data collection and entry, 14 percent for reading information disseminated via the cellular network (mostly continuing medical education), 10 percent for playing games, and the remaining (25 percent did not have opportunity to use PDAs for various reasons, including lack of accessibility and training to operate them. Those who were using the PDAs had done so for a period ranging from 6 months to one year. The exceptions included those who had used them for periods ranging from a few days to one month and others for six years, but these were few. Among those using the PDAs, a vast majority (86 percent) had last handled the PDA-based health information forms a few days prior to the survey. A very small proportion (7 percent) had handled the PDA-based health information forms only weeks prior to the survey while the rest (7 percent) had not handled PDAs at all. This demonstrates commendable accessibility and usability of the PDA by health workers involved with the HMIS.

5.1.3 Duty assignment for registration and aggregation

Registration: It is important to know which personnel perform the different tasks in either type of HMIS, partly to enable policy makers to deploy staff efficiently but, also to compute the hourly rates of personnel remuneration. Table 5.1 summarizes information on the tasks performed by different personnel for both HMIS. It is evident that nurses mainly perform the task of registration followed by the In-charges. This study observed

that most In-charges in lower units are actually nurses emphasizing their role in the process of registering data. The average wage of these personnel was used to compute the hourly pay rate used in costing personnel expenses in each HMIS. Other personnel playing a crucial role at registration include midwives, laboratory technicians and records officers, especially for the Paper-based HMIS. Overall, the distribution does not show a significant difference on the performance of tasks under each HMIS. This implies that in the event that the UHIN solution for HMIS is scaled up and rolled out to cover more districts the same personnel implementing the Paper HMIS will be involved.

Table 5.1: Duty assignment for registration (UHIN versus the Paper HMIS)

Health personnel who register patients	**Paper HMIS**		**UHIN HMIS**	
	Frequency	**Percent**	**Frequency**	**Percent**
Administrator	4	3	-	-
Anaesthetist	1	1	1	2
Clerk	2	2	-	-
Clinical Officer	6	5	2	5
Counsellor	7	6	3	7
HMIS officer	4	3	1	2
In-charge	**23**	**18**	**11**	**26**
Lab technician	21	17	1	2
Midwife	19	15	6	14
Nurse	**28**	**22**	**11**	**26**
Records officer	9	7	4	10
Theatre person	3	2	1	2
Vaccinator	-	-	1	2
Total	**127**	**100**	**42**	**100**

Aggregation: The UHIN HMIS skips the aggregation stage since this is automatically done electronically, requiring no man hours. Once data is entered in the PDA, it is programmed to automatically aggregate the data. Thus, these costs are automatically avoided by the UHIN HMIS. The cost effectiveness analysis in this study seeks to establish the most cost effective way of delivering services with the least expenses. The fact that the UHIN HMIS at this phase does not require manpower to conduct aggregation demonstrates a window for cutting costs, although these costs may be transferred to the

acquisition and maintenance of the electronic systems. At a later stage, this comparison will be made to establish which of the two HMIS minimizes costs significantly. Table 5.2 summarizes the performance of the aggregation task by different health personnel under the Paper-based HMIS. It was evident that the In-charge (33 percent) engaged the largest proportion of personnel responsible for aggregation, followed by laboratory technicians (21 percent), nurses (18 percent), records officers (14 percent), and the administrators, midwives, HMIS officers and clinical officer altogether for the remaining (15 percent). As mentioned earlier, the In-charges in most health facilities are nurses, midwifes and clinical officers. What emerges is that under the UHIN HMIS, time is freed-up for these personnel to perform other duties and responsibilities, emphasizing the role played by the electronic system..

Table 5.2: Duty assignment for the aggregation of data using the Paper-based HMIS

Aggregation	**Freq**	**Percent**
Administrator	4	5
Clinical Officer	1	1
HMIS officer	1	1
In-charge	25	33
Laboratory technician	16	21
Midwife	4	5
Nurse	14	18
Records officer	11	14
Total	**76**	**100**

5.2 Personnel costs

Personnel costs are incurred by both the UHIN solution for HMIS and the Paper-based HMIS. The estimation of the salary (wage) for personnel who perform the actual completion t and transcription of the paper forms and PDA forms, including personnel costs for converting forms into electronic format, was performed using *equation 3*. The numbers of forms differ by the form type as shown in the Table 5.3 where H033B has the largest number and H107 has the smallest number. To compute the personnel costs, we use the hourly rate (UGX. 2500) paid to the health workers for transcribing, entering into the computer (Paper-based HMIS), and registering and converting forms (UHIN HMIS).

This hourly rate is derived from the salary scales of the workers. We use the official number of hours per month which is 160 hours and the salary scale of the health workers doing this work. Although there were slight differences in the remuneration ranging from UGX 300,000 to UGX 500,000, the figure UGX 400,000 was used because it serves as an average and a median. By dividing the salary of UGX 400,000 by 160 hours per month we obtain UGX 2,500, which is the hourly rate. The total number of hours (that go into registration, aggregation and data entry) is then multiplied by the hourly rate to give us the cost of filling the forms in a month. To obtain the annual personnel cost per form, we multiply the monthly cost by 12 months. Finally to obtain the annual personnel cost per each individual form "f" we divide the annual personnel cost (UGX 1,826,000) by the annual number of forms, for example H033B (1320), which gives us UGX 1,383. This is done for the other forms **H105, H055B, H108, H106 and H107** and results are summarized in Table 5.3 and 5.4 demonstrating that higher costs are incurred by the Paper-based HMIS compared to the UHIN solution for HMIS, with the exception of the H107.

Direct observation of the actual time taken to complete the tasks of registration, aggregation, and data entry in both paper and on the PDA were critical metrics in demonstrating the cost effectiveness of the two HMIS approaches. Self-reports from personnel do not provide an accurate measure of the completion times for the various forms, the aggregation function, and data entry into the computer and can be misleading in the calculation of real costs. This study aimed to gain a more precise measurement of completions times for these key tasks involved in data collection.

The Paper-based HMIS incurs personnel costs for registration, aggregation and data entry into the computer while the UHIN solution for HMIS has costs for registration only. There is evidently more time used in all the three key activities under the Paper-based HMIS, demonstrating the resource-intensive nature of the system. The combined number of hours for the 6 forms under the Paper-based HMIS range from 30 to 60 in one month for all the 30 health facilities visited. The greater the number of forms the higher the

chances of reduced personnel costs as shown by the costs. The personnel cost of processing an individual form "f" ranges (depending on the type of form as shown in Table 5.3) from UGX 1,383 to UGX 7,546.

Table 5.3: Paper-based HMIS Personnel cost for registration, aggregation and data entry-computer for all the health facilities studied

Form	Time in minutes for			Time per month Hours	Number of forms		Hourly Wage Rate	Personnel Cost for forms (UGX)		
	Regist-ration	Aggre-gation	Entry into computer		Per month	Per[1] Annum		Monthly	Annual	Annual cost/form
H033B	700	93	120	60.9	110	1320	2500	152,167	1,826,000	1,383
H105	2,362	948	400	61.8	30	360	2500	154,583	1,855,000	5,153
H055B	812	236	360	23.5	20	240	2500	58,667	704,000	2,933
H108	335	376	1,100	30.2	10	120	2500	75,458	905,500	7,546
H106	-	956	1,500	40.9	30	120	2500	102,333	409,333	3,411
H107	-	1,261	1,800	51.0	30	30	2500	127,542	127,542	4,251

Note: As an example for form H033B, it took 700 minutes to register all forms in all the health facilities visited, 93 minutes to aggregate and 120 minutes to enter them. This translated into 60.9 hours for one month, which multiplied by the hourly rate of 2,500 gives the monthly cost of 152,167 and the annual cost of 1,826,000. When this is divided by 1320 number of forms per year, the cost for an individual H033B form is 1,383.

On the other hand, as mentioned earlier, the UHIN HMIS does not have the aggregation costs, although this is implicitly included into the database creation and form conversion costs from paper into electronic format. Forms completed on the PDA are automatically entered into the database so that immediately after registration reports are generated without any further personnel costs. The advantage of having paper forms converted into electronic format is that they can be re-used, incurring costs once at the beginning. There may be modifications that could be made on the forms but this is a rare event. This is the advantage the UHIN HMIS wields over the Paper-based HMIS. As demonstrated in Table 5.4, it is very costly to convert and create each form - it takes on average 56 hours to perform this task for each type of form. The hourly costs for this task is estimated at UGX 6,250 derived from the monthly pay of the UCH staff at UGX 1,000,000 per month. The time taken for registration is costed at the health workers' hourly rate of UGX 2,500. Note that the time taken for completing a registration form is very short owing to the advantage of using the PDA. The total annual cost per type of form is

[1] These are the number of forms returned to the district HMIS office at the end of each year for each category of forms from the 29 health facilities visited

derived by adding the annual cost for conversion/creation to annual cost for registration. We finally derive the cost of the individual form "f" for each form type by dividing the personnel cost by the number of forms. It is observed that the costs range from UGX 414 to UGX 3,171 with an outlier of UGX 11,667 for form H107.

Table 5.4: Personnel cost for the conversion/creation of database and registration (PDA forms)

	Cost of conversion/ creation of database			**Monthly time for registration**		**Cost for registration**			**PDA forms[1]**		**Annual Personnel Cost for forms**	
	Hours	wage rate	Annual	Minutes	Hours	Per hour	Monthly	Annual	Monthly Quarterly Annually	Annual	Total	Per form
H033B	56	6,250	350,000	393	7	2,500	16,375	196,500	110^{m}	1320	546,500	414
H105	56	6,250	350,000	1,012	17	2,500	42,167	506,000	29^{m}	348	856,000	2,460
H055B	56	6,250	350,000	393	7	2,500	16,375	196,500	20^{m}	240	546,500	2,277
H108	56	6,250	350,000	61	1	2,500	2,542	30,500	10^{m}	120	380,500	3,171
H106	56	6,250	350,000		-			-	30^{q}	120	350,000	2,917
H107	56	6,250	350,000		-			-	30^{a}	30	350,000	11,667

Note: m stands for monthly, q for quarterly and a for annually

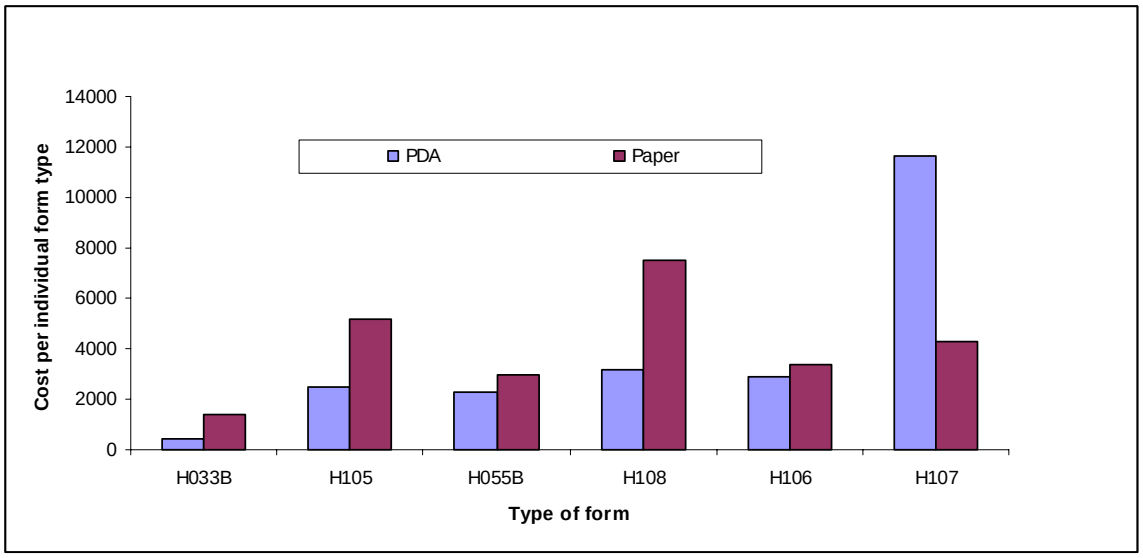
With the exception of the H107 form, the other forms demonstrate that the UHIN solutions for HMIS incurs less time utilization and is therefore cheaper to process forms than the Paper-based HMIS as illustrated in Figure 5.1. Given the reduced time needed for this task, this implies also that health personnel are likely to be freed-up to attend to other responsibilities, especially in rural areas where there are an inadequate number of staff members.. This can be seen from Tables 5.3 and 5.4 that whereas registration, aggregation and data entry under the Paper HMIS takes a total of 268 hours for all the six forms in all the health facilities visited, for the UHIN solutions for HMIS, it takes on average 32 hours to have the same tasks done. We noted earlier that the electronic HMIS has automated systems that perform some of these tasks automatically without any manual intervention.

There are also implicit costs of the Paper-based HMIS at this level in the form of missing data and transcription mistakes that compromise the quality of data. These costs arise from the fact that in the process of aggregating, the handwriting on registration forms

[1] The forms are either, monthly, quarterly, or annual as shown by superscripts.

may be illegible leading to omission of data or filling in wrong figures. In some cases, filled (registers) forms get lost making it difficult to have such data aggregated; resulting in not only explicit costs but implicit costs that make the Paper based HMIS more expensive compared to the UHIN solutions for HMIS. Therefore, in regard to personnel costs, we find that the latter is superior to the former (see figure 5.1)

Figure 5.1: Comparison of personnel cost per type of form for PDA versus Paper HMIS



When we compute comparative proportions, it is observed that for the tasks performed at the health facility, it takes only 30 % of the costs of the Paper -based HMIS to process one UHIN solution for HMIS H033B form, 48 percent of the H105 form, 78 percent of the H055B form, 42 percent of the H108 form, 86 percent of the H106 form and 274 percent of the H107 form.

However, it is observed that form H107 has higher average annual personnel cost for the UHIN solution for HMIS (UGX 11,667) than the Paper-based HMIS (UGX 4251) which is rather contrary to the rest of the forms. This is explained by the fact that this form's only cost, as seen from Table 5.4, is the conversion/creation of the database, and is an annual form generated by each health facility unlike the others that are monthly and many in number which brings the average unit personnel cost down. The cost of conversion is quite high (UGX 350,000) and the average cost is only likely to decrease for forms that

are completed quite often. In contrast, the H107 Paper HMIS form does not go through conversion but is filled out directly. Direct filling out takes less personnel time compared to conversion. As shown in Table 5.4, it takes UGX 6,250 per hour for conversion and UGX 2,500 per hour to fill out directly. The advantage, however, is that once the forms are converted and created electronically this cost is not incurred in subsequent data collection processes.

The mean personnel costs were further subjected to statistical significance tests to establish the robustness of the results, which improves the confidence in the generated results. We used the ***t*** test in this respect to test whether the means (average personnel cost for each type of form) comparing the two HMIS are statistically different from each other. The results are summarised in Table 5.5.

Table 5.5: Results of t-tests for difference of means for personnel costs for each type of form.

		Mean/standard errors	**T value**	**P-value**			**Confidence interval**
				<0	**!=(different)**	**>0**	
H033B	PDA	414 (2.599)	t=76.565	=1.000	=0.000	=0.000	408.7 419.3
	Paper	1383 (12.44)					1357 1408
H105	PDA	2460 (23.95)	t=58.842	=1.000	=0.000	=0.000	2410 2509
	Paper	5153 (38.99)					5073 5209
H055B	PDA	2277 (63.2)	t=5.378	=1.000	=0.000	=0.000	2149 2404
	Paper	2933 (104.9)					2718 3147
H108	PDA	3171 (56.82)	t=27.779	=1.000	=0.000	=0.000	3054 3287
	Paper	7546 (146.8)					7245 7846
H106	PDA	2917 (27.29)	t=9.09	=1.000	=0.000	=0.000	2861 2972
	Paper	3411 (46.9)					3314 3507
H107	PDA	11667 (292.6)	t=-23.31	=0.000	=0.000	=1.000	11067 12266
	Paper	4251 (124.6)					3995 4506

Column 3 shows the generated means (personnel costs) and their respective standard errors in parenthesis. The means all fall between the confidence interval at 95 percent. The standard errors are small, which is a sign that the average personnel costs generated are robust. The ***t*** values are on the other hand are large demonstrating that the generated average personnel costs are robust. The ***p***-values clearly show that the average personnel costs for the two HMIS are statistically different from each other. This implies that the average costs are not the same for the two HMIS. The first column for the p-values

(except for form H107) shows that we make a 100 percent error if we say that the difference in the means is less than zero.

The second column of the p-value shows that the sets of the average personnel costs for the two HMIS are different and are statistically significant at less than 1percent (P-value, 0.000). The third column for the p-values (except for form H107) shows that the two sets of the average personnel cost are statistically different at less than 1 percent (P-value, 0.000). Overall, the tests of statistical significance demonstrate that for all the forms, the average personnel cost are different and not the same. It is plausible to conclude that the two HMIS incur different personnel costs for the different forms. Since for policy purposes a recommendation of an HMIS that minimises cost is the option, the UHIN solution for the HMIS is superior.

5.3 Annual office supply costs

The office supply costs include stationery, folders, binders, printing forms and general printing, transporting of blank forms from the district to the health facilities, accessing the internet, writing the reports, and posting and faxing information. The estimation of these costs is done using *equation 4*. We adopt equal proportions where the costs apply to both systems, since these costs are difficult to assign proportionally for each HMIS and we note that these equal shares are reasonable. However, printing of forms, transporting of forms and writing reports do not arise as expenses for the UHIN solution for the HMIS and therefore these are not factored in as expenses for the UHIN solution for the HMIS. Table 5.6 shows that, for the 30 health facilities visited and the respective districts HMIS offices, the Paper-based HMIS has annual office supply costs that are more than double the costs for the UHIN solution for the HMIS. This clearly arises from the printing and transporting of forms, and the writing of reports which do not exist under the UHIN solution for the HMIS. On average, while it costs UGX 7,023 on office supplies for the PDA HMIS, it costs UGX 19,320 for the Paper HMIS which is more than double. The proportion of office supplies under the UHIN solution for the HMIS is thus only 36 % of the UHIN solution for the HMIS. By adopting the UHIN solution for the HMIS, we would cut down on expenses by more than half at this level. It is thus prudent to consider the UHIN solution for the HMIS as a way of cutting costs, *ceteris paribus*.

Table 5.6: Comparison of annual office supply costs for the PDA Versus paper HMIS

Type of office supply cost	**PDA**			**Paper**		
	Annual cost	**Forms**	**Annual cost per form**	**Annual cost**	**Forms**	**Annual cost per form**
Stationery	6,690,000	2178	3,072	6,690,000	2190	3,055
Archive Folder	4,968,000	2178	2,281	4,968,000	2190	2,268
Binders	98,400	2178	45	98,400	2190	45
Printing Forms and general printing			-	16,497,600	2190	7,533
Transport blank forms from the District			-	7,818,000	2190	3,570
Internet Access	3,540,000	2178	1,625	3,540,000	2190	1,616
Report writing		2178	-	2,682,000	2190	1,225
Posting and faxing	174,000	2178	8	174,000	2190	79
Total/average	**15,313,800**	**2178**	**7,023**	**42,311400**	**2190**	**19,320**

Note: The number of forms (2178 and 2190 were given from the units. The discrepancy arose from non conversion of a few forms from the units.

The costs included for both HMIS (stationery, internet, posting, faxing, etc) are for the running of the HMIS office and not directly into the collection and transmission of the data.

To further increase the confidence in the results, we conducted a ***t*** test to establish the robustness of the generated average supply costs. Unlike in the case of the personnel costs where we used costs for each individual type of form, this was not possible and therefore we used combined average supply costs. The ***t*** value was small (1.972) and the ***P***-value for the test of difference was statistically significant at 2.7 percent (***P***-value 0.0267). The test to show whether the means for the two HMIS supply costs were different was significant at 5 percent (***P***-value 0.0535). Details can be seen in Appendix (A4: 6). Although the results for the test of difference of means for the supply costs are statistically significant, in comparison to personnel costs they are less robust. This means that we are likely to make a smaller difference in reducing costs when we choose the UHIN solution to HMIS over the Paper-based HMIS.

5.4 Transport operational costs for the paper based HMIS

This is a cost solely for the Paper-based HMIS as the UHIN solution to HMIS does not depend on transport. Transport expenses depended on the method used and included vehicles such as motor-cycles; bicycles; public means; and walking, depending on the location. The estimation of these costs was done using *equation 5*. The cost was calculated by capturing expenditure on gasoline, oil, and repairs and servicing in addition to costs arising from other means of transport indicated above. To avoid lumping transport costs for other purposes/uses on forms, the questions to respondents were phrased to capture fuel costs only when forms were transported. The transport cost for purposes other than forms is thus excluded. Oil costs were a proportion of the gas costs as shown in the questionnaire. The most difficult item to capture was repairs since these are general and difficult to isolate. We retrieved the actual total repair costs from records and computed a fraction equivalent to that for fuel. In this way the repair costs for other means of transport were eliminated. The cost information was retrieved from expenditure records/document from the district and health facilities. We computed travel costs per month and per form "*f*", and estimated for the whole year by multiplying by 12. Since it is not possible to disaggregate costs per type of form we computed the cost per form as an average cost. For obvious reasons the type of form with the largest number of forms had the highest cost but not per unit. Table 5.7 shows the details of the results. To transport one form "f" from the health facility to the districts costs UGX 14,640.

Table 5.7: The unit cost of transporting the individual "f" form to the district from the health facility

Annual transport costs	**Number of Annual forms**	**Total cost for each type of form**	**Annual cost per individual form "f"**
H033B	1320	19,324,509	14,640
H105	348	5,094,643	14,640
H055B	240	3,513,547	14,640
H108	120	1,756,774	14,640
H106	120	1,756,774	14,640
H107	30	439,193	14,640
Total	**2178**	**31,885,440**	**14,640**

It is evident that transport plays a major role in increasing the costs of the Paper based HMIS. This cost could altogether be eliminated if the entire HMIS system is made electronic. Note that the electronic system eliminates the delays encountered under the Paper HMIS as well.

5.5 Annual capital costs

The estimation of the annual capital costs for either HMIS was done using *equation 7*. The study identified buildings, vehicles (including motorcycles), training of staff to use PDAs, chairs, desks, cabins and shelves, printers, computers and accessories, solar panels, the server, AAPs, PDAs, internet connection and the internet cost per AAPs as the capital costs that we annualized to obtain the cost for one year.

Note that not all costs apply to the two HMIS. The UHIN solution for HMIS for example does not need a vehicle to operate. Since the UHIN solution for HMIS does not require storage of forms in hard copy, the costs of cabins and shelves were excluded from these computations. Plausibly the latter costs can be used for other joint purposes; however, the point to emphasise here is the need to store copies of empty forms and filled forms. Initially the project used jacks[1] but now uses AAPs; in this case we compute costs for the latter. This explains why they are not included in the annual capital costs. On the other hand, training costs have not been included in the costs of the Paper based HMIS because this cost was exclusively captured for the training of staff at the time of the introduction of the PDA HMIS in addition to subsequent training thereon. The Paper HMIS does not rely on solar panels that are crucial for the the PDA HMIS to charge the batteries that power the PDAs. Other costs to the PDA HMIS that should not appear in the paper HMIS system include the costs for the server, PDAs, AAPs, and for internet connectivity. Computers in this case appear in both because they serve both systems. For the Paper system the computers are used for entering the data and for the PDA HMIS computers are critical as all the data are stored in electronic form. It is important to note that the capital costs are captured from the offices that run the HMIS and not other administrative

[1] These are electronic devises that were initially used to upload and down load data to and from the server

facilities. The estimates for the buildings and furniture/fittings were exclusively for the office premises used by the HMIS offices.

Table 5.8 shows that the PDA HMIS has a higher unit annual capital cost (UGX 31,932) compared to the Paper-based HMIS (UGX 17,844). The capital cost per form for the Paper HMIS is 56 percent that of the UHIN solution for HMIS. This does not come as a surprise since initializing the operation of the UHIN solution for HMIS requires a lot of initial capital equipment to run the electronic components. The advantage, however, is that these equipment serve for some time and they save on the hard copy materials requirements and transport otherwise incurred by the Paper-based HMIS. On a comparative basis this is where the Paper based HMIS incurs less unit costs in comparison to the UHIN solution for HMIS.

Table 5.8: The annual capital cost for the PDA HMIS versus Paper HMIS

	PDA			**PAPER**		
	Annual cost	**Forms**	**Cost per form**	**Annual cost**	**Forms**	**Cost per form**
Building	5,843,217	2178	2,683	5,843,217	2190	2,668
Vehicle		2178	-	24,693,742	2190	11,276
Training	533,585	2178	245		2190	-
Chairs	588,041	2178	270	588,041	2190	269
Desks	971,966	2178	446	971,966	2190	444
Cabins and shelves		2178	-	5,620,008	2190	2,566
Printers	812,427	2178	373	812,427	2190	371
Solar panels	10,241,957	2178	4,702		2190	-
Computer accessories	549,615	2178	252	549,615	2190	251
Server	6,341,667	2178	2,912		2190	-
PDAs	21,189,104	2178	9,729		2190	-
AAPs	2,764,479	2178	1,269		2190	-
Internet connection	12,151,558	2178	5,579		2190	-
Internet Cost per APP	7,560,000	2178	3,471		2190	-
			31,932			17,844

The ***t*** test for statistical significance of the difference of means confirms this. The ***t*** value is 46 which is large enough to demonstrate difference in the means. The ***P***-value is significant at less than 1 percent (***P***-value 0.000). Although it is more expensive in terms

of capital costs to establish the PDA HMIS compared to the Paper HMIS, the operational costs are considerably lower for the former than for the latter.

5.6 Miscellaneous costs

In the process of conducting business, offices incur costs like water, electricity, phone expenses, gas and other indirect or direct services. Either HMIS is likely to use these various services. We captured these costs by using monthly averages over a period of six months extracted from the records at the facilities and the districts offices. The average helps to overcome the fluctuations that are likely to occur over the months in a year. The outstanding costs that we recorded include water, electricity and telephone. It is difficult to disaggregate and thus exclusively attribute the costs to the either HMIS. Water and electricity are divided into two equal proportions while the telephone costs are divided into one quarter for UHIN solution for HMIS and three quarters for the Paper-based HMIS. This is based on the fact that the Paper-based HMIS depends on the telephone for communication on the flow of both empty forms and filled forms as compared to the UHIN solution for HMIS. A lot of calling goes on among the health workers and the records/HMIS officers regarding collection and timely delivery of forms which is not the case with the UHIN solution for HMIS. There was a problem regarding these costs because they are shared centrally. To overcome this problem, we used estimates for the HMIS offices in particular and not the entire establishment costs. In this way, we minimised overestimation of the electricity water and telephone expenses. As shown in Table 5.9 it costs UGX 8,672 per PDA individual form "f" compared to UGX 11,263 per Paper individual form "f" of the miscellaneous cost.

Table 5.9: Miscellaneous cost for the PDA HMIS versus Paper HMIS

Cost	**PDA**			**PAPER**		
	Annual cost	**Forms**	**Cost per form**	**Annual cost**	**Forms**	**Cost per form**
Water	5,649,000	2178	2,594	5,649,000	2190	2,579
Electricity	10,350,000	2178	4,752	10,350,000	2190	4,726
Telephone	2,889,000	2178	1,326	8,667,000	2190	3,958
	18,888,000		**8,672**	**24,666,000**		**11,263**

5.7 Computation of the Cost effectiveness ratio

In this section, we proceed to estimate the cost effectiveness of the two HMIS starting with the summation of all the costs and using the ingredients presented in *equation 1* to obtain the desired ratio. This is the sum of all ingredients (costs) associated with a specific form aggregated at district level, divided by the total number of forms successfully filled out at district health office level as shown in Tables 5.10. The process uses *equation 9* to compute the ratios given in the last column. The estimated ratios give the associated cost of the HMIS by aggregated form and by district level. The higher the ratio of a particular HMIS in comparison to another, the less cost effective it is.

Table 5.10: The cost effectiveness ratios for the Paper HMIS versus the PDA HMIS

Paper HMIS									
	Form type	**No. forms**	**Personnel cost**	**Office supply**	**Miscell-aneous**	**Transport**	**Capital cost**	**Total cost**	$CER = \frac{C}{E}$
1	H033B	1,320	1,383	19,320	11,263	14,640	17,844	64,450	**49**
2	H105	360	5,153	19,320	11,263	14,640	17,844	68,220	**190**
3	H055B	240	2,933	19,320	11,263	14,640	17,844	66,000	**275**
4	H108	120	7,546	19,320	11,263	14,640	17,844	70,613	**588**
5	H106	120	3,411	19,320	11,263	14,640	17,844	66,478	**554**
6	H107	30	4,251	19,320	11,263	14,640	17,844	67,318	**2,244**
PDA HMIS									
	Form type	**No. forms**	**Personnel cost**	**Office supply**	**Miscell-aneous**	**Transport**	**capital cost**	**Total cost**	$CER = \frac{C}{E}$
1	H033B	1320	414	7,023	8,672	-	31,932	48,041	**36**
2	H105	348	2,460	7,023	8,672	-	31,932	50,087	**144**
3	H055B	240	2,277	7,023	8,672	-	31,932	49,904	**208**
4	H108	120	3,171	7,023	8,672	-	31,932	50,798	**423**
5	H106	120	2917	7,023	8,672	-	31,932	50544	**421**
6	H107	30	11,667	7,023	8,672	-	31,932	59,294	**1,976**

In this particular case all the ratios for the Paper HMIS are larger than those for the UHIN solution for HMIS, demonstrating that the latter is more cost effective than the former. The UHIN solution for HMIS ratios range between 72 percent and 88 percent of those of the Paper-based HMIS. In other words, the costs of running the UHIN solution for HMIS

are about three quarters of the costs for the Paper HMIS. The HMIS can save as much as a quarter of its running expenses by switching from the Paper based to the PDA based HMIS. Therefore, the use of UHIN solution for HMIS for data gathering and reporting provided 25 percent cost savings compared to Paper-based HMIS. In this case, if policy is basically looking at costs without considering other factors, the UHIN solution for HMIS is superior to the Paper HMIS.

We further conduct significance tests on the ratios to establish if they are statistically different from each other as shown in Table 5.11. In this way, we establish the robustness of the estimates by examining the standard errors, the ***t***-values, the ***P***-values and confidence intervals. All standard errors for the estimated mean ratios for all forms are small implying that the estimates are good. The confidence intervals at 95 percent illustrate that all the mean CER ratios are within the interval. We are thus, 95 percent confident that all the mean CER ratios are correct. The *t*-values for all the CER ratios with the exception of form H107 are large enough, demonstrating that the CER ratios for the two HMIS are comparatively different.

Table 5.11: Results of t-tests for difference of means for the CER ratios for each type of form

		Mean/standard errors	T-value	P-value			Confidence interval
				<0	!=(different)	>0	
CER H033B	PDA	36 (0.74)	t=2.565	=0.994	=0.013	=0.007	34.48 37.52
	Paper	49 (5.01)					38.73 59.27
CER H105	PDA	144 (7.24)	t=5.222	=1.000	=0.000	=0.000	129.2 158.8
	Paper	190 (5.01)					179.7 200.8
CER H055B	PDA	208 (10.24)	t=5.534	=1.000	=0.000	=0.000	194.7 221.3
	Paper	275 (6.49)					254.0 295.9
CER H108	PDA	423 (6.31)	t=11.287	=1.000	=0.000	=0.000	410.1 435.9
	Paper	588 (13.18)					560.9 615.0
CER H106	PDA	421 (10.58)	t=9.202	=1.000	=0.000	=0.000	533.8 574.2
	Paper	554 (9.84)					399.8 442.7
CER H107	PDA	1976 (106.96)	t=1.632	=0.946	=0.100	=0.050	1756 2195
	Paper	2244 (124.60)					1988 2499

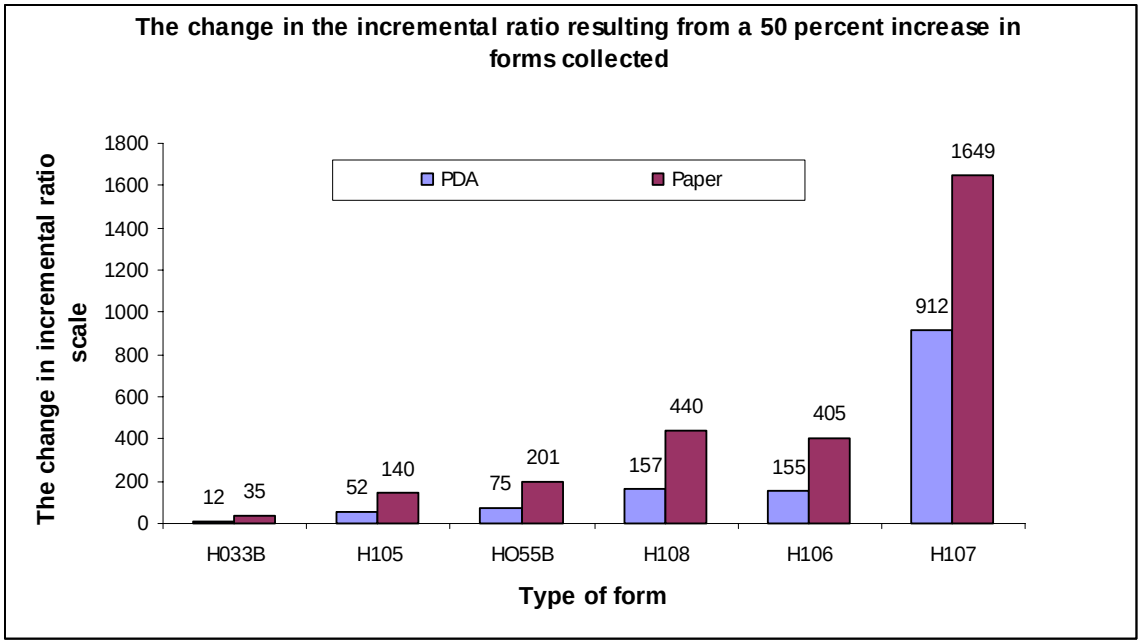
Similarly the P-values are highly statistically significant at less than 1 percent (***P***-value 0.000) with the exception of form H107 which is statistically significant at 5 percent. What emerges from the analysis is that the CER ratios for all forms for the UHIN solution for HMIS are statistically different from those of the Paper HMIS. We can from the foregone presentation and discussion plausibly conclude that the UHIN solution for HMIS is more cost effective than the Paper-based HMIS.

5.8 The sensitivity analysis

The CER ratio used to compare programmes for intervention suffers from the lack of robustness of the parameters estimated especially when subjected to shock. Owing to this limitation, we performed a sensitivity analysis to augment the CER ratio parameters to study the changes in case of shocks. In the case of forms, there could be instances when epidemics break out making the work of filling forms more expensive. The sensitivity analysis makes a comparison of the two HMIS to establish the one with less marginal costs as a result of shocks. In addition, the analysis provides evidence in the event that the PDA HMIS must be scaled up to cover more districts. The effects on marginal cost of producing one extra unit of output (one more form) due to an unexpected increase in the number of forms filled out was done by conducting simulations. In this case we assume a 50 % increase in the number of forms of either HMIS due to shocks like epidemics or scaling up. To understand the underlying assumptions behind the simulations we rely on the economic theory of production and contextualize the analysis. We vary output by changing variable costs while holding fixed costs constant. Among the costs, we treat capital costs as fixed costs in which case they do not vary even when we increase the number of forms collected. On the other hand, personnel costs increase because more hours will be spent on registration, aggregation and data entry into the computer. Transport costs are treated as variable costs because more movements will have to result especially in the event of epidemics or influx of populations. Office supply costs and miscellaneous costs will likewise increase thus treating them as variable costs. Tables A4:1 and A4:2 in the Appendix A4 show the results of the sensitivity analysis and

Figure 5.2 demonstrates the differences between the changes in the CER indices for the forms in either HMIS.

Figure 5.2: The change in the incremental ratio resulting from a 50 % increase in forms



Results of lower marginal costs imply less sensitivity of the total costs of a specific form to shock. It is preferred that this ratio be low since a higher number is more sensitive and thus more expensive when exposed to shocks. It is observed that for all the forms, the UHIN solution for HMIS has a lower change in ICER index compared to the Paper-based HMIS. In all cases the ratio for the Paper-based HMIS is more than twice that of the UHIN solution for HMIS. This means that in cases of shocks like epidemics, or large inflows of internally displaced persons or refugees, the stress on the costs is less for the UHIN solution for HMIS. The latter has high absorption capacity to shock compared to the paper based system. In line with economic theory, the marginal costs under the Paper HMIS are higher compared to the marginal costs under the UHIN solution for HMIS. In essence, the latter is better placed for scaling than the former. Put another way, if policy makers are considering the two HMIS systems to make a prudent choice, the UHIN solution for HMIS is vastly superior (dominates) in handling shocks and scaling than the Paper-based HMIS.

The other way to study the change resulting from shocks is to examine the change in total cost resulting from a 50 percent increase in the number of forms collected which is presented in Figure 5.3 (details of the computations are in Appendix 4A Tables A4:1 and A4:2).

Figure 5.3: Percentage change in total cost resulting from a 50 percent increase in the number of forms

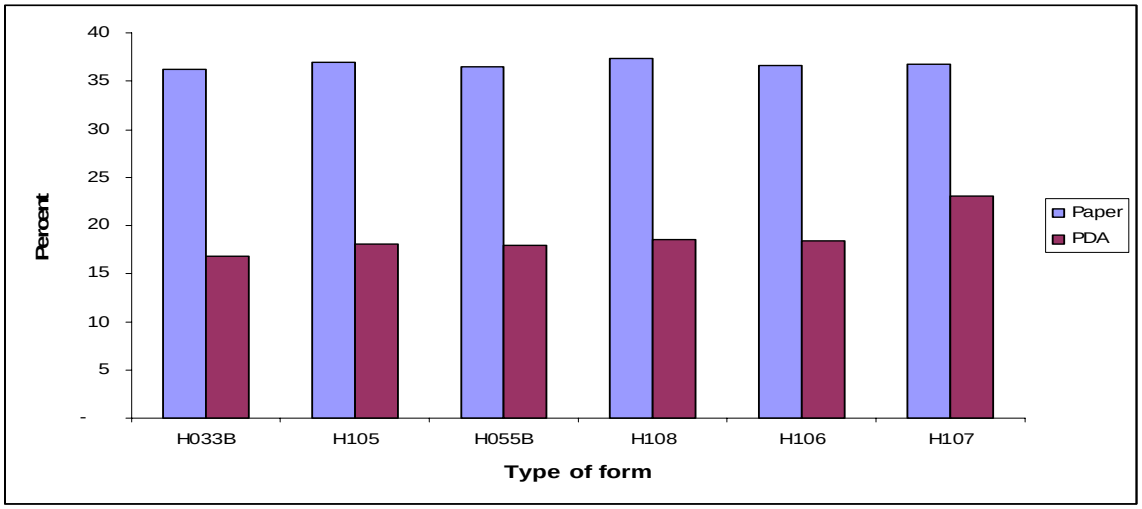


Figure 5.3 demonstrates that a 50 percent increase in the number of forms collected leads to a less than proportionate change in the total cost for each type of form. The change in total cost is less than 37 percent for the Paper-based HMIS and less than 23 percent for the UHIN solution for HMIS. This implies that in the event of a shock requiring collection of more forms, the increase in the costs will be proportionately less and the marginal costs will be falling with collection of more forms. However, a comparison of the two systems reveals that the Paper-based HMIS incurs proportionately more costs than the UHIN solution for HMIS. Whereas the costs for the paper HMIS increase by 36 to 37 percent, the costs for the UHIN solution for HMIS HMIS increase by 17 to 23 percent. This marked difference in the change in the cost by the two HMIS is largely because of the transport costs and paper costs. The Paper-based HMIS will require more empty forms and transport to take them to health facilities while UHIN solution for HMIS will not.

5.9 Qualitative analysis and indicators

In this section, we estimate a health information system state index taking into account the system attributes and the corresponding multiplicative factors. The study adopted the Health Utilities Index (HUI) because of its use of the multi-attribute utility theory for the estimation of the utility formula. The attributes of either HMIS include: the accuracy of the data; timeliness and vertical integration; completeness and reliability; degree of conflict with usual activities; supervision; prestige; motivation; need for training for better skills; and the degree of safety of retrieval of information. A descriptive analysis of the attributes is presented in Table A4:3 in Appendix A4 and the following is the summary.

- The UHIN solution for HMIS always has more accurate (76 percent) data than the Paper-based HMIS as the latter is plagued by data accuracy problems (79 percent).
- On timeliness of data, respondents show that reporting is always fast (62 percent) for the UHIN solution for HMIS and sometimes fast (69 percent) for the Paper-based HMIS. Overall, the UHIN solution for HMIS is superior to the Paper-based HMIS in timeliness of reporting data.
- Completeness and reliability of data is very crucial for accurate planning. The UHIN solution for HMIS always has complete and reliable forms (83 percent) compared to the Paper-based HMIS, which has forms often missing relevant information (66 percent).
- Regarding time allocation to performing other usual activities, both HMIS have some problems as they withdraw personnel from performing other assignments.
- There is a strong need for technical assistance and advanced skills (72 percent) in filling PDA forms compared to paper forms (62 percent) that are easy to complete. The UHIN solution for HMIS with a new technology requires more training than the Paper-based HMIS.
- The need for supervision is required for both HMIS although it is needed more in the UHIN solution for HMIS than in the Paper-based HMIS.
- The UHIN solution for HMIS is more prestigious than the Paper-based HMIS.

- The UHIN solution for HMIS is quite motivating (72 percent) compared to the Paper-based HMIS (52 percent) which does not motivate the staff to work on it.
- The Paper-based HMIS does not ensure data safety and retrieval is always problematic (79 percent). The UHIN solution for HMIS on the other hand ensures reasonable safety but failure may occur during retrieval (48 percent). Overall the UHIN solution for HMIS has more chances of ensuring that health information is protected and can easily be retrieved.

What emerges from the perspectives of the respondents on the attributes of the two HMIS is that the UHIN solution for HMIS is superior compared to the Paper-based HMIS as indicated by the respective proportions in the above summary.

However, the health utility index offers a precise and robust comparison of each HMIS than the proportions presented above. We compute the HMIS health utility index by using the multiplicative factors assigned to responses. The final outcome of this computation is a single health utility index value for the state of each health information system on the standard scale where HMIS state is rated as one (for good) and as zero (for bad) based on the nine specified attributes. The summary of the responses and the final computation of the health information system indices according to *equation 14* are shown in Tables A4 4 and A4 5 in Appendix A4. The overall average health utility index for the Paper-based HMIS is 0.39 and the one for the UHIN solution for HMIS HMIS is 0.57. Given that the latter has a higher health utility index than the former, the expressed views of the stakeholders are that the UHIN solution for HMIS HMIS is superior compared to the paper based over the 9 system attributes.

When we subject the HUI indices to a significant test to establish whether the two are the same or different, all parameters generated demonstrate that they are different. The t value is 7.4957, which is large enough to prove that the parameters generated are statistically significant. The standard errors are very small, a good sign that the parameters generated are robust and the P-value is significance at less than 1 percent (P-value 0.000).

5.9.1 Computation of the cost utility ratio

Districts allocate funds for running the HMIS activities for 12 months. With limited resources to be allocated among legitimate competing options, the District Directorate of Health Services has an incentive to choose the best alternative among competing options. In this case the competing options are the UHIN solution for HMIS and the Paper-based HMIS. We apply the health utility index, based on the budget constraint to examine how we can allocate resources to maximize their utility. We use *equation 15* to compute the cost utility index ratio which is a ratio between the total cost of implementing a programme and the perceived HUI computed above.

The allocation of funds within the district directorates of health services for recurrent expenditure to the HMIS offices is quite limited and sometimes purchases are made centrally making it difficult to get the exact amounts. However, the Heads of Department advised that it is about 5% of the overall directorate budget. We thus compute 5 % of the budget and use the figure to compute the cost utility ratio. For Lyantonde district this figure is UGX 53,365,100 (Fifty three million, three hundred sixty five thousands and one hundred) and for Mbale district, it is UGX 57,000,000 (Fifty seven million) to run HMIS activities for the Financial year 2009/2010. Table 5.12 presents the computed cost utility ratio (CUR) for the districts independently and then jointly. We use the cost-utility analysis to compute the corresponding measures of effectiveness that can guide the decision on which option to take. The CUR should help policy makers to make a choice between the two "competing" HMIS approaches.

Table 5.12: The Cost Utility Ratios for the districts

	HMIS	Health Utility Index (utility)	HMIS Budget in UGX (cost)	Cost utility ratio $CUR = \frac{Costs}{Utility}$
Combined	Paper HMIS	0.39	110,365,100	282,987,436
	PDA HMIS	0.57	110,365,100	193,622,982
Mbale	Paper HMIS	0.40	57,000,000	142,500,000
	PDA HMIS	0.56	57,000,000	101,785,714
Lyantonde	Paper HMIS	0.39	53,365,100	136,833,590
	PDA HMIS	0.59	53,365,100	90,449,322

Results show that the use of PDAs yields greater utility (benefits) than those derived from the Paper-based health information system as shown by the CUR. The results show a similar trend for the individual districts and jointly. Whereas, it takes about UGX 283 million to run the Paper-based HMIS, it takes about UGX 192 million to do the same using the UHIN solution for HMIS.

1 Discussions, policy implications and conclusions

In this section we discuss the results of the study, derive conclusions, and propose recommendations. The Uganda Ministry of Health (MoH) implements the HMIS for capturing information needs required for effective planning, monitoring and evaluation for health service delivery at all levels. Data collection in health management systems is crucial to effective health service delivery, health practitioners and policy makers. The methods by which data are collected and transmitted from lower level units to the districts and ultimately to the national level have a strong bearing on the actions that are taken.

The survey established that the occupations that had the largest representation were nurses and records assistants although staffs in other categories perform tasks associated with HMIS activities. To enhance performance of personnel for the UHIN solution for HMIS especially, health professionals at all levels need to be supported with hands-on computer training so that on the job training time is reduced plus the accompanying expenses.

Regarding registration of forms, both HMIS perform this task. There was no significant difference regarding the category of staff which performed this task for the two systems. This implies that in the event that the UHIN solution for HMIS is scaled up and rolled out to cover more districts, the same personnel implementing the Paper-based HMIS can be used. However initial training is necessary to support the use of the electronic system. This further strengthens the argument for the training of health professionals in institutions to include a component on using computers.

The UHIN solution for HMIS skips the aggregation task since this is automatically done electronically. The aggregation costs are thus automatically eliminated by the UHIN solution for HMIS. This implies that the electronic HMIS is more cost effective than the Paper-based HMIS at this phase. The fact that the UHIN solution for HMIS at this phase does not require man power to conduct aggregation demonstrates a window for cutting

costs. Under the UHIN solution for HMIS, personnel are free to perform other tasks and responsibilities.

Although the creation and conversion of forms is an expensive exercise, once completed the forms can be used repeatedly. In the long run, this would cut costs since the same forms can be used for many years as compared to the paper system where every entry has a cost implication. In this respect, the UHIN solution for HMIS is superior and should thus be promoted as a way of cutting costs.

It emerged clearly that the Paper-based HMIS requires more man hours to conduct the registration, aggregation and data entry than the UHIN solution for HMIS. This was demonstrated by both the difference in the mean personnel costs and the statistical significant tests in addition to the hours spent by each system. Given that most health facilities are under staffed with units operating below the established numbers of personnel, the UHIN solution for HMIS offers an opportunity for increasing the amount of time available to attend to clients (patients). The other advantage of the UHIN solution for HMIS is its ability to automatically aggregate data and generate reports which not only reduces incidence of errors, but also quickens the process for response and requires less time. Therefore, for policy purposes, the recommendation of the UHIN solution for HMIS is the best option as it minimises cost, reduces errors and improves the time for reporting.

The study demonstrated that office supply costs are a major component of the Paper-based HMIS compared to the UHIN solution for HMIS. The fact that these costs for the Paper-based HMIS more than double the costs for the UHIN solution for HMIS, sends a strong signal to policy makers in regard to minimising costs. There is a lot of printing of forms in addition to transporting them, which is totally absent under the UHIN solution for HMIS. With the health service delivery system in the country struggling to finance activities, this would offer a golden chance to reallocate funds meant for printing forms and transporting them to and from health facilities. Therefore by adopting the UHIN solution for HMIS, we would cut down on all these expenses by more than half at this

level. It is thus prudent to consider the UHIN solution for HMIS for scaling and rolling to more districts.

It is evident that transport plays a major role in increasing the costs of the Paper based HMIS. To transport one form "f" from the health facility to the districts costs UGX 14,640 which is not at all incurred under the UHIN solution for HMIS . This cost can be eliminated if the entire HMIS system is made electronic. There are other advantages of the electronic system regarding data quality and timely delivery of data for appropriate interventions. The fact that the UHIN solution for HMIS does not require the massive paper work (forms) to operate implies that policy makers should consider it as a viable alternative for reducing costs and the other implicit costs of data poor quality and non timely delivery.

The study revealed that the UHIN solution for HMIS has higher capital costs compared to the Paper HMIS. This is because initializing the operation of the UHIN solution for HMIS requires a lot of initial capital equipment to run the electronic components. On a comparative basis this is where the Paper based HMIS incurs less annual costs in comparison to the UHIN solution for HMIS. However, the capital equipment (the server, AAPs, computers, the PDAs among others) once acquired serve for some time (3 to 7 years) before they are replaced.

All the CER for the UHIN solution for HMIS are lower than those for the Paper-based HMIS demonstrating that the former is more cost effective than the latter. The study revealed that the costs of running the UHIN solution for HMIS are about three quarters of the costs for the Paper HMIS. Therefore, the use of UHIN solution for HMIS for data gathering and reporting provided 25 percent cost savings compared to Paper-based HMIS. An area that this study did not address, although it is crucial for decision making, is establishing the comparative cost of establishing each of the two systems. If policy is basically looking at running costs without considering establishment costs, the UHIN solution for HMIS is superior to the Paper-based HMIS and should therefore considered. A comparative study of start up costs for both HMIS is crucial to establish what it takes

financially to get them started, especially countrywide. This study should also consider costs of running the systems as presented and discussed in the present study. By considering both start up costs and running, policy makers will make more informed decisions on which system is the best in the long run.

The results of the sensitivity analysis further improve the grounds for considering the UHIN solution for HMIS as a more viable option especially with the ability to handle shocks. The UHIN solution for HMIS exhibits lower change in ICER indices compared to the Paper-based HMIS. This advantage largely arises from the fact that paper HMIS will require more empty forms and transport to take them to health facilities while the UHIN solution for HMIS will not. In cases of shocks like epidemics, or large inflows of internally displaced persons or refugees, the stress on the costs is less for the UHIN solution for HMIS. Therefore policy makers considering the two HMIS systems are likely to find the UHIN solution for HMIS superior (dominates) in handling shocks and scaling up to cover more districts compared to the Paper-based HMIS.

The results of the health utility index generated from the qualitative data clearly demonstrated the preference of the UHIN solution for HMIS over the Paper based HMIS. The overall average health utility index for the Paper based HMIS is 0.39 and the one for the UHIN solution for HMIS is 0.57, indicating that the stakeholders viewed the UHIN solution for HMIS to be superior when compared to the paper based system for all 9 system attributes.

The UHIN solution for HMIS in the districts where it has been implemented has demonstrated that it can offer other services critical in health service provision in addition to data collection and transmission which not only deserve mention but should be put in perspective. The UHIN solution for HMIS has been used to provide Continuing Medical Education (CME) and Continuing Professional Development where materials are compiled and up-loaded onto the server and down loaded by health workers, studied and used in their daily provision of health care. Lyantonde district has a Nutritional Program for Enhancing Nutrition of Children in which the PDA technology is used. The project

aims at improving the diet and health of children by putting them on nutrient rich foods as well as demonstrating to the mothers how to prepare these meals. The PDA technology has been used for data collection when conducting surveys. The data are aggregated and electronically transmitted which saves stationery costs, eliminates data entry costs and saves time. Lynatonde and Rakai districts have used the PDA technology to enhance public health and sanitation among communities. The practice targets improving both household and community hygiene and sanitation using data collected and stored on the PDAs for monitoring and supervision. For administrative purposes, PDAs have been used to improve resource management for efficiency in service delivery by hospital/health centers and the district health department. The program uses the PDA for tracking the utilization of resources, management of staff and tracking of patients admitted in Kalisizo and Lyantonde hospitals and the respective district health departments.

In conclusion, the UHIN solution for HMIS emerges as a superior system for transmitting data than the Paper-based HMIS. It is more cost effective owing to the fact that the incremental ingredients cost less. This arises especially, from absence of transport and hard copy forms with associated costs like printing. There are also other benefits like Continuing Medical Education which are conducted over the UHIN solution for HMIS and not only improve the services provided by health workers but reduce the costs of providing CME. The perceptions of the health worker for the two systems have clearly shown preference of the UHIN solution for HMIS over the Paper-based HMIS. Therefore, taking running costs without the establishment costs, and the other benefits listed above, the UHIN solution for HMIS is superior to the Paper-based HMIS and should be seriously considered. By conducting a comparative study on start up costs for both HMIS, in addition to the present study (running costs), policy makers will be in a better position to make more informed decisions on which system is the best in the long run.

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APPENDICES:

Table A1: List of Health Facilities in the Survey

Lyantonde District Health Units			
HSD Name	Health Unit Name	Level	Ownership
KABULA	Lyantonde	Hospital	Government
	Kinnuka	III	Government
	Kaliiro	III	Government
	Kasagma	III	Government
	Mpumudde	III	Government
	Kabayanda	II	Government
	Buyanja	II	Government
	Lyakajula	II	Government
	Kijukizo	II	NGO
	Moslems	II	NGO
	Born Med. Centre	II	NGO
	Allena	II	Private
	Kemunyu	II	Government
Mbale District			
HSD	Health unit name	Level	Ownership
Bungoho North	Kolonyi	III	NGO
	Nakaloke	III	NGO
	Namanyonyi	II	NGO
	Bufumbo	IV	NGO
	Thombony	II	NGO
	Bumadanda	II	Government
	Budwale	II	Government
Bungoho Sourth	Bungokho Mutoto	II	Government
	Bunampango	II	Government
	Bushikoli	III	Government
	Siira	III	NGO
	Lwangoli	III	Government
	Busiu	IV	Government
	Nakhonje	III	Government
	Namawanga	III	Government
	Nyondo	III	Government
	Naiku	III	Government
	Busono	III	Government
	Buwangwa	III	Government
Mbale Municipal	Gongama	II	NGO

	Namakwekwe	II	Government
	Busomanga	II	Government
	Malukhu	II	NGO
	Municiple	II	Government

Appendix 2A: Consent form

The evaluation of the Uganda health information system (paper-based forms)

Dear Sir/Madam

My name is _____I am part of the team from Makerere University Faculty of Economics and Management collaborating with Uganda Chartered HealthNet, Faculty of Medicine Makerere University. We are evaluating the cost-effectiveness of the paper-based versus the PDAs health information system in Uganda Pilot Districts.

I thus request you to kindly answer some few questions concerning the Health Ministry Information System. The information you provide is expected to contribute to a better understanding of the functioning of the system and will be a great input in deciding and planning their future improvement regarding scaling up.

APPENDIX 3A: QUESTIONNAIRE

COST EFFECTIVESS ANALYSIS OF THE UHIN PROJECT – COMPARISON OF THE PAPER AND THE PDA BASED HMIS

Part 1: Background information of the respondents

Name of health unit: _____
Health sub-district: _____
Sub County: _____
County: _____
District: _____
Contact telephone: _____

	Questions	**Description**	**Answer**
Q01	Sex	Male Female	1 2
Q02	Age of respondent	(age in years)	
Q03	Education level	1. Primary 2. Secondary (g8-10) 3. Secondary (g10-g12) 4. Higher education (University)	1 2 3 4
Q04	Title	1. HMIS officer 2. Records assistant 3. In-charge health centre 4. Administrator 5. Other staff (specify)	1 2 3 4 5
Q05	How long have you been working here? (approximate years or months)?	Months Years	
Q06	Which of the HMIS are you involved with?	1. Paper based HMIS 2. PDA based HMIS 3. Both 4. none	1 2 3 4
Q07	What exactly do you do?	The PDA	1 2
		Paper based	1 2
Q08	When did you start using a PDA?	Month ____ Year ____	
Q09	When did you last handle the PDA- based health information forms	Days ago ____ / Weeks ago ____ / Months ago ____ / Years ago ____ / Not applicable (88) ____	

Part 2: Time allocation of activities

<u>Activity 1</u>: Daily registration of health information into HMIS paper-forms and PDAs which is done only at health facility level:

The HMIS administrator or in charge at the health facility should answer this section.

Q10: I would like you to provide me with the following information regarding the amount of time it takes to perform the activities mentioned below as well as the total number of staff involved?

Daily register form (used at health facility level)	Q10.1. How long does it takes to complete each of the following daily register forms in **Paper (self-reports)?**		Q10.2. How long does it takes to complete each of the following daily register forms in **PDA (self-reports)?**		Q.10.3. How many members of staff are involved in completing the forms?		
					Staff occupation	**Paper**	**PDAs**
1: Out Patient Department Registers (OPD)	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
2: Laboratory registers	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
3: Antenatal registers, PMTCT are combined (ANC, PMTCT)	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
4:Family planning registers (FP)	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
5: HIV counselling and testing Register (HCT)	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
6: Ant Retroviral	a) 15 min		a) 15 min		1: HMIS officer		

Therapy (ART)	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
7: Postnatal register	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
8: Inpatient register (for all wards e.g. Paediatrics ward, female, Male word etc)	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
9: Theatre register	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
10: X-ray register	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		
11: Ward census form.	a) 15 min		a) 15 min		1: HMIS officer		
	b) 30 min		b) 30 min		2: Record assistant		
	c) 45 min		c) 45 min		3: In-charge HC		
	d) 1h		d) 1h		4: Administrator		
	e) > 1h (specify)		e) > 1h (specify)		5: Other (specify)		

Activity 2: Manual aggregation into weekly/monthly forms at health facility level only

Q11: I would like you to provide me with the following information regarding the amount of time it takes to perform the activities mentioned below as well as the total number of staff involved?

Weekly/monthly (form (used at health facility level)	Q11.1. How long does it takes to aggregate the following form (self-reports)?				Q.11.2. How many members of staff are involved in aggregating the **weekly paper** forms?	
	Weekly forms		**Monthly forms**		**Staff occupation**	**Number of staff involved**
1: Heal Unit monthly report - (HMIS 105)	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours		b) 48 hours			
	c) > hours (specify)		c) > hours (specify)			
2:District monthly report - (HMIS 123)	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours		b) 48 hours			
	c) > hours (specify)		c) > hours (specify)			
3:Health Unit & district weekly report - (HMIS 033b	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours		b) 48 hours			
	c) > hours (specify)		c) > hours (specify)			
4:Health Unit monthly report - (HMIS 055b) for laboratory (reported separate)	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours		b) 48 hours			
	c) > hours (specify)		c) > hours (specify)			
5:Health Unit in patient monthly report (HMIS 108)	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours		b) 48 hours			
	c) > hours (specify)		c) > hours (specify)			
6:District in patient monthly report (HMIS 124)	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours		b) 48 hours			
	c) > hours (specify)		c) > hours (specify)			
7:Health unit quarterly report (HMIS 106)	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
8:Health Unit annual report (HMIS 107)	a) 24 hours		a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	

<u>Activity 3</u>: Manual data entry of health center monthly aggregated data into computer

Respondent is HMIS administrator at district directorate of health office

Q12: I would like you to provide me with the following information regarding the amount of time it takes to perform the activities mentioned below as well as the total number of staff involved?

Monthly form (used at health facility level)	Q12.1. How long does it takes to enter health center monthly aggregated data into computers?		Q.12.2. How many staff members are involved in manual data entry of health center monthly resumes into computers?	
	Monthly aggregated data		**Staff occupation**	**Number of staff involved**
1: Heal Unit monthly report - (HMIS 105)	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
2:District monthly report - (HMIS 123)	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
3:Health Unit & district weekly report - (HMIS 033b	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
4:Health Unit monthly report - (HMIS 055b) for laboratory (reported separate)	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
5:Health Unit in patient monthly report (HMIS 108)	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
6:District in patient monthly report (HMIS 124)	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			

<u>Activity 4:</u> Conversion of HMIS forms into PDAs and creation of HMIS report database at district level

Respondent is HMIS administrator at health facility level

Q13: I would like you to provide me with the following information regarding the amount of time it takes to perform the activities mentioned below as well as the total number of staff involved?

Activity	Q13.1. How long does it take to perform this activity?		**Staff qualifications**	**Number of staff involved**
1. Conversion of paper registers into electronic format for the PDA	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
2. Create of HMIS Report database at district level and configuring the server	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
3. Automatic electronic transmission of daily registers to district directly into HMIS Reporter database	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			
4. User support provided by district and UHIN staff	a) 24 hours		1: HMIS officer 2: Record assistant 3: In-charge HC 4: Administrator 5: Other (specify)	
	b) 48 hours			
	c) > hours (specify)			

Part 3: Staff salaries and working schedule of personnel

Respondent is financial office at the district and the respective personnel

	Staff occupation				
	1.HMIS officer	**2.Records assistant**	**3.In-charge Health Center**	**4.Administrator**	**5. Other (specify)**
Q16.1. What the salary scale of?					
Q16.2. What is the monthly pay including allowances for….?					
Q16.3.On average, how many hours in a week does…..work?					

Part 4: The costs of transport for manual forms

Respondent is administrator of the health facility/financial officer at health facility level/district directorate of health financial officer

Transportation costs of weekly/monthly forms

17. This corresponds to regular transmission of weekly/monthly forms from the health facility to the district health directorate.

Q17.1. What is/are the mode(s) of transport used to transport manual forms to the district health directorate? Vehicle …….Motor bike……..Public transport…….Bicycle……..Footing …….			
17.2.1. Km traveled per **week** from the health facility to the District office. **Check with the financial officer**		17.3.1. Total Oil/ Lubrication components costs = 15% x weekly expenditure on fuel	
17.2.2. Total liters spent per week			
17.2.3. Cost per liter		17.3.2. Total Oil or Lubrication components costs = 15% x monthly expenditure on fuel	
17.2.4. Km traveled per **month** from the health facility to the District office. **Check with the financial officer**			
17.2.5. Total liters spent per month		17.4. Spare parts costs = 24% x purchase price of vehicles	
17.2.6. Cost per liter			
17.2.7. Public means			
17.2.8. Footing			

Part 5: Infrastructure and operational costs at health facility and district office levels.

Ingredients		**Health facility costs**	**District health office**
		Total costs per month	**Total costs per month**
1	Paper and stationery (pencils, pens, rubbers, etc)		
2	Archive Folders		
3	Binders		
4	Cost of printing paper copies of blank daily, weekly and monthly forms		
5	Transport costs of blank forms from the District office to the Health facility		
6	Internet access		
7	Connectivity (costs of connecting to PDA network)		
8	Training costs		
9	Maintenance costs		
10	Meetings		
11	Report writing		
12	Posting/faxing		
13	Water		
14	Electricity		
15	Telephone		

Note: these are utilities related to both paper and PDA methods of collection of health data

Part 6: Capital costs at health facility and district health office.

Ingredients	**Health facility level**			**District health facility**		
	Purchase costs	Useful life of the good (this has to be filled by the researcher)	Annual replacement costs	Purchase costs	Useful life of the good (this has to be filled by the researcher)	Annual replacement costs
1. Buildings						
2. Vehicles (ONLY those used to transport paper forms from the health unit to district office)						
3. Training costs (please indicate the average costs of the last training initiative that took place at your unit)						
4. Chairs						
5. Desks						
6. File cabinets / Shelves						
7. Computers						
8. Printers						
9. Solar panel						
10. Other computer accessories (software, hardware)						
11. UPS						
12. AAPs						
13. Server						
12. Others						

Q19. Information regarding the number of paper and PDA forms transferred

Respondent is the HMIS officer at the district.

Description of aggregated monthly forms	**Total number of HMIS monthly return forms sent from District Directorate to the MoH headquarters**		**Total number of HMIS monthly return forms sent within 28 days of the following months**	
	Paper forms	**PDA forms**	**Paper forms**	**PDA forms**
1: Heal Unit monthly report - (HMIS 105)				
2:District monthly report - (HMIS 123)				
3:Health Unit & district weekly report - (HMIS 033b				
4:Health Unit monthly report - (HMIS 055b) for laboratory (reported separate)				
5:Health Unit in patient monthly report (HMIS 108)				
6:District in patient monthly report (HMIS 124)				

Part 7: This section aims at collecting qualitative data that will be used to compute the health utility of the paper based health information system in Uganda.

This form has to be administered to all staff that deal with both filling up and transcription of the paper forms into computers. **However this can be extended to staff working at the all the HMIS levels.**	HMIS Officers Records Assistants In-Charges Administrative members Other (specify)	**Please indicate your choice here ☑**

	A. Data accuracy		
Level	Code	Description	
1	A1	Data is always accurate and precise	
2	A2	Often there are problems with data accuracy	
3	A3	Always have problems with data accuracy	
	B. Timeliness		
Level	Code	Description	
1	B1	Reporting is always fast	
2	B2	Reporting is sometimes fast	
3	B3	Reporting is rarely fast	
	C. Completeness and Reliability		
Level	Code	Description	
1	C1	Forms are almost always complete and reliable	
2	C2	Forms often miss relevant information	
3	C3	Forms are almost always reported with missing information	
	D. Conflict with usual activities		
Level	Code	Description	
1	D1	No problems with performing usual activities	
2	D2	Some problems with performing usual activities	

3	D3	Unable to perform usual activities	
	E. Need for additional training or advanced skills required		
Level	Code	Description	
1	E1	Forms are very easy to fill in	
2	E2	Sometimes there is a need for assistance in filling the forms	
3	F3	There is a strong need for technical assistance or advanced skills	
	F Supervision		
Level	Code	Description	
1	F1	Supervision process is easier under this HMIS system	
2	F2	Sometimes supervision is deficient	
3	G3	There is almost ineffective supervision in this HMIS system	
	G. Prestige		
Level	Code	Description	
1	G1	The nature of the HMIS system is very prestigious	
2	G2	The HMIS system is reasonable	
3	G3	The nature of the HMIS system is not prestigious at all	
	H. Motivation		
Level	Code	Description	
1	H1	This HMIS system is quite motivating	
2	H2	The system is reasonable	
3	H3	This system does not motivate staff to work on it at all	
	I. Degree of safety and retrieval of information		
Level	Code	Description	
1	I1	This HMIS ensures that health information is safe and can easily be retrieved	
2	I2	The HMIS ensures reasonable safety but there may occur failures during retrieval	
3	I3	The HMIS does not ensure data safety and retrieval is always problematic	

APPENDIX A4: Tables from results

Table A4:1 Sensitivity analysis and computation of marginal costs of the Paper HMIS

Form Type/ 50 % increase in form		No. forms	Personnel cost	Office supply	Misce.	Transport	capital cost	Total cost	Ratio
		1,980	2,074	28,980	16,894	21,960	17,844	87,753	
	original	1,320	1,383	19,320	11,263	14,640	17,844	64,450	
H033B	change	660	691	9,660	5,631	7,320	-	23,303	**35**
	Percentage change in total costs							**36.2**	
50 % increase		540	7,729	28,980	16,894	21,960	17,844	93,408	
	original	360	5,153	19,320	11,263	14,640	17,844	68,220	
H105	change	180	2,576	9,660	5,631	7,320	-	25,188	**139**
	Percentage change in total costs							**36.9**	
50 % increase		360	4,399	28,980	16,894	21,960	17,844	90,078	
	original	240	2,933	19,320	11,263	14,640	17,844	66,000	
H055B	change	120	1,466	9,660	5,631	7,320	-	24,078	**200**
	Percentage change in total costs							**36.5**	
50 % increase		180	11,319	28,980	16,894	21,960	17,844	96,997	
	original	120	7,546	19,320	11,263	14,640	17,844	70,613	
H108	change	60	3,773	9,660	5,631	7,320	-	26,384	**439**
	Percentage change in total costs							**37.4**	
50 % increase		180	5,116	28,980	16,894	21,960	17,844	90,795	
	original	120	3,411	19,320	11,263	14,640	17,844	66,478	
H106	change	60	1,705	9,660	5,631	7,320	-	24,317	**405**
	Percentage change in total costs							**36.6**	
50 % increase		45	6,376	28,980	16,894	21,960	17,844	92,055	
	original	30	4,251	19,320	11,263	14,640	17,844	67,318	
H107	change	15	2,125	9,660	5,631	7,320	-	24,737	**1,649**
	Percentage change in total costs							**36.7**	

Table A4:2 Sensitivity analysis and computation of marginal costs of the PDA HMIS

Form Type/ 50 % increase in form		No. forms	Personnel cost	Office supply	Misce.	Transport	Capital cost	Total cost	Ratio
		1,980	621	10,534	13,008	-	31,932	56,095	
	original	1,320	414	7,023	8,672		31,932	48,041	
H033B	change	660	207	3,511	4,336	-	-	8,054	**12**
	Percentage change in total costs							**16.8**	
50 % increase form		522	3,690	10,534	13,008	-	31,932	59,164	
	original	348	2,460	7,023	8,672		31,932	50,087	
H105	change	174	1,230	3,511	4,336	-	-	9,077	**52**
	Percentage change in total costs							**18.1**	
50 % increase form		360	3,415	10,534	13,008	-	31,932	58,890	
	original	240	2,277	7,023	8,672		31,932	49,904	
H055B	change	120	1,138	3,511	4,336		-	8,986	**74.9**
	Percentage change in total costs							**18.0**	
50 % increase form		180	4,756	10,534	13,008	-	31,932	60,231	
	original	120	3,171	7,023	8,672		31,932	50,798	
H108	change	60	1,585	3,511	4,336	-	-	9,433	**157.2**
	Percentage change in total costs							**18.6**	
50 % increase form		180	4,375	10,534	13,008	-	31,932.0	59,850	
	original	120	2,917	7,023	8,672		31,932.0	50,544	
H106	change	60	1,458	3,511	4,336	-	-	9,306	**155.1**
	Percentage change in total costs							**18.4**	
50 % increase form		45	17,500	10,534	13,008	-	31,932	72,975	
	original	30	11,667	7,023	8,672		31,932	59,294	
H107	change	15	5,833	3,511	4,336	-	-	13,681.0	**912.1**
	Percentage change in total costs							**23.1**	

Table A4:3 Descriptive analysis of the qualitative indicators

	PDA		PAPER	
Accuracy of data	**Freq.**	**Percent**	**Freq.**	**Percent**
Data is always accurate and precise	22	75.9		
Always have problem with data accuracy	2	6.9	6	20.7
Often there are problem with data accuracy	5	17.2	23	79.3
Total	**29**	**100**	**29**	**100**
Timeliness of data	**Freq.**	**Percent**	**Freq.**	**Percent**
Reporting is always fast	18	62.1		
Reporting is sometimes fast	8	27.6	20	69
Reporting is rarely fast	3	10.3	9	31
Total	**29**	**100**	**29**	**100**
Completeness and reliability of data	**Freq.**	**Percent**	**Freq.**	**Percent**
Forms are always complete and reliable	24	82.8	5	17.2
Forms are always reported with missing information	1	3.5	5	17.3
Forms often miss relevant information	4	13.7	19	65.5
Total	**29**	**100**	**29**	**100**
Degree of conflict with usual activities	**Freq.**	**Percent**	**Freq.**	**Percent**
No problem with performing usual activities	11	37.9	7	24.14
Some problem with performing usual activities	17	58.6	14	48.3
Unable to perform usual activities	1	3.5	8	27.6
Total	**29**	**100**	**29**	**100**
Need of additional training	**Freq.**	**Percent**	**Freq.**	**Percent**
Forms are very easy to fill in	4	13.8	18	62.1
Sometimes there is a need for assistance in filling forms	4	13.8	11	37.9
There is a strong need for technical assistance /advanced skills	21	72.4		
Total	**29**	**100**	**29**	**100**
Supervision	**Freq.**	**Percent**	**Freq.**	**Percent**
Supervision process is easier under this HMIS	2	6.9	18	62.1
Sometimes supervision is deficient	18	62.1	11	37.9
There is almost inefficient supervision in this HMIS	9	31.03		
Total	**29**	**100**	**29**	**100**
Prestige	**Freq.**	**Percent**	**Freq.**	**Percent**
The nature of the HMIS system is very prestigious at all	10	34.5		
The HMIS system is reasonable	18	62.1	8	27.6
The nature of the HMIS system is not prestigious	1	3.5	21	72.4
Total	**29**	**100**	**29**	**100**
Motivation	**Freq.**	**Percent**	**Freq.**	**Percent**
This HMIS is quite motivating	21	72.4	1	3.5
The system is reasonable	1	3.5	13	44.8
This system does not motivate staff to work on it at all	7	24.14	15	51.7
Total	**29**	**100**	**29**	**100**
Degree of safety and retrieval information	**Freq.**	**Percent**	**Freq.**	**Percent**
This HMIS ensure that health information is safe and can easily be retrieved	7	24.14		
The HMIS ensures reasonable safety but there may occur failures during retrieval	14	48.3	6	20.7
The HMIS does not ensure data safety & retrieval is always problematic	8	27.6	23	79.3
Total	29	100	29	100

Table A4:4. The multiplicative attributes of the PDA versus Paper HMIS

District	Accuracy		Timeliness		Completeness Reliability		Conflict		Training		Supervision		Prestige		Motivation		Retrieval	
HMIS	**PDA**	**Paper**	**PDA**	**Paper**	**PDA**	**Paper**	**PDA**	**Paper**	**PDA**	**Paper**	**PDA**	**Paper**	**PDA**	**Paper**	**PDA**	**Paper**	**PDA**	**Paper**
Mbale	1	0.95	0.95	0.86	0.86	0.86	0.95	0.95	0.85	0.95	1	1	1	0.95	0.86	0.86	0.86	0.86
Mbale	1	0.95	1	0.95	1	0.95	0.86	0.86	0.85	0.95	0.86	0.95	0.95	0.86	0.86	0.95	1	0.86
Mbale	1	0.95	1	0.95	1	0.95	1	0.95	0.95	1	1	0.95	0.95	0.86	1	0.95	1	0.86
Mbale	1	0.95	1	0.95	1	0.95	1	1	0.85	0.95	0.95	1	1	0.95	1	0.86	0.95	0.86
Mbale	1	0.95	1	0.95	1	0.95	1	1	1	1	0.95	0.95	1	0.95	1	0.95	0.86	0.95
Mbale	1	0.95	1	0.95	1	0.95	1	1	0.85	0.95	0.86	1	0.95	0.86	1	0.86	0.86	0.95
Mbale	1	0.95	1	0.95	1	0.95	1	1	0.95	1	0.95	0.95	1	0.95	1	0.95	1	0.86
Mbale	0.95	0.86	1	0.95	1	0.95	0.95	0.86	0.95	1	0.95	1	1	0.86	1	0.86	1	0.86
Mbale	1	0.95	1	0.95	1	0.95	0.95	0.86	0.85	1	0.95	0.95	0.95	0.86	1	0.95	1	0.86
Mbale	1	0.95	0.95	0.86	1	0.95	0.95	0.86	0.85	0.95	0.86	1	0.95	0.86	0.86	0.86	0.86	0.86
Mbale	0.86	0.86	0.86	0.86	0.95	0.86	0.95	0.86	0.85	1	0.95	1	0.86	0.86	0.86	0.95	0.86	0.86
Mbale	1	0.95	1	0.95	0.95	0.86	0.95	0.95	0.85	0.95	0.95	1	0.95	0.86	0.86	0.86	1	0.95
Mbale	1	0.95	1	0.95	1	1	1	0.86	0.85	1	0.86	1	0.95	0.86	1	0.95	0.86	0.86
Mbale	1	0.95	1	0.95	1	0.95	1	0.86	0.85	1	0.95	0.95	0.95	0.86	1	0.95	0.95	0.95
Mbale	1	0.95	0.95	0.95	1	0.95	0.95	0.95	0.85	1	0.95	1	0.95	0.95	1	0.86	0.95	0.95
Mbale	0.86	0.86	0.95	0.86	1	1	0.95	0.95	0.95	1	0.95	1	0.95	0.86	1	0.95	0.95	0.86
Mbale	1	0.95	1	0.95	1	0.95	0.95	0.95	1	1	0.95	1	0.95	0.86	0.86	0.86	0.86	0.86
Mbale	0.95	0.86	0.95	0.95	1	0.95	0.95	0.95	0.85	0.95	0.86	0.95	1	0.95	1	0.95	0.95	0.86
Mbale	1	0.95	0.86	0.86	1	0.95	0.95	0.95	0.85	1	0.95	1	0.95	0.86	0.95	0.95	1	0.86
Mbale	1	0.95	0.86	0.86	0.95	0.86	0.95	0.95	0.85	1	0.95	1	1	0.86	1	0.86	0.95	0.86
Lyantonde	1	0.95	1	0.95	1	1	0.95	0.95	0.85	1	0.95	0.95	0.95	0.86	1	0.95	0.95	0.86
Lyantonde	1	0.95	1	0.95	1	0.95	0.95	0.95	0.85	0.95	0.95	1	0.95	0.86	1	0.95	0.95	0.86
Lyantonde	0.95	0.95	1	0.95	1	0.95	0.95	0.95	0.85	1	0.86	1	0.95	0.86	1	0.86	0.95	0.86
Lyantonde	1	0.95	1	0.95	1	1	1	1	0.85	0.95	0.95	1	1	0.86	1	0.86	0.95	0.86
Lyantonde	1	0.95	1	0.95	1	1	1	1	0.85	1	0.95	0.95	1	0.95	1	0.86	0.95	0.86
Lyantonde	1	0.95	1	0.95	1	0.95	1	1	0.85	0.95	0.86	1	1	0.95	1	0.86	0.95	0.95
Lyantonde	0.95	0.86	0.95	0.86	0.95	0.86	0.95	0.95	1	1	0.86	0.95	0.95	0.86	1	0.95	0.95	0.86
Lyantonde	0.95	0.86	0.95	0.86	1	0.95	0.95	0.95	0.85	0.95	0.95	1	0.95	0.86	1	0.86	0.86	0.86
Lyantonde	1	0.95	0.95	0.86	1	0.95	1	0.86	1	1	0.86	0.95	0.95	0.86	0.86	0.86	0.95	0.86

Table A4:5. Computation of the health utility index for the PDA and Paper HMIS

	PDA HMIS				PPAPER HMIS			
District	**Constant**	**Multiplicative factor measuring the weight of the level chosen by respondent**	**Model Error of the health utility index**	**Results**	**Constant**	**Multiplicative factor measuring the weight of the level chosen by respondent**	**Model Error of the health utility index**	**Results**
Mbale	1.25	0.49	0.25	0.36	1.25	0.45	0.25	0.31
Mbale	1.25	0.51	0.25	0.39	1.25	0.47	0.25	0.33
Mbale	1.25	0.90	0.25	0.88	1.25	0.54	0.25	0.43
Mbale	1.25	0.77	0.25	0.71	1.25	0.57	0.25	0.47
Mbale	1.25	0.82	0.25	0.77	1.25	0.70	0.25	0.62
Mbale	1.25	0.60	0.25	0.50	1.25	0.57	0.25	0.47
Mbale	1.25	0.90	0.25	0.88	1.25	0.63	0.25	0.54
Mbale	1.25	0.81	0.25	0.77	1.25	0.42	0.25	0.28
Mbale	1.25	0.73	0.25	0.66	1.25	0.49	0.25	0.37
Mbale	1.25	0.46	0.25	0.33	1.25	0.40	0.25	0.25
Mbale	1.25	0.34	0.25	0.18	1.25	0.38	0.25	0.23
Mbale	1.25	0.60	0.25	0.49	1.25	0.49	0.25	0.37
Mbale	1.25	0.60	0.25	0.50	1.25	0.55	0.25	0.43
Mbale	1.25	0.73	0.25	0.66	1.25	0.54	0.25	0.43
Mbale	1.25	0.66	0.25	0.57	1.25	0.63	0.25	0.54
Mbale	1.25	0.63	0.25	0.54	1.25	0.49	0.25	0.37
Mbale	1.25	0.63	0.25	0.54	1.25	0.52	0.25	0.40
Mbale	1.25	0.60	0.25	0.49	1.25	0.52	0.25	0.40
Mbale	1.25	0.60	0.25	0.49	1.25	0.52	0.25	0.40
Mbale	1.25	0.60	0.25	0.49	1.25	0.42	0.25	0.28
Lyantonde	1.25	0.69	0.25	0.62	1.25	0.57	0.25	0.47
Lyantonde	1.25	0.69	0.25	0.62	1.25	0.54	0.25	0.43
Lyantonde	1.25	0.60	0.25	0.49	1.25	0.52	0.25	0.40
Lyantonde	1.25	0.77	0.25	0.71	1.25	0.55	0.25	0.43
Lyantonde	1.25	0.77	0.25	0.71	1.25	0.60	0.25	0.50
Lyantonde	1.25	0.69	0.25	0.62	1.25	0.63	0.25	0.54
Lyantonde	1.25	0.63	0.25	0.54	1.25	0.40	0.25	0.25
Lyantonde	1.25	0.57	0.25	0.46	1.25	0.40	0.25	0.25
Lyantonde	1.25	0.63	0.25	0.54	1.25	0.40	0.25	0.25
Total for all health units				**16.51**	**Total for all health units**			**11.43**
Average for all units				**0.57**	**Average for all units**			**0.39**

Difference in the CER and qualitative indices

		Mean/standard errors	T value	P-value			Confidence interval	
				<0	!=	>0		
qualitative ratios	PDA	.5683 (0.2293)	t=7.496	=1.000	=0.000	0.000	.5092	.6293
	Paper	.3945 (0.0192)					.3552	.4338
CER H033B	PDA	36 (0.74)	t=2.565	=0.994	=0.013	=0.007	34.48	37.52
	Paper	49 (5.01)					38.73	59.27
CER H105	PDA	144 (7.24)	t=5.222	=1.000	=0.000	=0.000	129.2	158.8
	Paper	190 (5.01)					179.7	200.8
CER H055B	PDA	208 (10.24)	t=5.534	=1.000	=0.000	=0.000	194.7	221.3
	Paper	275 (6.49)					254.0	295.9
CER H108	PDA	423 (6.31)	t=11.287	=1.000	=0.000	=0.000	410.1	435.9
	Paper	588 (13.18)					560.9	615.0
CER H106	PDA	421 (10.58)	t=9.202	=1.000	=0.000	=0.000	533.8	574.2
	Paper	554 (9.84)					399.8	442.7
CER H107	PDA	1976 (106.96)	t=1.632	=0.946	=0.100	=0.050	1756	2195
	Paper	2244 (124.60)					1988	2499

Difference of means for personnel costs for unit of type of form

		Mean/standard errors	T value	P-value			Confidence interval	
				<0	!=	>0		
H033B	PDA	414 (2.599)	t=76.565	=1.000	=0.000	=0.000	408.7	419.3
	Paper	1383 (12.44)					1357	1408
H105	PDA	2460 (23.95)	t=58.842	=1.000	=0.000	=0.000	2410	2509
	Paper	5153 (38.99)					5073	5209
H055B	PDA	2277 (63.2)	t=5.378	=1.000	=0.000	=0.000	2149	2404
	Paper	2933 (104.9)					2718	3147
H108	PDA	3171 (56.82)	t=27.779	=1.000	=0.000	=0.000	3054	3287
	Paper	7546 (146.8)					7245	7846
H106	PDA	2917 (27.29)	t=9.09	=1.000	=0.000	=0.000	2861	2972
	Paper	3411 (46.9)					3314	3507
H107	PDA	11667 (292.6)	t=-23.31	=0.000	=0.000	=1.000	11067	12266
	Paper	4251 (124.6)					3995	4506

Difference of means for office supply

		Mean/standard errors	T value	P-value			Confidence interval	
				<0	!=	>0		
H033B	PDA	1406 (252.5)	t=1.972	=0.9733	=0.0535	=0.0267	888.9	1923
	Paper	2423 (449.8)					1502.2	3345

Difference of means for office supply

		Mean/standard errors	T value	P-value			Confidence interval	
				<0	!=	>0		
H033B	PDA	1487 (252)	t=-14.5	=0.000	=0.000	=1.000	2548	2772
	Paper	2660. (917)					1365	1608