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THE USE OF COMPUTERISED CLINICAL DECISION SUPPORT SYSTEM IN MATERNAL AND NEONATAL CARE IN RURAL AFRICA: ENTHUSIASM AND CONCERNS

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The use of computerised clinical decision support system in maternal and neonatal care in rural Africa: enthusiasm and concerns

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ABSTRACT

Background: Maternal and neonatal mortality rates remain high in sub-Saharan Africa. The shortage of skilled Healthcare Workers (HCWs) and poor access to guidelines are plausible reasons for the reported low quality in maternal and neonatal services in rural Africa. One strategy to support HCWs at point of care is to provide easy access to guidelines using computerised Clinical Decision Support Systems (CDSS). Still, data are lacking on how such systems are optimally designed and implemented to be useful for HCWs.

Aims: The aims were to develop a CDSS to be used in rural Africa (I), to understand perceived needs and attitudes among HCWs to the use of a CDSS based on the WHO guidelines in maternal and neonatal care in Burkina Faso (II), and to explore the reasons why the HCWs failed to use the CDSS as expected (III).

Methods: The CDSS was programmed in java software language to be able to run on any hardware (I). The CDSS was part of an intervention to improve quality of care in six rural healthcare facilities in Burkina Faso for 24 months. A total of 45 HCWs were interviewed to capture perceived needs and attitudes to the CDSS. Data were analysed with content analysis (II). To understand any reduced use of the CDSS a workshop was organised (group discussions and a plenary session) with 13 HCWs with data analysed thematically (III). Socio-demographic data were analysed descriptively (II-III).

Results: The CDSS was designed with a user interface and an XML database for storing patient data (signs and symptoms) as well as an algorithm to provide advice on recommended care and actions based on WHO guideline information. The CDSS was developed with limited input from HCWs (I). The HCWs expressed willingness to use new technologies such as a CDSS and computers but reported a fear of extra workload as well as a fear that the CDSS should be complicated to use (II). After 12 months, the decreased use of the CDSS was partly explained by unreliable power supply and poor fit between the CDSS and the daily workflow. Still, the HCWs were enthusiastic to learn more by using the CDSS (III).

Conclusions: The CDSS was successfully developed and tested in rural Burkina Faso. Despite this, its use was unexpectedly low. It was found that: 1. the design and the implementation of a CDSS have to be contextualised; 2. the usage of the CDSS and the software performance need to be continuously monitored and 3. the HCWs need to be actively consulted during all phases of design and testing of a CDSS to enhance its use.

Key words: Africa, Burkina Faso, Computerised Clinical Decision Support System, Healthcare Workers, Maternal Care, Neonatal Care, Qualitative Methods, Rural Area

LIST OF SCIENTIFIC PAPERS

This thesis is based on the following three papers, which will be referred to in the text by their roman numerals.

I. Blank A, Prytherch H, Kaltschmidt J, Krings A, Sukums F, Mensah N, **Zakane A**, Loukanova S, Gustafsson LL, Sauerborn R, Haefeli WE. "Quality of prenatal and maternal care: bridging the know-do gap"(QUALMAT study): an electronic clinical decision support system for rural Sub-Saharan Africa. BMC Med Inform Decis Mak 2013;13:44.

II. **Zakane SA**, Gustafsson LL, Tomson G, Loukanova S, Sié A, Nasiell J, Bastholm-Rahmner P. Guidelines for maternal and neonatal "point of care": needs of and attitudes towards a computerized clinical decision support system in rural Burkina Faso. IntJ Med Inf 2014:83:459-69.

III. **Zakane SA**, Gustafsson LL, Sie A, Tomson G, Loukanova S, Bastholm-Rahmner P. Opportunities and obstacles towards a clinical decision support system for maternal care in Burkina Faso. Online J Public Health Inform 2017;9:7905.

CONTENTS

LIST OF ABBREVIATIONS

ANC	AnteNatal Care
CDSS	Clinical Decision Support System
CRSN	Centre de Recherche en Santé de Nouna
DHIS	District Health Information System
eTG	electronic Therapeutic Guideline
EU	European Union
FP	Family Planning
GA	Genetic Algorithm
HCW	Healthcare Worker
HIV	Human Immunodeficiency Virus
IBM	International Business Machines corporation
ICT	Information Communication Technology
ICT4D	Information Communication Technology for Development
IeDA	Integrated electronic Diagnosis Approach
KB	Knowledge Based
mHealth	mobile Health
nKB	Non Knowledge Based
PBF	Performance Based Financing
PBI	Performance Based Incentive
PDF	Portable Document Format
QUALMAT	QUAlity of MATernal care
REC	Registre Electronique de Consultation
SMS	Short Message Service
SSA	Sub Saharan Africa
TAM	Technology Acceptance Model
UCD	User-Centered Design
WHO	World Health Organisation
XML	eXtensible Markup Language

Key definitions and explanations

Concerns: Any fear or worry that results from the use of the computerised decision support systems (CDSS) during the implementation phase among healthcare workers (HCWs).

Enthusiasm: Any feeling or interest derived from the use or implementation of the CDSS among HCWs. Great and intense enjoyment to use the CDSS.

Healthcare Workers (HCWs): Healthcare workers are also called healthcare providers. They provide healthcare services to people in a preventive or curative way. In my thesis, nurses, midwives, nurse assistants and midwife assistants at the primary healthcare facilities are defined as HCWs.

Needs: Essential requirement or prerequisite expressed by HCWs regarding the CDSS design, implementation and use in rural healthcare facilities.

1 BACKGROUND

1.1 PROBLEMS WITH THE QUALITY OF MATERNAL AND NEONATAL CARE IN SUB SAHARAN AFRICA AND IN RURAL BURKINA FASO

1.1.1 Maternal and neonatal mortality

Maternal mortality due to pregnancy or childbirth decreased globally from 1990 to 2015 [1,2]. Despite this, maternal mortality is still high in Sub-Saharan Africa (SSA) with more than 300 000 women dying annually due to pregnancy related complications. In SSA, the maternal mortality remains as high as 546 deaths per 100 000 pregnancies, and neonatal mortality is 27 per 1000 newborns [1,2]. This is despite neonatal mortality rate falling from 36 deaths per 1000 live births in 1990 to 19 in 2015. Most deaths are due to infectious diseases and neonatal complications [2].

In Burkina Faso, the neonatal and maternal mortality is as high as 27 per 1000 newborns and 400 per 100 000 pregnancies, respectively [1,2]. These deaths could be prevented and treatable with enough skilled healthcare workers (HCWs), proven cost-effective and quality delivered care and with access to basic lifesaving procedures, medicines, blood and other commodities [2].

1.1.2 Lack of skilled healthcare workers

In SSA, the shortage of HCWs are affecting the quality and access of rural healthcare services. WHO has estimated that SSA is the most affected continent with respect to shortages of HCWs. To improve availability and quality of healthcare services in SSA, additional funds are needed in addition to more and better trained HCWs [3]. The shortage of HCWs in SSA is due to many reasons including international migration and career changes [3]. Many African countries have less than 1 HCW per 1000 inhabitants and the whole WHO Africa region has 1.9 HCWs per 1000 inhabitants. This compares with the WHO region of America where in 2009 the number of HCWs were 7.8 per 1000 inhabitants [3–6].

1.1.3 Motivation among healthcare workers

In Burkina Faso, rural healthcare facilities are mainly managed by nurses, nurse assistants and midwife assistants, with occasional access to midwives, physicians or obstetricians (See section 3.2.1). It is well known that skilled and educated HCWs provide high quality maternal and neonatal care [1]. However, unequal distribution of the HCWs in rural and

urban area is a real concern since few HCWs are willing to serve in rural areas due to poor working conditions [4,5,7–9]. Good performance in work is mostly associated with skills and training. HCWs often do less than they are capable of doing due to concerns with motivation as well as shortages of lifesaving supplies and resources [9–11]. Many different types of interventions have been used to increase the motivation of HCWs, thereby helping them to use their knowledge and resources effectively [9–11]. Following Performance-Based Financing (PBF) research in Rwanda and Burundi [8], these countries experienced improved quality of services. In Burundi with PBF, institutional deliveries increased while Antenatal Care (ANC) and tetanus vaccination didn't show any improvement [12]. Another strategy to improve the situation is to support HCWs with knowledge-based CDSS containing for example therapeutic guidelines (eTG) at point of care [13–16]. When there is lack of skilled HCWs, this is a potential way to increase the knowledge of HCWs and their subsequent care [13–16].

1.2 POTENTIAL BENEFITS OF CLINICAL DECISION SUPPORT SYSTEMS (CDSS) AND INFORMATION COMMUNICATION TECHNOLOGY (ICT) IN AFRICA

A study undertaken in Burkina Faso, Ghana and Tanzania, showed that paper-based guidelines are absent or less used by HCWs in rural healthcare facilities [17]. To scale up the use of guidelines and thereby impact on the HCWs skills, one strategy in rural Africa is to provide easy access to guidelines and information at "point-of-care" by using a CDSS or ICT [18–23]. CDSS has been suggested to ensure correct decisions by prompt availability of updated guidelines if presented in a pedagogic manner for optimal daily care as well as for continuous medical education [13,14,17–19]. In Africa currently there are scanty experiences in the use of CDSS or ICT [13,18–20,22–24] in healthcare services. While there is rapid development of mobile telecommunication infrastructure and use in Africa, ICT projects remain few and challenging [22–24]. Most ICT projects have been applying SMS services using mobile phones when supporting maternal or HIV patient care [13,20,24–31] or for drug prescribing [24,32]. In Burkina Faso, a project for Integrated electronic Diagnosis Approach (IeDA) for the management of childhood illnesses started in 2014 using computers and tablets in two regions of Burkina Faso [33]. Today this use of IeDA is being undertaken in 606 healthcare facilities in the country. However, Africa lags behind other world regions in testing mobile health (mHealth) solutions and implementing them in a sustainable way in rural healthcare settings [24,29,30].

1.3 THE DIFFERENCE BETWEEN KNOWLEDGE BASED CDSS AND NON KNOWLEDGE BASED CDSS

CDSS, as a tool to improve healthcare quality by positively influencing HCWs decisions, can incorporate two different types; Knowledge Based (KB) building on evidence or non Knowledge Based (nKB) CDSS [34] using mostly information over internet. The differences between these two types of CDSS include.

1) A knowledge based (KB) CDSS:

Knowledge based CDSS is the most used approach in healthcare today and contains three parts [34]:

- Recommendations from experts including rules to follow. It could be a guideline for maternal and neonatal care (like the system described in this thesis) or a recommendation for a specific drug to be prescribed for a disease (like the Janus decision support system [35,36]).
- An algorithm that is mostly based on probability principles. An algorithm applies knowledge and the HCW submits patient related data (signs and symptoms) such as fever, weight or age as well as patient medical record data from laboratory, pharmacy or other clinical services to guide in selection of treatment options.
- A user interface: after submitting data, the CDSS can display the advice or alert for the HCW to make a decision. At this stage, it is only a suggestion and the HCW is free to accept or ignore the recommendations given by the CDSS. An advanced user or local software review committees, through the programmer interface, should be able to modify and update the knowledge or the recommendations to keep the CDSS to avoid obsolete knowledge, problem or harm when using it.

2) A non knowledge based (nKB) CDSS:

This type of CDSS is supported by artificial intelligence or by using learning-machine approaches in the algorithms. The Watson program developed by IBM is an example of using this approach [37]. This means that the CDSS learns and modifies its contents of decision by experience based on examples and through searching into the Internet. The algorithm takes a major part in this type of CDSS through Bayes' rules using complex joint probabilities. The algorithm is based on Bayesian probability to make a decision for more than one symptom (5

to 6 symptoms) that may occur with a patient. The next time, the algorithm of the CDSS will learn from previous decisions before making another one. This type of CDSS is used by Genetic Algorithms (GA) that is a bio-inspired solution based on natural selection (molecular rearrangement of chromosomes and genes). The GA select randomly the parents in the population and suggest what potential children they can have [34,38]. In neural networks, the nKB CDSS is also used [34]. This type of CDSS is mostly used by physicians as post-diagnostic tools to broaden and complete or correct their diagnosis.

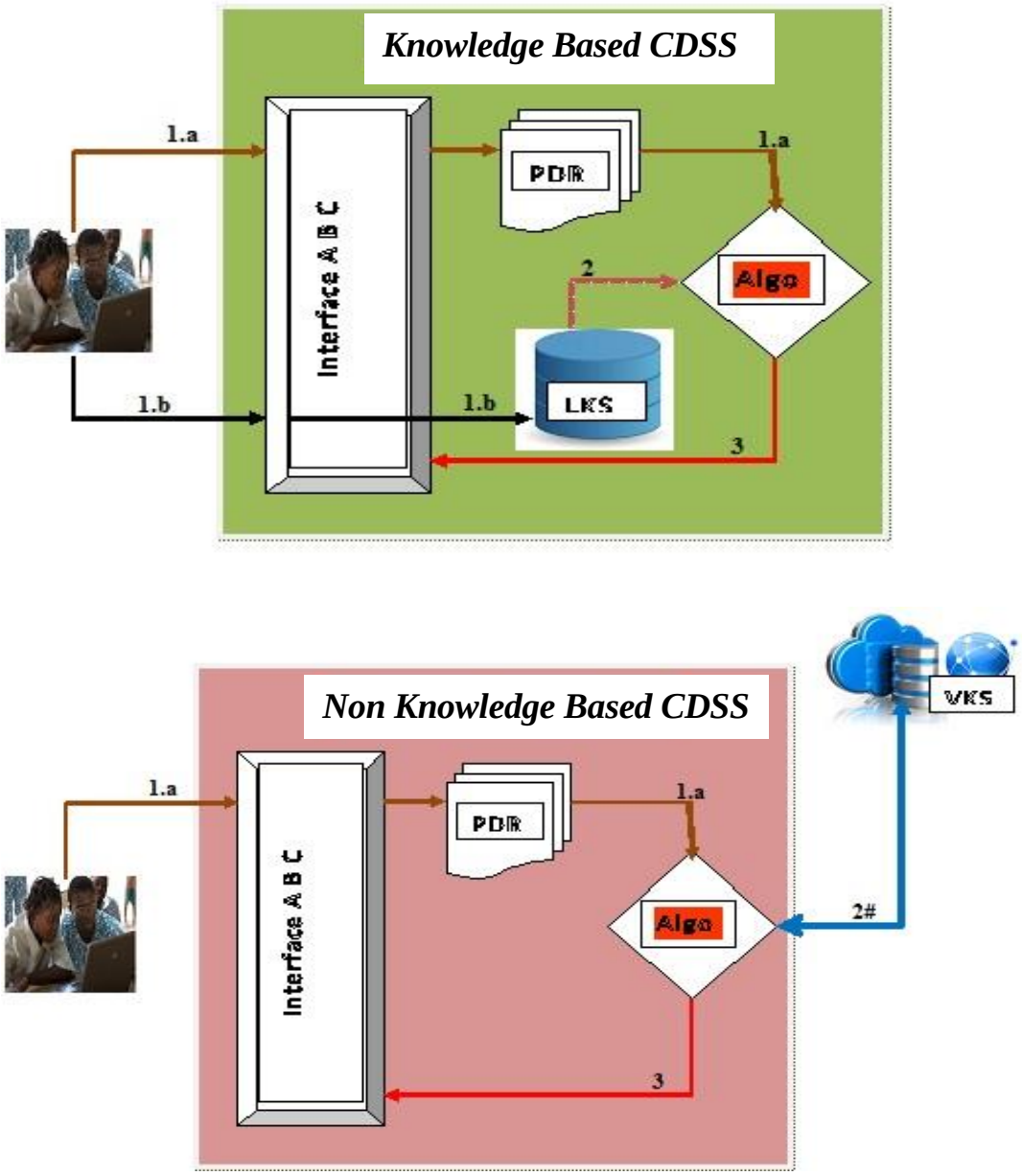

Figure 1: Simplified overview of Knowledge Based CDSS versus Non Knowledge Based CDSS.

Legend:

Algo: Algorithm; **LKS:** Local Knowledge Source; **PDR:** Patient medical Data Record; **VKS:** Various Knowledge Source specially from Internet

Explanations:

User or programmer Interfaces A B C: the interface can be different depending on what the user or the super-user or the programmer wants to do. (A) For patient input data **(flow 1.a)**. (B) Output data from the CDSS regarding the decision to be taken, like diagnosis, prescribing, or alerts **(flow 3).** (C) This is a programmer interface for maintenance and updating of the knowledge (Guidelines); this is only for the knowledge based CDSS **(flow 1.b).**

PDR: Patient data medical record in electronic form in a local computer or restricted communications network (intranet)

LKS: Local knowledge source, mostly a guideline or recommendations. This is locally saved on the computer or on the intranet. Only applicable for the knowledge-based CDSS

Algo: Algorithm, for the knowledge based CDSS, this algorithm uses patient data directly at the Point of Care or from **PDR (flow 1.b**), combining patient data with the knowledge (guidelines) **(flow 2)** to make the decision **(flow 3).** On the non knowledge based CDSS, the algorithm is based on Bayesian probability and uses knowledge from various sources from the Internet or other databases **(flow 2#).**

VKS: Various knowledge sources through mostly Internet searches.

The QUALMAT CDSS is a knowledge based CDSS. However, it was not possible to update the content of the knowledge. This option was not allowed during the programming of the software.

1.4 THE QUALMAT CDSS PROJECT IN BURKINA FASO

1.4.1 The QUALMAT consortium

The QUALMAT (QUAlity of pre-natal and MATernal care: Bridging the know-do gap) project is an attempt to achieve the Millennium Development Goals (MDGs) for maternal care. With lack of qualified HCWs with low motivation, the QUALMAT project aimed to reduce the "know-do gap" that represented insufficient translation of knowledge about best care into practice. The general objective of this research was to improve maternal health care through better pre-natal and maternal care services offered by better motivated HCWs in rural districts of the three African countries Burkina Faso, Ghana and Tanzania. To accomplish this objective, two interventions were carried out: **(a)** The provision of knowledge at the point of

care using a technological innovation (CDSS) to improve the quality of care and **(b)** The introduction of a performance based incentive (PBI) package to impact the quality of care by increasing the level of motivation of the HCWs.

The QUALMAT project (www.qualmat.net) was financed by the EU within the 7th Framework program from 2009 to 2014 and included experienced partners from East, West Africa and Europe [14,21,39–45]:

- Senior researchers from Germany (Heidelberg University) with experience in developing and introducing CDSS systems and with extensive public health research and practice expertise and experience from Africa and Asia.
- Senior researchers from Sweden (Karolinska Institutet) with experience in health systems research, in CDSS design and implementation as well as to evaluate ICT services to improve health care in Sweden and Africa.
- Senior researchers from Belgium (Ghent University) with experience in maternal and obstetrics care in rural Africa.
- Three African patners from East (Tanzania) and West (Ghana and Burkina Faso) with experience of health research in rural Africa and runing demographic surveillance systems.

Based on this expertise, the QUALMAT project from June 2009 to April 2014 built and organised the use of a CDSS for 18 rural maternal healthcare services in Burkina Faso, Ghana and Tanzania as a pilot testing.

1.4.2 My role in the QUALMAT project in Burkina Faso

As a computer scientist, I was involved with the QUALMAT project and was close to the activities with the CDSS. In the Burkina Faso QUALMAT team I also helped with other activities like “Economic evaluation” of the QUALMAT healthcare facilities where I built the Database for Burkina Faso, Ghana and Tanzania. I managed Burkina Faso data for the “Quality of care analysis assessments” and for the “Performance Based Incentive”. In the three studies presented in this thesis my roles were:

Study I:

I was responsible for the baseline assessments of the availability of technical infrastructure (mobile phone network coverage, electricity assessment) in the healthcare facilities. I assisted also the technical consultant for the installation of the solar panel equipments at all healthcare

facilities identified for testing the CDSS. I have organised and conducted with the district medical officer in Nouna (co-trainer) the training in Burkina Faso of the HCWs on how to use the computer for three days, and later on how to use the CDSS for three days. I translated the CDSS from English into French together with the co-trainer, the district medical officer in Nouna. I was responsible to upload and upgrade the different versions (prototypes and final version) of the CDSS on the laptop used at the various healthcare facilities. I collected each month the encrypted CDSS data from the healthcare facilities laptop using memory sticks for sending them to the QUALMAT server based in Germany. I supervised the support to users of the CDSS each month, and I was in charge of maintenance of the CDSS software and the hardware used by the healthcare facilities. I was not directly part of the programming of the software but I helped to send feedback from the HCWs during the different stages of the prototyping of the CDSS. During the training we received in Heidelberg (Train the trainers meetings) together with the district medical officer of Nouna, we gave our opinion and suggestions on the design and implementation of the CDSS to the developer and his team.

Study II:

I designed Study II with the support of my supervisors. I wrote the Ethical protocol of the study and I submitted it to the Nouna Institutional Review Board. I wrote the interview guide and I tested it with two HCWs before instigation. I carried out all the interviews with the participants in French face to face at the 12 healthcare facilities in Burkina Faso. I transcribed the interviews and translated them into English. I made the analysis with the support of my supervisor Pia Bastholm-Rahmner with input from the other supervisors.

Study III:

I designed Study III with input from my supervisors when we were discussing if the Technology Acceptance Model can be used in our project to understand the use and attitudes to the CDSS. I conducted the workshop with the support of my social scientist colleague in the Burkina Faso QUALMAT team. I transcribed and translated the data into English. I made the analysis with the support of my supervisor Pia Bastholm-Rahmner with input from the other supervisors.

2 AIMS

2.1 GENERAL AIM

The aim of this thesis is to increase the knowledge about barriers and opportunities involved with the use of a CDSS in maternal and neonatal care in rural Burkina Faso.

2.2 SPECIFIC AIMS

The specific aims are:

1. To develop a knowledge-based CDSS for rural maternal care, delivery and post delivery and neonatal care (I).

2. To explore and describe perceived needs and attitudes among HCWs to access WHO guidelines using CDSS in maternal and neonatal care in rural Burkina Faso (II).

3. To explore the reasons and explanations why the HCWsfailed to use the CDSS on a regular basis (III).

3 OVERALL DESIGN OF STUDIES

All practical parts of the studies were carried out during the QUALMAT research project lasting from June 2009 to April2014. The overview and timelines of the different three studies (I-III) are described below. The use of the CDSS started in May 2012 with prototype 3, but the final version of the CDSS did not arrived until May 2013. The use ended in April 2014.

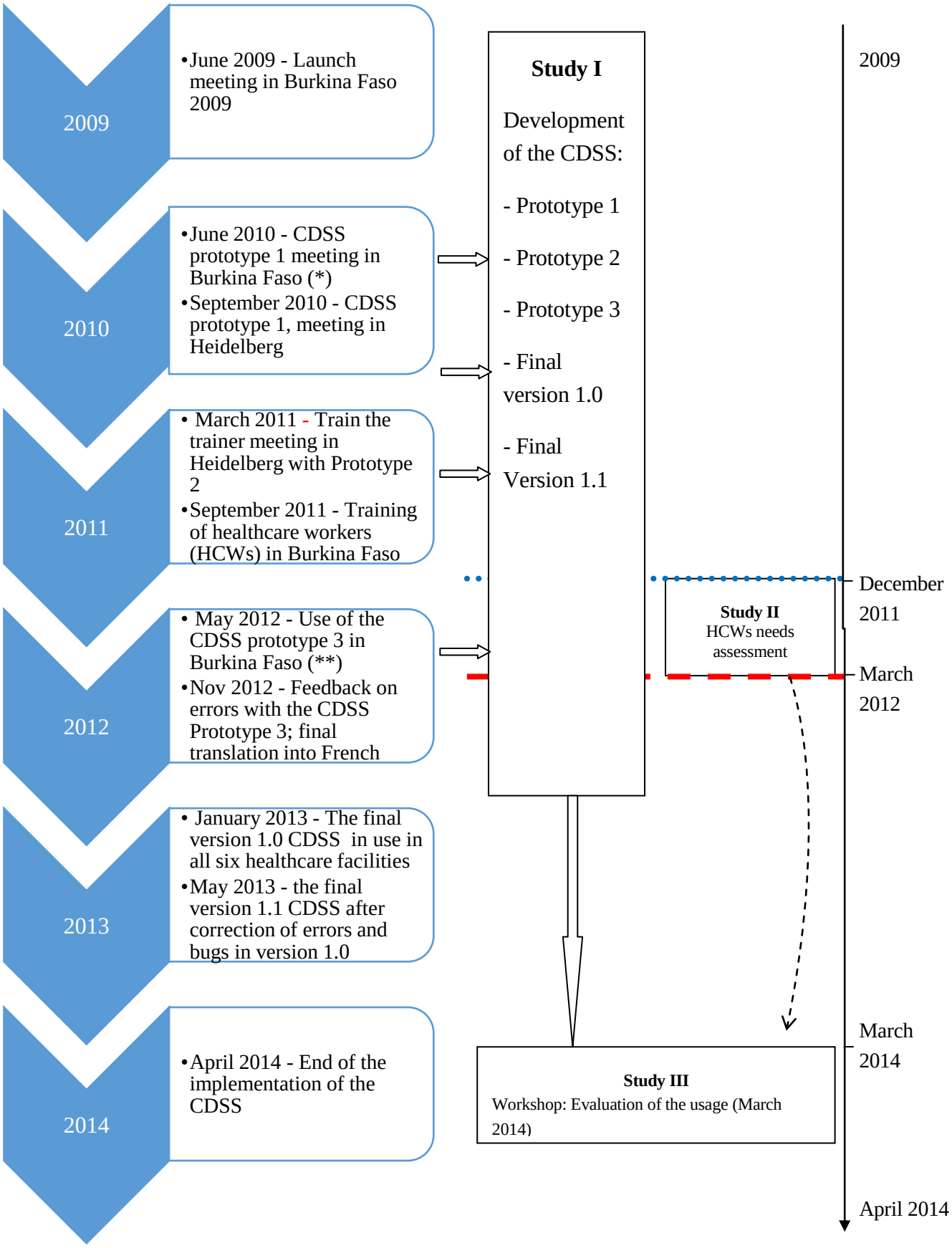

Figure2: Project overview. Development and implementation of the CDSS, including needs assessment and usage evaluation phases. *(*) at the same time prototype 1 was demonstrated for users in Ghana and for users at two healthcare facilities in Burkina Faso for 2 hours.(**) the use of the CDSS (prototype 3) started in May 2012 in six healthcare facilities in Burkina Faso and ended in April 2014.*

4 METHODS AND DATA COLLECTION

To accomplish the overall aim of the thesis, both quantitative and qualitative data were used. Study I is a description of the CDSS concept and how it was designed and built. Study II explored the HCWs needs and attitudes to the CDSS in their context. Study III aimed to obtain knowledge on why the HCWs did not use the CDSS in clinical practice as expected if pertinent. Study III was initiated as we found from the logfiles that HCWs reduced their use of the CDSS after one year.

In studies II and III, a qualitative approach was chosen since this is a way to get deeper understanding of how people think of a CDSS within their specific working context [46] to provide direction for the future. The design, settings, number of participants, data collection and methods for analysis of the results are summarised in Table 1.

Table 1: Overview of the design, study settings, number of participants, methods for data collection and analysis for studies I-III.

Study (data collection, design period)	**Design**	**Setting**	**Number of participants**	**Data collection**	**Data analysis**
I (from June 2009 to December 2012)	Description of the conceptual design of the CDSS software: • Type of CDSS • Guideline used • Algorithm • Different prototypes	• Burkina Faso • Ghana • Tanzania	-	-	-
II (December 2011 to March 2012)	Qualitative	In Burkina Faso: • Six healthcare facilities in Nouna Health District • Six healthcare facilities in Solenzo Health District	45	Semi-structured interviews face to face	Inductive content analysis [47]
III (March 2014)	Qualitative	In Burkina Faso: six healthcare facilities at Nouna Health district, district that implemented the CDSS	13	Workshop: group discussion and plenary session	Thematic analysis [46]

4.1 MAP OF THE STUDY SETTINGS

Burkina Faso is a landlocked Sub Saharan country located in West Africa surrounded by Mali to the north, Niger to the east, Benin to the southeast, Togo and Ghana in the south and Ivory Coast to the southwest (Figure 3, map 1). In 2015, Burkina Faso had a population of 17.9 million with 63 health districts, 1, 698 public healthcare facilities and 47 district hospitals [48]. The QUALMAT project selected Nouna health district that is well served with HCWs and Solenzo health district with approximately the same population but with lower number of HCWs and less equipment as its study and control areas (Table 2). In 2015 the Solenzo district had high referral rates for obstetrical complications from healthcare facilities and higher rates of maternal mortality and neonatal deaths as compared to Nouna health district (Table 3) [48].

Table 2: Number of HCWs in Nouna and Solenzo health districts in 2015 [48]

	Population	**Healthcare facilities**	**Physicians**	**Midwives**	**Midwife-assistants**	**Nurses**	**Nurse-assistants**
Nouna Health District	349 000	47	8	46	45	113	43
Solenzo Health District	342 000	34	1	24	37	85	35

Table 3: Maternal and neonatal morbidity and mortality in Nouna and Solenzo health districts in 2015 [48]

	Births	**Stillbirths**	**Neonatal deaths**	**Maternal mortality rate**	**Pregnant women**	**Pregnant women referred to the district hospital**	**Obstetrical complications referred to the district hospital**	**Obstetrical complications referred to high level hospital***
Nouna Health District	15 072	371	39	63	20 173	276	511	480
Solenzo Health District	13 853	235	42	144	19771	78	792	283

** =high level hospital. It can be a regional hospital in Dédougou or University hospitals in Ouagadougou or in Bobo-Dioulasso*

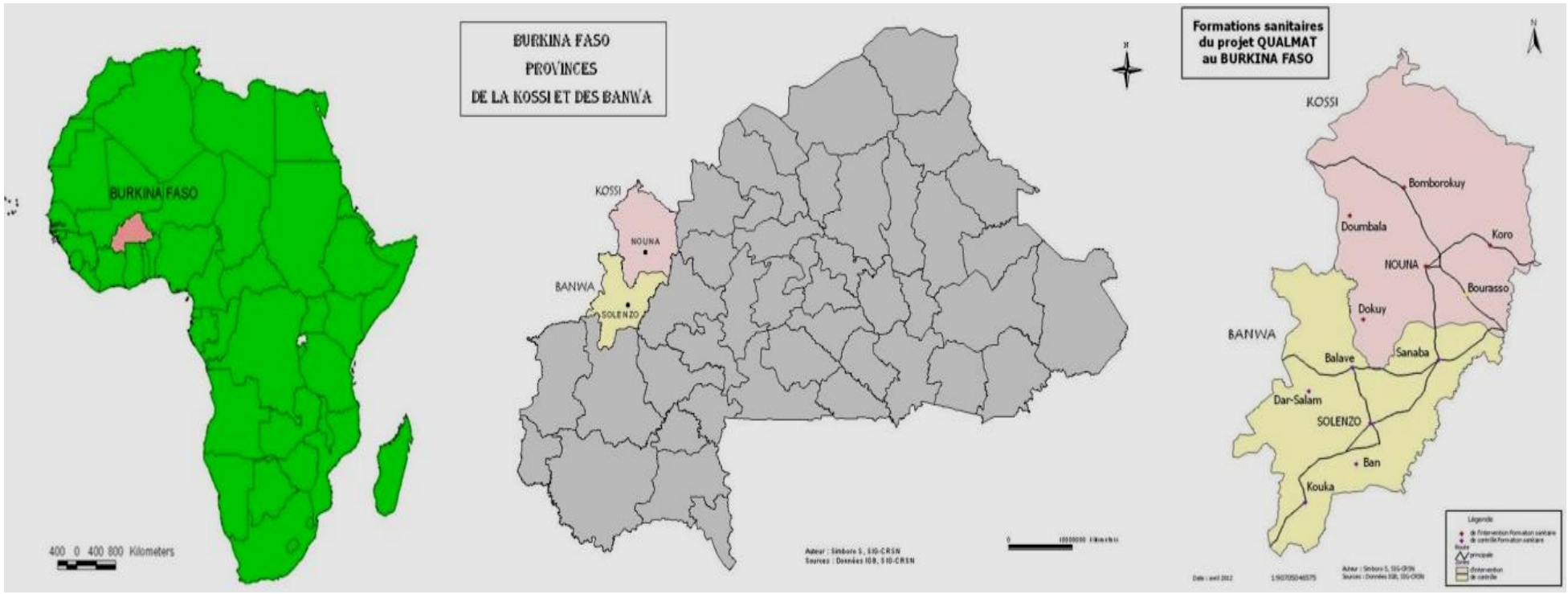

Figure 3: Map1 (left) - Africa and Burkina- Faso in Western part of Africa.

Map2 (middle) –Location of Nouna (pink) and Solenzo (yellow) health districts in Burkina Faso

Map3 (right) - The twelve healthcare facilities in Nouna (pink) and Solenzo (yellow) health districts

From Nouna Health Research Centre – Geographic Information Systems Division, 2012

4.2 SELECTION OF HEALTHCARE FACILITIES IN THE QUALMAT PROJECT

The QUALMAT project chose two districts for the intervention; one better equipped health district, i.e. Nouna, and one poorer health district, i.e. Solenzo. These two health districts have approximately the same populations but differ regarding the number of staffs (Table 2). The district of Nouna was chosen as the intervention district because it is located where the Centre de Recherche en Santé de Nouna (CRSN) is located and conduct health research in Burkina Faso. The selection of the healthcare facilities from the districts was undertaken in two phases using purposive sampling. Firstly, the healthcare facilities had to fulfill minimum standard in terms of human resources with at least one nurse and either one midwife or one midwife-assistant. Secondly, it was required that the healthcare facilities had an infrastructure with a dispensary unit, a maternity unit and had access to standard equipment for primary care as well as uncomplicated basic maternal and neonatal care. A total of 34 out of 47 healthcare facilities in Nouna health district and 29 out of 34 healthcare facilities in Solenzo health district fulfilled these criteria. In addition for Burkina Faso, the QUALMAT project decided that one facility should be chosen at the capital of the healthcare district because primary healthcare facilities at the centre of the district have more staff compared to other facilities. Consequently, randomly five healthcare facilities were selected from these 33 healthcare facilities in the Nouna health district and five healthcare facilities from the 28 healthcare facilities in the Solenzo health district (Figure 3, map 3).

4.3 STUDY SETTINGS AND PARTICIPANTS IN THE STUDIES

4.3.1 Study I - Development of the CDSS

Study I is a conceptual and methodological study describing how the CDSS was designed, built, tested and which concept was used. The QUALMAT CDSS used a stand-alone software for maternal care, delivery and neonatal care. The CDSS was built in Java and had four parts [14]:

- User interface
- Database in XML to store patient data
- Algorithms using a WHO guideline for maternal care "*Pregnancy, childbirth, postpartum and newborn care: a guide for essential practice*"
- Information documents for reading

The development phase (Figure 1) included three versions of the prototype CDSS. First, after the project launch meeting in June 2009 in Ouagadougou, in June 2010, the local QUALMAT teams (IT support as well) in the three African countries received a presentation of the 1st prototype CDSS. At the same time, in Burkina Faso, computer illiterate HCWs also received a presentation of the first prototype. Later in September 2010, this first prototype was also presented during a meeting in Heidelberg to representatives from all QUALMAT countries. In March 2011, IT representatives and maternal care experts from Burkina Faso, Ghana, and Tanzania, undertook three days training using the second prototype in Heidelberg. During this training, some comments and recommendations were given by trainees for revision of the second prototype version. In September 2011, all HCWs from the six healthcare facilities in Nouna health district received training on how to use the CDSS (second prototype, partly translated into French). In May 2012, the HCWs started to use the final version of the CDSS (third prototype partly translated into French). During this time, the French translation of the CDSS was ongoing. All countries sent feedback reports in November 2012. The feedback from the different countries regarding the CDSS was not based on formal questionnaires. Mainly errors and bugs were reported by HCWs and suggestions for improvement. In Burkina Faso, the complete French translation was sent to the Heidelberg team in December 2012, and in January 2013 we received the final CDSS. However, due to bugs and some errors in the system, it had to be updated in May 2013.

4.3.2 Study II - Needs of the CDSS and attitudes to innovative techniques in rural Burkina Faso

In order to obtain deeper knowledge about HCWs needs of a CDSS, the focus was on midwives, midwife-assistants, nurses, and nurse assistants (referred to as HCWs) who were the intended users of the system (Table 2, paper II). The study was conducted in 12 primary healthcare facilities from the two districts of Solenzo (six healthcare facilities) and Nouna (six healthcare facilities) in Burkina Faso (Figure 3). The participants were selected from a list provided by the District Medical Officers in Nouna and Solenzo with the inclusion criteria being *"working in a maternity unit in a local healthcare facility".* During the data collection,45 out of 49 HCWs were interviewed (in Nouna 23 out of 26 and in Solenzo 22 out of 23) since four HCWs were absent on sick leave or vacation. Of the interviewed HCWs, 16 were men and 29 were women. In Nouna 11, and in Solenzo 14, were midwife assistants (Table 2, paper II).

4.3.3 Study III - Assessment of the use of the CDSS

The implementation of CDSS started in May 2012 (Figure 2) in six rural healthcare facilities in Nouna Health District with 26 HCWs [21]. After 23 months, 12 HCWs were still working in facilities using the CDSS. All these were invited to take part in the workshop. Only one user declined to participate due to a busy working schedule. The inclusion criteria for the HCWs to participate in the workshop were that they had used the CDSS or had received training in on how to use the CDSS. We also invited two managers at the Nouna Health District in charge of monitoring the healthcare facilities (one male midwife and one male nurse specialised in obstetric care) They were invited to give their external view on the utilisation of the CDSS during the study period. In total 13 participants from six healthcare facilities participated in the workshop, 6 men and 7 women. Six (6) of the participants were midwife assistants with 4 to 15 years of experience in maternal care (Table 2, paper III).

4.4 DATA COLLECTION

4.4.1 Study II – Needs of the CDSS and attitudes to innovative techniques in rural Burkina Faso

Individual semi-structured interviews were performed with 45 HCWs in 2012 before they had started to use the CDSS. The semi-structured interview was preferred as this has a certain degree of structure that permits change in the order of the questions or to reformulate them to reach a better understanding or facilitate the clarification needed [46]. A semi-structured interview guide was developed and pilot tested on two HCWs working in rural facilities in the Nouna district to check for clarity of the questions. Three broad questions were asked in the interview:

1. What is your daily or routine work in maternal and neonatal care?
2. What do you find difficult or tricky with your work? How are you managing these difficulties?
3. What is your opinion about the value of access to electronic guidelines and CDSS in maternal care in your healthcare unit?

All participants were asked by phone if they wanted to participate in an interview. During the phone call, the respondents were informed that they could withdraw at any moment of the interview. They had also the possibility to stop the interview or to interrupt it and continue later if they had to see a patient or had other urgent matters to carry out.

All interviews were performed face-to-face in the informant's workplace by S Alphonse Zakane (SAZ). The interviews were in French and lasted for approximately 40 minutes each. Prior to the interview, the informants from Nouna received training in computer use as well as a demonstration of the CDSS for three days. In Solenzo health district, each participant was informed about the QUALMAT project and the CDSS for 15 to 30 minutes before starting the interview. The reason for interviewing HCWs from Solenzo was to see if there were any differences between the two groups in perceived needs and attitudes to computerised tools.

The interviews were audio-recorded and transcribed verbatim in French and translated into English. Before each interview, socio-demographics questions on informants' characteristics were asked including their education, work experience and type of work they were undertaking (Table 2, paper II).

4.4.2 Study III – Assessment of the use of the CDSS

After 23 months of the implementation of the CDSS (March 2014, Figure 2), we saw from the log files a decreasing use of the CDSS. It started already after one year (Table 1, paper III). Consequently, we invited the HCWs to a workshop with the aim of understanding the reasons of this. A workshop was defined as a group discussion where the participants explore their own statements in small groups and in a concluding plenary session [27,49]. The workshop method was preferred since we thought it was easier for the HCWs to explore the reasons why they have reduced their use of the CDSS in group discussions. Within the group discussions, they could help each other to remember and to clarify different views [50]. In total, 13 participants took part in the workshop discussion (March 2014). The discussion was conducted in French and was carried out at the research centre in Nouna. Two researchers were present during the workshop, one researcher from the social science part of the Burkina Faso QUALMAT team acted as a moderator (MK) and one computer scientist taking notes (SAZ). The data collection had three parts and lasted in total for approximately 4 hours.

a. After the explanation of the aim of the workshop, all participants answered a socio-demographic questionnaire. The questionnaire contained eight questions on sex, education, experience of maternal care, specialisation and usage patterns of the CDSS such as *have you used the CDSS and frequency of use* (Table 2 and 3, paper III).

b. In the next step, we allowed the participantsto discuss in small groups with three to five participants from different healthcare facilities in each group

(three groups in total). In each group, there were at least one midwife or one midwife assistant and one nurse or one nurse assistant. All groups were given guiding questions as for example: *What is your overall impression about the CDSS? What is your experience with the partograph? What is your experience about the overall implementation, education and training with the utilisation of the CDSS?* (See discussion guide, Table 2, paper III). Each group chose a moderator who made a written report of their answers to the questions. The group discussion lasted for 90 minutes.

c. The last part of the workshop was a plenary session during which all group reports were projected on a screen. All participants were free to comment, discuss and agree or disagree with what was projected. When needed, the moderator of the workshop (MK) asked for clarification. The session lasted for two hours. All participants agreed that the session could be audio recorded. The data was transcribed verbatim in French and later translated into English.

4.5 DATA ANALYSIS

4.5.1 Quantitative data analysis: Study II-III

The questionnaires were analysed using descriptive statistics (frequency and central tendency trends) by the Epi Info Windows software version 3.5.1 (Epi Info™, made available in the public domain by the Centre for Disease Control (CDC), Atlanta US).

4.5.2 Qualitative data analysis: Study II – Needs of the CDSS and attitudes to innovative techniques in rural Burkina Faso

The transcripts were analysed using a qualitative manifest content analysis as outlined by Graneheim and Lundman [47]. The analysis includes multiple steps. The transcripts were read several times to acquire a good grasp of the whole material. Subsequently, the text was sorted to identify relevant meaning units, i.e., informants' responses to the aim of the study (Table 4, paper II). In the next step, the meaning units were condensed. The condensed meaning units were then coded as showed with an example in Table 5 Paper II. The codes were compared for differences and similarities, and sorted into sub-categories. Finally, quotes were selected to illustrate each category of results.

4.5.3 Qualitative data analysis: Study III – Assessment of the use of the CDSS

Data from the group discussions and the plenary session were analysed using an inductive thematic analysis with no predetermined categories [46]. In this approach, the themes identified are strongly linked to the data themselves without trying to fit into a pre-existing theoretical frame [46]. The analysis was performed in a stepwise manner. All recorded material from the plenary session was transcribed. The transcripts, together with the written answers from the group discussions, were read several times to get a sense of the main findings.

The analysis started by sorting all text into two main themes of strengths and weaknesses in relation to the use of the CDSS. The sections of text in each group were summarised and grouped by content into preliminary categories. The next step was to find related patterns within each preliminary category, which means that sections of text were moved between categories and new categories were formed. The categories were finally grouped under two main themes: i) inhibiting factors and ii) learning factors in relation to the use of the CDSS. Each theme is presented with its consistent category and subcategory (Table 5, paper III). Quotes were selected to validate and illustrate each subcategory.

4.6 ETHICAL CONSIDERATIONS

All studies in this thesis have been approved by an Ethical Review Board and were conducted in accordance with the Helsinki Declaration (World Medical Association, 2013).

3) For study I, the study was conducted under the ethical approval of:

- The Ethics Committee of the Medical Faculty, University of Heidelberg, Germany (ref. S-173/2008),
- The Institutional Review Board of the Navrongo Health Research Centre, Ghana (ref. NHRCIRB 085/2009),
- The Muhimbili University of Health and Allied Sciences Ethical Review Committee, Tanzania (ref. MU/RP/AEC/Vol.XIII/2011)
- The Institutional Review Board for Nouna Health Research Centre, Burkina Faso (ref. 2010.05/CLE/CRSN),
- The Ethics Committee for Health Research, Burkina Faso (Ref. 2010-31).

4) Study II was conducted according to the following ethical approvals:

- The Institutional Review Board for Nouna Health Research Centre, Burkina Faso (ref. 2010.05/CLE/CRSN),
- The Ethics Committee for Health Research, Burkina Faso (Ref. 2010-31).
- The Ethics Committee of the Medical Faculty, University of Heidelberg, Germany (ref. S-173/2008),
- The ethical approval of the Institutional Review Board for Nouna Health Research Centre, Burkina Faso (ref 2011-004/CIE/CRSN).

5) Study III was conducted according to the following ethical approvals:

- The Institutional Review Board for Nouna Health Research Centre, Burkina Faso (ref. 2010.05/CLE/CRSN),
- The Ethics Committee for Health Research, Burkina Faso (Ref. 2010-31).
- The Ethics Committee of the Medical Faculty, University of Heidelberg, Germany (ref. S-173/2008),

For Study II and III, all participants were informed about the purpose of the studies and that the findings were to be published in scientific journals. The participants received verbal and written information about the studies. For Study II, the informants signed informed consent forms. The participants for Study III were invited by telephone and they gave their verbal consent to take part in the workshop. The participants were also informed that they could withdraw at any time without any explanations. They agreed that the interviews and plenary session could be audio recorded. The identities of the respondents were removed from the transcript to guarantee confidentiality.

5 SUMMARY OF MAIN FINDINGS

5.1 STUDY I – DEVELOPMENT OF THE CDSS

The CDSS was developed by the QUALMAT research project team in Heidelberg, Germany. The Java software design was preferred because a Java program is easily installed and can be adapted to run on various hardware using many different operating systems such as Windows, Android or Linux. The CDSS was based on the WHO guideline "*Pregnancy, childbirth, postpartum and newborn care: a guide for essential practice*" [51] with three main sections [14]:

1. Guidance through routine actions in maternal and neonatal care
2. Integration of clinical data to detect situation of concern linking algorithms to the WHO guidelines for maternal care
3. Electronic partograph to follow the progress of the delivery phase

There was also a training section offering documents as PDF files (Portable Document Format) for self-reading (Figure 10, paper I). These documents were mostly in English and a few in French. It was even possible for the HCWs without password to have access to this reading section. This reading section contained various documents [14] such as WHO guideline for maternal care, national guidelines for maternal care for the different African countries being partners in the QUALMAT project, and a CDSS user guide in English. These documents were scanned from the original books as PDF-files.

This knowledge-based CDSS with WHO guideline for maternal care was developed for use during maternal care, for monitoring the delivery phase (partograph) and for the first 24 hours of post-partum and neonatal care.

It was not possible for the HCWs, nor the IT supporting users in the different African countries, to monitor and maintain the knowledge base of the CDSS since it was not considered as an issue during programming of the CDSS software.

5.2 STUDY II – NEEDS OF THE CDSS AND ATTITUDES TO INNOVATIVE TECHNIQUES IN RURAL BURKINA FASO

Before the CDSS was to be implemented in May 2012, we aimed to assess the HCWs needs of CDSS in clinical practice. After the first prototype was demonstrated for two hours in two rural health care facilities in June 2010, the HCWs were asked to give feedback in order to

revise the prototype (Figure 1). However, with meager computer literacy of the HCWs, this approach to get their feedback was seen as too shallow because it would be difficult for people who never had used a computer to give in depth comments and valuable feedback in such a short time. Subsequently, we decided to conduct this study to get deeper knowledge about HCWs needs and attitudes to the CDSS in clinical practice from December 2011 to March 2012 (Figure 1, paper II).

Four main findings emerged from the analysis of the interviews, and these could be divided into aspects of motivators and barriers in the use of the CDSS. The findings are shown with selected citations from the HCWs.

A) The motivational factors were described as an opportunity for the implementation of the CDSS:

1) An appreciable willingness among HCWs for and a great interest to adapt and use modern technologies like computers to learn more in the workplace.
2) A positive attitude to get easy access to guidelines and implementation of decision-support using computers in the workplace.

"This system will be very welcomed. It will help us to improve our knowledge and will be a good tool for training (female midwife-assistant)".

B) The barriers expressed by HCWs toward the CDSS were:

3) A fear that the CDSS would require more working time and lead to workload (double-work).
4) A concern that the CDSS would be complicated and require substantial computer training and extensive instructions to fully use it.

"My question is, with this new system, shall we continue to fill in paper and also use the computer at the same time? My suggestion is that we go through with computer and stop filling paper otherwise it would be very tricky and time consuming to use the CDSS (female midwife-assistant)"

5.3 STUDY III – ASSESSMENT OF THE USE OF THE CDSS

At 23 months after the use started of the CDSS (Figure 2), it was observed that the HCWs were not using the CDSS much in daily practice as expected. We also saw that half of HCWs that received training on how to use the CDSS moved to other work places after one year of usage. Therefore, the research question was to explore why the HCWs reduced their use. The

analysis of the workshop transcripts showed two main themes: inhibiting and learning factors in relation to the use of the CDSS.

A) The inhibiting factors reported by HCWs:

1) Technical challenges including the unreliable power supply, the incorrect partograph and the poorly integrated CDSS into the workflow which created high workload.
2) Lack of motivational and expected incentives

Group3: "Data entry takes time. It is a double work, as we have to fill in all information on paper while we already have problem with lack of staff"

Group2: "The time we spent for one patient now, before it was two patients for the same time … now we spent 30 to 40 min for one patient in ANC, while it was 15 to 20 minutes before we had the CDSS".

Participant to the plenary: "The CDSS was a motivating factor for us to stay in our posts on rural health facilities, but with time this change and some workers asked to be posted in others health facilities. The CDSS was complicated to be used and it was not allowed to use the computer for others task. This was a real disappointment for us."

B) The learning factors that created expectation and enforced the use of the CDSS:

3) The HCWsexpressed enthusiasm for the learning provided by guidance and alerts in the CDSS. They learned what symptoms to look for in their patients. This information supports them to discover problems earlier.
4) They expressed also the learning received in computer use.*Group2:*

"The CDSS improved considerably our knowledge in obstetric care: no matter of our profile at the beginning of the project. We all gained skills and we are now comfortable to provide ANC or delivery without doubt."

6 DISCUSSION

6.1 DISCUSSION OF THE FINDINGS

This thesis highlights the enthusiasm and concerns among end-users regarding the CDSS in rural Africa and what is needed to achieve appropriate use. The main findings can be divided into:

1) The development of a knowledge-based CDSS based on agreed WHO guidelines to support maternal care in rural Africa was succesful (Study I);
2) The reported needs and opportunities but also barriers of the usage of the CDSS among HCWs which create low use of it (Study II and III).

6.1.1 The QUALMAT intervention project: original order of the studies I – II – III and preferable order II – I - III

6.1.1.1 Reflection on the design of the QUALMAT intervention

The QUALMAT multifaceted intervention aimed to improve the quality of care by using a CDSS to improve HCWs performance and knowledge [14]. However as stated by Savigny [52] in the "*systems thinking for health systems strengthening*", the way to successfully conduct an intervention in healthcare should be in accordance with:

1. Convene stakeholders and select intervention designers and implementers, users of the health system, and representatives of the research community.

2. Collectively brainstorm on possible system-wide effects.
3. Conceptualise effects to map how the intervention will affect health and the health system.
4. Adapt and redesign to optimise synergies and minimise any negative effects.

With the QUALMAT CDSS, we lacked this approach as the project focused on how human resources with technical innovations could fill the "know" in the "Know do gap" by improving the performance and knowledge of HCWs [10,11].

Our findings indicate that we lacked a comprehensive approach to consider the HCWs perspectives in an early phase of the development of the CDSS, and this is the third point of the recommendations by Savigny [52]. Figure 2 (under the heading overall study design) and Figure 4 (below) show that we started the development of the CDSS with little involvement of the users and only during prototype testing. Later, we realised the necessity to have in-

depth information to get insight in the HCWs needs in the specific context of maternal care in rural areas [21]. When you have knowledge of the users' needs, this can guide the development of the CDSS into a User-Centered Design [20,53] of the application and thereby also reach a successful intervention [52]. The CDSS developers should know the context of the end-users work, and how the tools will impact on the work place, environment and working condition before building any CDSS. This is crucial and is a solid pathway to strengthening the healthcare settings in accordance with the recommendations by Savigny [52].

Figure 4: Original time order of the Study I to III

Many factors can explain the process of why we undertook the studies in this opposite order (Figure 4). First, as a research project financed by the European Union (EU), it was short-term funding (5 years) and there were obligations to show results quickly and still the programming of the CDSS took as long as three years (Figure 2). Secondly, the consortium partners of the project were a broad multisite and a multidisciplinary team. In such a group, it has been easy to find experts and rich experience; however, this was complicated to manage and to agree on the same vision for planning and implementation of the CDSS during the short time allocated for the development of the CDSS. Thirdly, based on the specific context of complex and resource constrained situations in maternal and neonatal care in rural Sub-Saharan Africa, the QUALMAT intervention focus on human resources in order to address the "Know" gap [15,16,25,54] and thereby upgrade the healthcare workers knowledge of and compliance to maternal and neonatal guideline [14]. It is well known that there are many challenges in rural areas including a shortage of skilled and performing healthcare workers, lack of life saving supplies, unreliable power supply, and low motivation among HCWs to work in rural areas, leading to high turn-over [44,55–57]. These could be potentially addressed by the use of CDSS and other forms of motivation.

6.1.1.2 Learning moments to achieve sustainable use of the CDSS in practice

A learning moment from these three studies is that instead of starting by developing a CDSS (Study I) with slight and short involvement of the HCWs during the prototyping and usability testing, we should have started with Study II and acquired understanding of the specific context of HCWs work [52]. This would have helped us gain insights about the needs of the

HCWs (Study II), and from that information initiate the process of developing the CDSS. When you take into account the user perspective, it has been shown that this approach helps to reduce usability problems [20,53,58,59]. In addition, when users are part of the design process, they are more eager to use and accept the system [20,53,58,59] and this would help to create a User-Centered Design (UCD) CDSS [20,53,58,59].

Creating a CDSS based on the user needs and work context is a way to make the system easy to use and easy to evaluate the usability, making sure that the HCWs are able to make full use of the CDSS in the context specific work environment [20,53,58,59]. If we had undertaken the development of the QUALMAT CDSS in this way, we would probably have discovered some concerns early . This would have helped develop a user friendly partograph and avoid double documentation that became time consuming for HCWs as reported in study III and by other users of the QUALMAT CDSS in Tanzania and Ghana [40,42].

As shown in Figure 5, and in agreement with findings from the QUALMAT project in Tanzania [42], prior to the implementation of a system like the CDSS, we need to have an assessment of potential barriers and fears of the future users regarding innovation in their work environment [33,42]. We need to understand the context specific problems to maternal care in rural Africa. In Study II, we obtained in-depth understanding of the HCWs needs in the context, training and education. After this study we had a better understanding of the situation (Study II). Consequently, the development of the CDSS should be undertaken in a stepwise manner to get a useful, adequate and adapted software (study I). Finally, monitoring and evaluation of the usage can be undertaken continuously (study III) to correct any problems that can occur, and help to increase the usage of the CDSS in routine practice. This is what has been recommended "*Adapt and redesign to optimize synergies and minimize any negative effects*" [52]. Our findings are in line with another study in Kenya [20] on UCD CDSS, where the process is summarised with three words "*Hear – Create - Deliver*". Firstly, we must "hear" the HCWs needs to understand the specific context and the desire of innovation. Secondly, we "create" by using the results of the "hear" process and HCWs experience and knowledge to build the CDSS. Finally, we "deliver" the final software after impact evaluation of its use. This was also undertaken by the SORMAS project in Nigeria who used a mobile phone application based Surveillance and Outbreak Management and Analysis System (SORMAS) for public Health in Africa [60]. For the SORMAS tools, three stages were followed. Firstly, the requirements of the needs of the different stakeholders, secondly the technical development, and finally the implementation and evaluation [61].

These studies show how important it is to have HCWs perspective during all the different stages of the development, usage and evaluation of a CDSS, and follow a User-Centered Design order [Figure 5], [20,25,58,59].

Figure 5: Preferred time order of the study I to III

6.1.2 Many concerns with the CDSS

The HCWs reported many concerns to the use of the CDSS in rural areas. They reported no possibility to update the CDSS knowledge source, which is an important issue of the CDSS. The CDSS needs to be updated when necessary in order to be more useful and create less arms for the patient and users [34]. The HCWs asked for feedback on how they perform and get statistical reports (Study II- III). Getting these information from the systems, is a kind of motivation for them, to know how they work, where to improve and how to reduce maternal morbidity or mortality, which are directly linked to how they perform, and is crucial for the motivation of HCWs [33,39,42]. In addition, using a power supply with solar panels did not reduce the problem of the power supply. When we want to use a CDSS in rural areas, the power supply is necessary and indispensable. Unreliable power supply was a challenge in Burkina Faso and may easily create a situation where no person uses the CDSS. The time consuming process due to double documentation during the implementation of the CDSS, and the fact that the time to provide ANC increased with the CDSS, were problems for the use of the CDSS. Finally, lower motivation of the HCWs, due to less incentives they received compared to expectations, combined with the high turnover of the HCWS, were appreciable challenges to the use of the CDSS.

All these concerns were stated by HCWS as a fear during the needs assessment study (II). However, we didn't address them well so this became a barrier during Study III and negatively impacted on the use of the CDSS. However, using the same CDSS in Tanzania and Ghana, they found the same concerns [40,42]. In Tanzania, one facility had national grid electricity and in Ghana only one facility used solar power. In Tanzania, the HCWs reported unreliable power supply as a major limitation to use the CDSS [42], in line with our findings in Burkina Faso. An example of the unreliable power supply challenge in Burkina Faso [33,62], the IeDA project used during the pilot of two years a solar panel for power for the laptop computer. However, during the large implementation phase (from 2014 to 2017), they

changed to tablets that are low voltage tools. A study from Malawi also showed that the problem could be solved by using low voltage tools [63,64].

Opposite to Burkina Faso and Ghana, in Tanzania, hardware and software problems with the CDSS and computer, and also privacy issues, were not considered as barriers to the use of the CDSS [39,42]. In Tanzania, there were some recurring problems of software reported by users in each visit like unresolved bugs, missing functionality of the software, and absence of statistical reports [42], in line with our findings in Burkina Faso. A study by Mensah et al [40] showed that the time for ANC increased after the introduction of the QUALMAT CDSS similar to Ghana and in Tanzania. However, the surprise is that this increase in the ANC time was also observed in the control facilities where the CDSS was not in use both in Ghana and in Tanzania [40]. This increase of the time in the control facilities in Ghana could be due to another intervention at the same time in these facilities aiming to improve maternal and neonatal care and outside of QUALMAT. Still, in another study in Ghana and Tanzania, users of the CDSS reported a perceived increase in workload due to CDSS use by the HCWs [42], in line with our findings in Burkina Faso [39].

6.1.3 Enthusiasm and opportunities to use the CDSS

Different factors can influence the use of the CDSS in clinical practice, but one common feature from the three studies is that the HCWs have a great willingness to learn more and use new technology (Study II and III). Despite all these concerns, HCWs were enthusiastic to use the CDSS in Burkina Faso. They reported during the needs assessment study, the positive attitude to use and adapt to modern technology at work and to use the CDSS (Study II). Later, the HCWs expressed enthusiasm for the learning provided by guidance and alert through the CDSS (Study III). However, this was not enough to force them to continually use the CDSS. Contrary to the HCWs in Burkina Faso, the HCWs in Tanzania and Ghana reported same enthusiasm and they continued to use the CDSS overtime [41]. In Tanzania, the HCWs perceived the CDSS as a modern innovation that mean modern care provision [42]. However, the enthusiasm and the fascination to use the CDSS can turn to barriers if not addressed well as shown by others [63–65].

6.1.4 Drawbacks with the QUALMAT CDSS

Our findings show that many concerns during the implementation of the CDSS did not facilitate the acceptance and use by HCWs [39]. In Study II, we found great expectations among the HCWs but also fears and barriers about how the usage was perceived. Previous

studies show that the motivational factor before interventions can rapidly turn into barriers if not properly addressed [64,65]. We noted that the Study III confirmed that all barriers which were not addressed well from Study II reduced the motivation of HCWs to use the CDSS. However, in Ghana and Tanzania [40,42] were they used the same CDSS, they obtained similar concerns. Having said this, the CDSS was used over time and the adoption of the CDSS was promising [42]. This arouses the question of why the HCWs didn't reduce the use of the CDSS in Ghana and Tanzania? One speculation is, different from Burkina Faso, the situation in Ghana and Tanzania might be due to factors like socio political context and organization of the healthcare sector or to some other motivation of the HCWs. The leadership and the organizations are different in Ghana and Tanzania with more HCWs per facilities compared to Burkina Faso [40,41]. Another explanation might be, the weak ownership among the local stakeholders during the different stages for designing and building the CDSS had a great impact on implementation. When the database of the CDSS is centralised in Germany and HCWs ask for feedback and they cannot have it, this turns to demotivation and can explain the non-use of the CDSS.

While the CDSS was used in Ghana and Tanzania and not so much in Burkina Faso, the conclusion from a study undertaken [43] on the quality of maternal care using the CDSS and Performance Base Incentive (PBI) in the three countries stated that there was no improvement in the Quality of Care before and after the implementation of the CDSS and the PBI [43]. From this conclusion by [43], we wondered if the CDSS was being used in an appropriate way across the three countries. Did the HCWs used the CDSS as a decision support system during care providing or did they used it as a data entry tool and entering patient information retrospectively afterward? From the database, it would be possible to investigate the history of logins on the CDSS, but this was not planned as an issue and we could not obtain this information. However, the need for rebuilding a next generation of the QUALMAT CDSS that integrates and addresses all these concerns and puts greater effort on training, and assisting HCWs in their facilities, can be the next challenge.

6.2 METHODOLOGICAL CONSIDERATIONS

According to the aims of Study II and III, a qualitative method was used as this permits the capture in detail and in-depth the views of the HCWs. Qualitative studies may help us to understand and give new perspectives of the HCWs' thoughts and experience of their work in the context of rural maternal care. In qualitative studies, there are different quality criteria to create trustworthiness [47,66,67]. In this thesis, trustworthiness was assured thorough

different actions. The credibility of Study II-III was assured through consideration of selection of participants and the approach to gathering data [68]. For Study II and III, data were collected by two different data collection methods including individual interviews [21] and a workshop discussion [39]. Individual interviews and group discussions (workshop) could be structured in different ways, ranging from closed answers as in a survey, to a narrative with a loose structure where the informants speak freely about the topic [66]. In this thesis, we decided to collect data with semi-structured guidance as we wanted to have the respondents'own view on their work in maternal care and how this could be connected to how they used and considered the importance of a CDSS in their clinical practice. With this approach, it was also possible to guide and redirect the questions in order to take into account the respondents answer or for more clarification during the interviews to get deeper information on what HCWs thought [46].

In Study II, individual face-to-face interviews were performed by a person working in the Nouna Health Research Centre (SAZ, author of this thesis), which could have biased the answers by informants from the Nouna health district. We assumed this was not the case since when we compared the interview data from Solenzo district (where the researcher is an unknown person for the informants), there was no difference in the replies. The HCWs appeared to express themselves frankly without difference of the district and area, and they brought up both positive and negative concerns toward the CDSS and the work place. Consequently, we believe there was no bias in the findings from the Nouna health district.

All data were collected before starting the analysis for both Studies II and III. For Study II, a content analysis according to Graneheim and Lundman was performed [47]. This method was chosen because we had material from 45 transcripts to analyse. When you have such large material, it is preferred to use a content analysis approach where you start the analysis with sorting the data into different codes. These codes subsequently help the researcher to sort the codes into different categories for further analysis. In content analysis, there are two levels of analysis, the latent level (where the researchers interprets the underlying meaning of what the informants report) and the manifest level (where the researcher describes the visible and obvious to what the informants report) [46,47]. We stopped the analysis at the manifest level, the lower level of abstraction of data, to be close to what the informants report according to the aim of the study.

In study III, we used a workshop approach as this method can provide rapid feedback on how the CDSS was used and accepted by HCWs. The data collected were not as extensive as in Study II. Consequently, a thematic inductive analysis with no predetermined themes was

performed [46]. In this analysis, according to the aim of the study, we started to sort the material into different themes and categories [46].

The credibility of the results was also ensured through a continuous dialogue between the researchers to seek agreement on categories and themes in the analysis. A common feature for these two analysis methods were that the researchers read the transcripts independently (four researchers in Study II and three researchers in Study III) many times and then two researchers sorted the data into different themes or categories. There after checked and validated the findings with the researchers who have read the transcripts. This was a process of negotiated consensus between the researcher [46,67].

For Study III, it was planned to undertake a Quantitative study (Technology Acceptance Model [69]) in all three countries of Ghana, Tanzania and Burkina Faso. We wanted initially to use the TAM method because it is a common method to evaluate the users' acceptance and use of a system like the CDSS. The TAM has two components named " perceived ease of use" and the "perceived usefulness" that guide the acceptance of technology systems by end-users [69,70]. The "perceived ease of use" is the degree to which a person believes that using a particular system would be free from effort, and the "perceived usefulness" the degree to which a person believes that using a particular system would enhance his or her job performance. However, due to financial and practical reasons including the lack of country responsible researchers in Ghana and Tanzania, and the imminent end of the implementation phase, this was not possible. Consequently, we chose the workshop method as a pragmatic method as we wanted to get good feedback from the users why they reduced their use before the QUALMAT project ended. In this thesis, data come from a number of sources. However, the findings can be comparable to potential findings from the TAM method [69]. With a large group of users, a quantitative questionnaire using the TAM method is generally preferable. However, the results from the Study II and III show how the qualitative methods used can be comparable to the construct of the TAM. In these studies, one could compare the concepts of "inhibiting factors" and "obstacles" and "concerns" with the TAM concept of "ease of use" and the concept "enthusiasm" and "opportunity" could be compared with the TAM concept of "usefulness".

7 CONCLUSIONS

The results from this thesis about enthusiasm and concerns among HCWs regarding use of CDSS in rural maternal care Africa can support future CDSS design, implementation and evaluation in low income countries. However, what is needed to achieve a proper use of a CDSS in rural Africa? Our findings give several insights for a successful design and implementation of a CDSS. These include:

1. Take care of the end-users needs (II) during CDSS design. With very limited knowledge, the HCWs give many importants prerequisites that can help with the design of a user friendly CDSS for rural area. Understand the real needs of end users before the introduction of innovative technology and addressing all issues mentioned by end users before any implementation of the CDSS can greatly facilitate its acceptance.

2. Continuously evaluate the use of the systems during the intervention but also monitor the CDSS software (III). Continuous evaluation during the whole period of design, testing and implementation of the usage and impact of the CDSS is needed to limit concerns and enhance the adoption of the CDSS in rural healthcare facilities in Africa. This can be a moment to re-address any needs not implemented. In addition, it will necessary to allow the update of the content of the CDSS according to update in the guideline through an editing module that can be integrated into the systems to keep guidance up-to-date.

3. Fnally, all design or implementation has to be contextualized. The context specific for work and routine organization must be studied well and integrated into the design of the CDSS as well as into the intervention to maximize the uptake of the innovative technology by HCWs in rural areas i.e the need to use low voltage tools like touchscreen tools or tablets where there are concerns with electricity supply.

8 FUTURE WORK

The QUALMAT CDSS was challenging but still it was a good experience. What is needed in future is to rebuild the QUALMAT CDSS and make it “easy to use” and “useful”. This new system could for example also integrate disease of children under-fives (as well as malnutrition). In addition, exploring using low voltage tools tablets, and with possibility to be connected through internet, to get access to expert advice from hospital.

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