Utrecht University

Faculty of Veterinary Medicine

MASTER THESIS
UTRECHT UNIVERSITY
FACULTY OF VETERINARY MEDICINE

Community Health Workers as data enterers in an early warning disease outbreak system

Confirmation of a low qualification level data enterer for an existing Near-Real Time Disease Surveillance system based on syndromic surveillance via the smart phone based application EMILIA.

Stijntjes, Martijn

3516288

23.05.2015

Supervision

1. Dr. Joris J. Wijnker[a]
2. Dr. Jacob J. Boreel[b]
3. LtCol. Dr. Katalyn Rossmann[c]
4. LtCol. Christian Janke[d]

[a]*: Faculty of Veterinary Medicine, IRAS, Utrecht University.*
[b]*: Expertise centre for Force Health Protection, Doorn.*
[c]*: Bundeswehr Medical Service Headquarter, Preventive medicine, Medical Intelligence, Munich.*
[d]*: DHSC NATO Military Medical Centre of Excellence, Munich.*

List of contents **page:**

List of Tables **page:**

List of Figures **page:**

Abbreviations/acronyms

ASTER	**Alert et Surveillance en Temps Reel (Real-time alert and surveillance system)**
CBRN	**Chemical, Biological, Radiological & Nuclear**
CEAG	**Coordinatiecentrum Expertise Arbeidsomstandigheden Gezondheidszorg (Expertise Centre for Force Health Protection)**
CHW	**Community Health Workers**
DHSC	**Deployment Health Surveillance Capability**
ESSENCE	**Electronic Surveillance System for the Early Notification of Community-Based Epidemics**
EVD	**Ebola Virus Disease**
FN	**False negatives**
FP	**False Positives**
GOARN	**Global Outbreak Alert and Response Network**
IMCI	**Integrated Management of Childhood Illnesses**
MEDINTEL	**Medical Intelligence**
NATO	**North Atlantic Treaty Organization**
NRDS & EW	**Near-Real Time Disease and Surveillance & Early Warning**
OCHA	**Office for the Coordination of Humanitarian Affairs**
OECD	**Organisation for Economic Co-operation and Development**
PRISM	**Prototype Remote Illness and Symptom Monitor**
RMS	**Real-time Medical Surveillance system**
SARS	**Severe Acute Respiratory Syndrome**
SWOT	**Strengths, Weaknesses, Opportunities & Threats**
TN	**True Negatives**
TP	**True Positives**
UN	**United Nations**
UNICEF	**United Nations Children´s Fund**
VSD	**Ventricular Septal Defect**
WHO	**World Health Organisation**

Abstract

Background – Several Near-real time disease surveillance and Early Warning (NRDS & EW) systems have been developed over the past decade. However, the Ebola outbreak of 2014 in Liberia was not detected nor predicted by any of these systems due to several reasons. Most of these systems make use of health professionals/experts to be the source of information. The proposed system within this thesis will make use of the already operable NRDS & EW system ASTER, which is in use within the French forces in Marseille and the DHSC NATO Military Medical Centre in Munich. This system will be filled with data coming from Community Health workers (CHWs) (in accordance to the World Health organizations' approach, now more than ever, 2008) via a smart phone based application called EMILIA.

CHWs have in most cases, in contrast to most local experts, already an enduring, close and trusting relationship with people coming from their community. In case of a potential new outbreak, they will probably be the first to be consulted by affected people. They will know how many people are affected, how severe the symptoms are and of what potential size this outbreak could be (Van Lerberghe, 2008) especially in post-conflict countries like Liberia, which contains a collapsed national health system. The hypothesis tested in this thesis will be "The use of Community Health Workers as data enterers into a Near-real time disease surveillance system gives a higher reliability, validity, objectivity and timeliness in detecting outbreaks of communicable diseases, than the prevailing medical qualified health workers as data enterers."

Methods – CHWs will have different aspects regarding doctors with respect to validity, reliability objectivity, sample group representativeness and timeliness. A literature review was conducted to examine the capabilities of CHWs with regard to their validity, reliability and objectivity. To determine the reliability of CHWs, Cohens´ kappa values were extracted from several literature researches to generate an overall reliability score for CHWs. To determine validity and objectivity of CHWs, their sensitivity and specificity are found out due to information from several studies. The sample group representativeness of the CHWs is determined by a distinction between household wealth and geographical residence of the population. Finally, these aspects are merged into a model to find out if CHWs are able to detect outbreaks.

Results – The proposed simulation model shows that, under certain assumed conditions, with low qualification level data enterers (e.g. CHWs) in combination with the NRDS & EW system ASTER, it is likely to detect outbreaks in a comparable degree and with a better timeliness with regard to professional health care data enterers. The composite sensitivity and specificity of CHWs is found to be 70.3% and 92.4% respectively. The sample group representativeness is found out to be much higher for CHWs due to a higher probability of visit by the poor population, which is mainly 90% of the nation´s population. The time savings of CHWs is found to be 1-3 days, and in combination with the ASTER system in can be heightened with 3-4 weeks.

Conclusions – This study shows that a NRDS & EW system with a low qualification level data enterer in post-conflict, developing countries is able to detect outbreaks with a higher degree of timeliness than the conventional system does. This result can contribute to the ongoing discussion about the prevention and detection of future outbreaks in vulnerable countries. The use of CHWs will have improved impacts on detecting outbreaks, but also on the overall health system of developing countries. A list of recommendations – derived from the results and discussion of this thesis – is provided which should be considered for the development of a proper NRDS & EW system.

1. Introduction & background

1.1. Background of the study

The Ebola Virus Disease (EVD) outbreak of 2014 is one of the largest from the last decades and, moreover, very unprecedented in scale and geographical reach (Gomes et al., 2014). 22.34 million people are living in areas where EVD transmission has been reported (Office for the Coordination of Humanitarian Affairs (OCHA), U.N., 2014). Before this outbreak in 2014, Ebola already has been marked to be a classical zoonosis, containing outbreak characteristics like the possibility to spread by man-to-man transmission and with reservoir species generally found in endemic areas. These reservoir species found out to be very probably fruit bats, insectivorous bats and rodents as stated in a review from Feldmann & Geisbert (2011). The susceptible end host of the virus are apes and man, and maybe other mammalian species as well (Feldmann & Geisbert, 2011). Already in 2012, Ebola and Marburg Haemorrhagic fever have been discussed by MacNeil & Rollin as unjustly excluded from the, by the more common protozoa, helminthic and bacterial-dominated list of 17 neglected tropical Diseases of the WHO (Daumerie, Savioli, Crompton, & Peters, 2010). Diseases which have a large global burden of disease, strong poverty-promoting effects, and persists as chronic infections despite effective medical treatment (MacNeil & Rollin, 2012).

When one focuses on the socio-demographical and political circumstances wherein this outbreak occurred, one is able to conclude that it is no coincidence that this outbreak happened in post-conflict and Collier's bottom billion countries like Liberia (Collier, 2007). The affected countries, including Liberia, are highly ranked – Liberia is 24 out of 178 – and are all centred around the so called 'alert'-countries in the 'fragile states index 2014', produced by the Fund for Peace in Foreign Policy magazine (Haken et al., 2014). This index is based upon 41 sub-indicators grouped into twelve different indicators which affect lives of residents of different countries to make them scalable and measurable. In summary, one could say; failed states are characterized by an implosion of state structure, which results in the incapability of governmental authorities to perform their functions. As a result of that, the health care systems of the countries concerned, are collapsed in most (if not all) cases. This, eventually, gives diseases the chance to spread easily and new epidemics cannot be properly monitored and controlled (Giorgetti, 2012).

The reason for this collapsed government apparatus of Liberia can be found in its history of conflict (M. E. Kruk et al., 2010; Lee et al., 2011). Conflicts are known to have great impact on different national government systems, like for example the country's health-care system. The, by conflict created, voids in the governmental structure of the country will have long-lasting effects on the development of the country (Collier, 2004). By 2008, 5 years after the civil war in Liberia ended, the study of Kruk et al. (2010) found out that the service package health care centres provided are far from the government's targets (M. E. Kruk et al., 2010). Targets which are set up with a general focus to achieve the UN Millennium Development Goals (African Development Bank, 2014). Again, this shows the incapability of the post-conflict government to properly deal with problems like rebuilding the national health care system. By 2010, Lee et al. found out that the governmental strategies had yielded significant improvements. However, still major challenges remained to be taken care of (Lee et al., 2011). This weakened and insufficient health governance which is left in post-conflict Liberia, gives infectious, neglected tropical diseases like Ebola the opportunity to develop in this society in need of a proper health system without being detected, prevented or predicted.

Next to the insufficiency of the health system, there seems to be a great distrust in the health care system of Liberia by its residents as well. Lori & Boyle (2011) stated in their qualitative study that most women do not want to leave their homes or communities for maternity care. They are fearful of the professional care probably due to a lack of understanding with Western medicine. Next to this, traditional healers and midwives are also highly accepted and recommended by community and family members (Lori & Boyle, 2011).

1.2. Near real time disease surveillance by community health workers

In the past decade, numerous Near-Real time disease surveillance systems and early warning (hereafter called: NRDS & EW) systems have been developed (Bravata et al., 2004; Lober et al., 2002). Most of these NRDS & EW systems make use of high qualification level data sources like doctors (Bravata et al., 2004; Lober et al., 2002; Pellegrin, Gaudin, Bonnardel, & Chaudet, 2010). Reasonably, this has a positive effect on the validity, reliability and objectivity of these systems (Meynard, Chaudet et al., 2008b; Meynard et al., 2009). On the other hand, when these data sources are of a lower qualification level, or if there is made use of no qualification level at all, like with the system of Google Trends, sensitivity and specificity of this early warning system appears to be sufficient enough to properly detect outbreaks (Carneiro & Mylonakis, 2009; Flahault et al., 2006; Ginsberg et al., 2009). But even these systems could not predict or detect the Ebola outbreak of 2014 in West Africa.

With the WHO strategy of Primary Health care (Van Lerberghe, 2008) in mind, and in order to focus on the Millennium Development Goals four and six, reducing child mortality and combating HIV, Malaria and Tuberculosis diseases (African Development Bank, 2014), it could be suggested that in particular cases Community Health workers (hereafter called CHWs) can be used as a low qualification level data source for NRDS & EW systems. With CHWs, it will be possible to engage full coverage of countries inhabitants, including the poor and rural population, which are found to be the most vulnerable (The Lancet, 2015). CHWs will be possible to access hard-to-access rural areas and intensify sensitivity and timeliness of the NRDS & EW systems (Lee et al., 2011).

CHWs are non-professional volunteers, living in communities in urban and rural sites of a country. In countries like Liberia, where most villages and communities are isolated and terrains are – especially in rainy seasons – hard to access (M. Kruk, Rockers, Varpilah, & Macauley, 2011; M. E. Kruk et al., 2010), the strengths of CHWs can be very useful. According to the WHO report of 2008, citizens in developing countries want health-care providers to be understanding, respectful and trustworthy. This will be achieved easier by CHWs than by foreign expert practitioners due to the enduring close and trusted relationship between citizens and CHWs, which they have already built up. People centeredness, to minimize social exclusion and avoid people from going to unregulated commercialized informal health care, can be raised by implementing CHWs in the health care system (Van Lerberghe, 2008). Stated this, CHWs have a high probability to be the only ones who are able to effectively address problems in the community. The effectiveness of CHWs to achieve in these characteristics already has been proven. Various studies in a wide variety of age have shown the capabilities of implementing CHWs into health system of developing countries and their effect on decreasing morbidity and mortality of certain diseases (Brenner et al., 2011; Degefie et al., 2009; Geldsetzer et al., 2014; Kelly et al., 2001; Konradsen, Amerasinghe, Perera, Van der Hoek, & Amerasinghe, 2000; Pagnoni, Convelbo, Tiendrebeogo, Cousens, & Esposito, 1997; Pandey, Daulaire, Starbuck, Houston, & McPherson, 1991; Tulloch et al., 2015). Further, health care seeking behaviour is demonstrated to be changing from non-regulated and regulated health care providers to CHWs after implementing them in the communities (Degefie et al., 2009; Delacollette, Van der Stuyft, & Molima, 1996; Konradsen et al., 2000; Seidenberg et al., 2012; Yansaneh et al., 2014).

With CHWs as a low quality level data source for NRDS & EW systems, outbreaks of communicable diseases can be detected earlier. However, lowering qualification levels of data enterers will have deteriorating effects on sensitivity and specificity of these detection systems. This deterioration will in fact have no noteworthy consequences on the detection and prediction of disease outbreaks, because the sample taken by CHWs is probably much more representative and larger. Also, the time between the onset of an outbreak and registering it, will be much lesser with CHWs as data enterers.

To achieve in this registering of possible future disease outbreaks, there must be made use of a proper NRDS & EW system that is extensively tested and evaluated, and is able to detect outbreaks weeks before conventional outbreak systems registered them. This functioning NRDS & EW system is developed by the French militaries and currently in use by the French forces in Marseille and by the DHSC NATO Military Medical Centre in Munich. This system is called *'Alert et Surveillance en Temps Reel'*; ASTER (Real-time alert and surveillance system) (Meynard, Chaudet et al., 2008a; Meynard et al., 2010).

For the data implementation into ASTER, there will be made use of a smart phone based application, called EMILIA. EMILIA is a prototype of a tablet and smart phone based mobile military medical expert application for Reconnaissance, Fact Finding and Site Survey missions as well as Risk assessments. This App, developed by the German Armed Forces unit Medical Intelligence (MEDINTEL) and now element of a joint German-Dutch (MEDINTEL-CEAG) cooperative project, is able to map field notes of different sources to provide joint situational awareness. Furthermore it is an information management system enabling to work on joint standardization documents. This application can be developed further to feed NRDS & EW systems for infectious diseases as well as data management and administration systems.

EMILIA will therefore be created as a smart phone-based platform under consideration of conflict levels and baseline prevalence of selected infectious diseases in order to quantify the a-priori-risk of defined entities (e.g. Ebola, Lassa, Malaria and Measles) in African settings. It will be used as a smart-phone based data entry tool with which it will be possible to implement the required data into ASTER. Today, the smart phone availability in West Africa is enormous and still growing (World Health Organization, 2014). Therefore, a smart phone-based application will be the ideal tool for data collection in African developing countries.

2. Aim & objectives

2.1. Hypothesis

The use of Community Health Workers as data enterers into a Near-real time disease surveillance system gives a higher reliability, validity, objectivity and timeliness in detecting outbreaks of communicable diseases, than the prevailing medical qualified health workers as data enterers.

2.2. Goal & purpose of the project

This thesis will examine the possibility of a low qualification level data enterer (e.g. Community Health Workers), which will theoretically be available country-wide in developing nations, for a Near-real time disease surveillance system with the preservation of the conventional objectivity, validity and reliability.

The purpose of this project is to develop a tool in order to warn earlier of future outbreaks of infectious diseases, and lower morbidity and mortality of possibly affected vulnerable populations in developing countries.

2.3. Objective 1:

Development of a simulation model in order to detect outbreaks by the ASTER system with conventional data enterers with a medical qualification level, and Community Health workers as data enterers via smart phone based application EMILIA.

2.4. Objective 2:

Examination of the timeliness of the ASTER system, with and without use of Community Health Workers, and application on the Ebola outbreak of 2014.

2.5. Objective 3:

Description and investigation of the representativeness of the sample group that will likely be examined by the Community Health workers.

2.6. Objective 4:

Implementation of a weighted and reasoned calculation regarding the sensitivity and specificity in order to quantify the validity and objectivity of the Community Health Workers.

2.7. Objective 5:

Consideration of whether the Community Health Workers are able to collect and process gathered information reliable.

3. Methodology

3.1. Literature review

3.1.1. Objective

The literature search is aimed to create insight in the different existing NRDS & EW systems and how to evaluate them. Furthermore, the background of the Ebola outbreak 2014 in post-conflict Liberia is investigated. Additionally, there is sought literature to elucidate the capacities of CHWs as health care data collectors and how to analyse data distilled from different literatures.

3.1.2. Search Strategy

A literature search is carried out at the offices of MEDINTEL in Munich, Germany. For this, there is made use of the following electronic literature **databases**:

- PubMed,
- Google Scholar
- Scopus
- Web of Science
- Ovid
- WHO - publications

The following search **terms** were concerned:

- Community Health Workers / Primary Health Care
- Validity / Sensitivity / Specificity
- Reliability,
- Performance,
- Health care system,
- Health seeking behaviour,
- West-Africa / Post-conflict / Liberia,
- Ebola / Haemorrhagic fever disease
- Syndromic Surveillance / Near-real time disease surveillance systems
- ASTER / Alert et Surveillance en Temps Reel
- Early Warning / Disease surveillance / Evaluation

Also cited references from mentioned articles are used to fill the literature database.

3.1.3. Selection process

Above stated terms are selected based on the 2008 WHO-report ´Primary Health Care – now more than ever´ (Van Lerberghe, 2008). Furthermore, related terms are chosen based on discussions and conversations with several parties within MEDINTEL in Munich and the faculty of Veterinary Medicine of Utrecht University.

3.2. Near real-time disease surveillance

There are several syndrome surveillance systems developed by several military forces in the past decade as part of their CBRN-defence (Chemical, Biological, Radiological and Nuclear). The importance of the establishment of these systems is accentuated in the past by the 2001 anthrax attacks and the outbreak of severe acute respiratory disease (SARS) in 2003 (Heymann et al., 2015). Three main military NRDS & EW systems have been developed and are described in the literature.

One of them is ESSENCE, developed by the military forces of the United States. ESSENCE is an internet-based syndromic surveillance system used by civilian and military health departments. The ESSENCE-system's usefulness is evaluated as inconsistent (Lombardo, Burkom, & Pavlin, 2004). Next, there was PRISM, followed by RMS, developed by the British forces between 1991 and 2005. PRISM had a lack of evaluation in field-theatre and after several months of use, only 10% of the users were actively using the system and finally it was abandoned in 2004. RMS was set up in 2005, building on the experiences of PRISM, and used in 2006 exercises, wherein it detected an anthrax outbreak within 24 hours (Meynard et al., 2008a).

In the meantime, much effort has been put in the development of a syndromic-surveillance and therefore NRDS & EW system by the French Forces, called ASTER. This operable system works with data enterers in the field which fill out questionnaires based on 69 signs and symptoms. These signs and symptoms together form a vast amount of syndromes, which further can refer to several differential diagnoses, e.g. haemorrhagic fevers or respiratory illnesses. The observed data is then compared with expected data; historical data of that same period and region from the past five years. When this observed data exceeds the expected data, the system will give an alert. The epidemiologist on duty, the required human factor in this system, will have to read the data given by ASTER and either reject the alert or confirm the alert into an alarm. This system is extensively tested and evaluated, and it showed to work sufficiently and with a high degree of timeliness in operating conditions in Kosovo, French Guiana, Djibouti and Mali (Jefferson et al., 2008; Meynard et al., 2008b; Meynard et al., 2009). Today the system is in use with the French military armed forces in Marseille and the DHSC NATO Military Medical Centre in Munich.

This NRDS & EW system could be applied to situations which arose as in Liberia; post-conflict countries with a heavily affected national health system, and thus susceptible for other outbreaks of communicable diseases. This syndromic surveillance system could help detect outbreaks of these communicable diseases (e.g. Lassa, Malaria, Measles as well as Ebola) which might threaten post-conflict and developing countries in the near future. However, there is a great lack of sufficient medical qualified personnel in these countries, so the data enterers of the system should be changed into a more readily available one: Community Health workers. With use of the EMILIA application they get the opportunity to fill in a questionnaire, based on the ASTER questionnaire, and in this way fill the ASTER system with epidemiological information from field-theatre. Eventually, this system, could be part of the new global health framework, as proposed in an article from Gostin & Friedman (2015) and Heymann et al. (2015) from The Lancet Journal of May 2015 (Gostin & Friedman, 2015; Heymann et al., 2015). This system will be able to help protect the local communities against probable catastrophic disease outbreak emergencies in the future.

3.3. Quality of Surveillance Parameters

3.3.1. Timeliness

For a proper NRDS & EW system, timeliness can be considered as a vital aspect of the system. Timeliness can be expressed as the proportion of saved time when an outbreak is detected relative to the onset of an outbreak (Jafarpour, Precup, Izadi, & Buckeridge, 2013). In the detection of Influenza like diseases, Dailey et al. (2007) present three different ways for the measurement of timeliness of NRDS & EW systems: Peak comparison (1), in which the time difference is calculated between the peak in one data source compared to another. Aberration comparison (2), wherein the date of an alert created by an algorithm is compared to the date of an alert in another algorithm. And correlation comparison (3), which is defined as the time lag at which the correlation between two data sources is at maximum significance (Dailey, Watkins, & Plant, 2007). For defining timeliness of the ASTER system in combination with CHWs compared to doctors, we will use aberration comparison.

For defining the timeliness of the different systems in detecting the Ebola outbreak 2014, there will be made use of peak comparison. With this comparison we will be able to exhibit clearly which profit there can be achieved with using the combination of CHWs with EMILIA and ASTER.

3.3.2. Representativeness

To properly identify the sample representativeness of the sample group taken by the CHWs, primarily the Liberian health care accessibility problems have to be identified.

Rossmann (2009) identified health care accessibility problems of displaced and marginalised people in Djibouti. In this report, seven different determinants for access to health care are stated, whereof five of them – the five A´s – are coming from a report of Penchansky & Thomas (Penchansky & Thomas, 1981; Rossmann, 2009):

- Accessibility; in terms of geographical and physical barriers.
- Affordability; in terms of individual availability of financial resources.
- Availability; in terms of the relation between medical needs and provided services.
- Accommodation; in terms of organisational parameters.
- Acceptability; in terms of trust and perceptions of reliability of the public.
- Cultural aspects; in terms of the presence of different cultural barriers.
- Language; in terms of the ability to easily consult the health care.

Applied on the situation of Liberia, there is made use of the thesis of Johnson et al. (2008) which did more or less the same observational study within the borders of Liberia. They identified significant barriers for access to health care experienced by Liberian residents (Johnson et al., 2008):

- Lack of payment ability ➔ affordability
- Health care too far away ➔ accessibility
- Lack of transit to care ➔ accessibility
- Health care not available ➔ accommodation
- Poor quality/Lack of medicine ➔ availability / accommodation
- Ignorance of health care options ➔ acceptability
- Facility overcrowded ➔ accommodation
- Other (not specified)

These barriers can be related to the determinants of Penchansky & Thomas (1981) (the five A´s), which are also used in the report of Rossmann (2009). The determinants ´cultural aspects´ and ´language´, which are added to the 5 A´s of Penchansky & Thomas (1981) by Rossmann (2009), could not be linked to the barriers of Johnson et al. (2008). Moreover, they turned out to have no great effects on the results of Rossmann (2009) as well. The determinants used for defining representativeness in the sample group of CHWs will be further explained in the results.

3.3.3. Validity & Objectivity of community health workers

According to several studies found in the literature search one should conclude that to quantify and measure validity and objectivity of CHWs, one must focus primarily on their sensitivity and specificity. These characteristics are well documented and tested by the literature, albeit not abundantly.

The capacities of CHWs to recognize true positive cases within a population, is called sensitivity. The capacity of CHWs to recognize true negative cases within a population is called specificity. When sensitivity is inadequate, real cases will not be sufficiently recognized. On the other hand; when systems lack specificity, they may create a high amount of false alarms. This could result in costly actions of clinicians and public health officials, or in a worst case scenario, officials ignoring the systems when they report suspicious events again (Bravata et al., 2004).

Sensitivity & Specificity

The sensitivity of a test is stated as the ratio between positive tested cases and true positive cases. The ratio between negative tested cases and true negative cases is called specificity.

Sensitivity = A / (A + C)
Specificity = D / (B + D)

		Golden Standard (Truth)	
		Positive	Negative
Test Results	Positive	A	B
	Negative	C	D

Table 1; Explanation of Sensitivity & Specificity with use of a two-by-two table

To create adequate and reliable predictive values for specificity and sensitivity, a small meta-analysis is conducted within this thesis. The use of meta-analysis for predictive validity and reliability of tests has been widely reported in the literature. However, there was not found any example wherein it has been done for predictive validity and reliability of CHWs. Also, there was no other literature found on the subject of predictive reliability, validity, sensitivity nor specificity of CHWs.

This meta-analysis is kept small due to a lack of information available about CHW sensitivities and specificities related to their performances, but moreover, due to a lack of sufficient time to perform a conventional extensive meta-analysis. Literature is sought on the subject of sensitivity and specificity of CHWs. 20 studies have been selected on the basis of their title and abstract. After this, reports are fully red and based on their contents, 9 out of these 20 reports were selected for further examination. The last selection was on basis of the availability of data within the reports. Out of the 9 selected studies, 7 reports remain eligible to withdraw information from for specificity, 8 reports were eligible to withdraw information for sensitivity. A summary of the used literature can be found in table 1 under appendices.

With use of an Excel 2007 spreadsheet format, created by Neyeloff et al. (2012), and the accompanying written literature the data is processed, resulting in evident values for sensitivity and specificity (Neyeloff, Fuchs, & Moreira, 2012).

3.3.4. Reliability of community health workers

For testing the reliability of CHWs, several authors have mentioned testing the inter-observer agreement with Cohens' Kappa scores. Kappa values can differ from $-1 \le x \le 1$, where values of 1 means perfect agreement, 0 is exactly what would be expected by chance and -1 is agreement less than chance (Otieno-Odawa & Kaseje, 2014).

3.4. Simulation Assumptions

Because the sensitivity and specificity parameter values were found in studies comparing CHWs competencies with regard to doctors and nurses, the golden standard of these studies had sensitivities and specificities of 100% both. Because normal ASTER data enterers are doctors and nurses, the sensitivities and specificities of the golden standard of this study will also be set to 100% both.

Developing countries have specific geographical and demographical characteristics. The African Development Bank Group described the household wealth distribution of many west-African countries in a report of 2012. This report states that 90.5% of the developing countries inhabitants can be considered as poor (≤$2-$10/day) and the remaining 9.5% can be considered rich ($10->$20/day) (Mubila, Lannes, & Ben Aissa, 2012). In addition, UNICEF statistics reveals the geographical residence distribution of Liberia. In 2012, 48.5% of the people lived in urban conditions, 51.5% were living in rural conditions (UNICEF, 2013). Stated this, and assuming that the rich are equally distributed over the country, we found that a major group of 46.75% of the people of an average developing country is living in poor and rural conditions. The results of the made distribution are summarized in table 2.

Demographic and Wealth distribution

Assuming that rich people are equally distributed over the country, we come up with the following inhabitant distribution of an average developing country in West Africa.

Data from: UNICEF 2013 & Mubila, Lannes et al. 2012

% of total population	Rich	Poor	
Urban	4.75%	43.75%	48.5%
Rural	4.75%	46.75%	51.5%
	9.5%	90.5%	100%

Table 2; Summary of demographic characteristics of a developing country with regard to geographical residence and wealth distribution

To determine the formal health care usage of all groups separately, UNICEF Statistics of Liberia published numbers on their website showing disparities by residence and disparities by household wealth. Using these numbers, we come to an average ratio between urban and rural usage of services, similar to health care (e.g. the use of skilled birth attendant), of 2.6. Next to this, using the numbers of the disparities by household wealth for similar services, we come to an average ratio between rich and poor of 2.4 (UNICEF, 2013).

To calculate the number of formal health care visits per person per year for each group, we made the following considerations:

- 51.5% of the total population lives in rural areas. Divided over 4.75% rich and 46.75% poor people (Mubila et al., 2012).
- The average rural formal health care visits for both groups together are 3 visits per person per year (M. Kruk et al., 2011).
- The rich population however, have 2.4 times more formal health care visits than the poor population has (UNICEF, 2013); despite the fact they are with fewer amounts (4.75% vs 46.75%).

To calculate the amount of visits poor rural people made per year, per person, can be achieved with the following formula:

$$AverageVisit = \frac{\%RichRural \ * \ UnicefRatio * X \ + \ \%PoorRural \ * X}{\%TotalRural}$$

Wherein *'X'* will be found as the number of visits to formal health care per person per year of the poor rural population. '*AverageVisit*' is considered as the average amount of visits, all rural people made in a period of one year. In this case it will be 3 visits per person per year (M. Kruk et al., 2011). *'%RichRural'* is the percentage of rich people in rural areas over the total population. *'%PoorRural'* is the percentage of poor people in rural areas and *'%TotalRural'* is the total percentage of people living in rural areas over the whole population. *'UnicefRatio'* stands for the ratio of health care usage between poor and rich people, in this case 2.4 (UNICEF, 2013).

Now, we apply all found values as stated before and *'X'* can be calculated;

$$3 = \frac{4.75 * 2.4 * X + 46.75 * X}{51.5} \quad \rightarrow \quad x = 2.66$$

'X' is found to be *2.66*. This means that poor rural people made *2.66* visits per person per year to formal health care. With this number, the number of formal health care visits for the rich rural population as well as for the urban populations can be calculated. We use the following table (table 3) for the calculation, based on UNICEF statistics (2013):

		Ratio R:P = 2.4	
	Formal Visits	*Rich*	*Poor*
Ratio: U:R = 2.6	*Urban*	*2.4 ∗ 2.6 ∗ X =* **16.60 visits per person per year**	*2.6 ∗ X =* **6.92 visits per person per year**
	Rural	*2.4 ∗ X =* **6.38 visits per person per year**	*X =* **2.66 visits per person per year**

Table 3: Overview of formal health care visits in a developing country

Next, the amount of CHW-visits will be calculated. For this, we assume that all informal visits (visits to country doctors, spiritual healers, black baggers (traveling pharmacist), pharmacy or traditional midwives) will be changed into CHW-visits. Meaning, when the number of informal visits is calculated, there is found the amount of CHW-visits. In order to do so, we will use again the number of Kruk et al. (2011), stating that for every formal visit per person per year, there were 3.33 informal visits per person per year (3:10 for Formal:Informal visits) (M. Kruk et al., 2011). We will combine this finding with the finding of Johnson et al. (2008), stating that 15% of the urban population does not have ready access to health care (Johnson et al., 2008). With this we come to the following table (table 4):

		Ratio R:P = 2.4	
	CHW Visits	*Rich*	*Poor*
Ratio: U:R = 2.6	*Urban*	**0 visits per person per year**	3.33 x *'Poor urban formal visits'* x *'15% extra visits'* = *3.33 x 6.92 x 1.15 =* **26.51 visits per person per year**
	Rural	**2 visits per person per year**	*3.33 x 'Poor rural formal visits' =* *3.33 x 2,66 =* **8.86 visits per person per year**

Table 4: Overview of informal health care visits in a developing country

In this table, there is no calculation made for the rich population. This is done due to the lack of information about their informal health care usage. The 2 visits per person per year for the rich rural population in this table is an assumption, based on the availability of drug shops in rural areas, and the assumption that rural rich people are not willing to travel for hours for formal health care. Instead, they will use informal health services for minor health care. For the rich urban population the amount of informal health care usage will be negligible, because it is assumed that in rich urban areas formal health care will always be within reach of the rich population.

The found 'health care usage' numbers will then be used to determine the probability of visit for each population group. To calculate these, we will use the following formulas:

$$P(formal) = \frac{\#FormVis}{\#AllVisits} \qquad \& \qquad P(informal) = 1 - P(formal)$$

In these formulas, *'P(formal)'* is the probability of a person of one group visiting the formal health care, and *'P(informal)'* is the probability of this same person going to the informal health care. *'#FormVis'* in this formula is the number of annual visits to formal health care and *'#AllVisits'* is the total amount of annual visits including both formal and informal visits. In the following table (table 5) the formulas are applied on each different population group:

	Probability of visit formal health care	**Probability of visit informal health care**
Poor Rural Population	*P(formal) = 2.66/11.52* P(formal) = **0.23**	*P(informal) = 1 – 0.23* P(informal) = **0.77**
Poor Urban Population	*P(formal) = 6.92/33.43* P(formal) = **0.21**	*P(informal) = 1 – 0.21* P(informal) = **0.79**
Rich Rural Population	*P(formal) = 6.38/8.38* P(formal) = **0.76**	*P(informal) = 1 – 0.76* P(informal) = **0.24**
Rich Urban Population	*P(formal) = 16.60 / 16.60* P(formal) = **1**	*P(informal) = 1 – 1* P(informal) = **0**

Table 5: Overview of probability of visit to formal & informal health care with regard to differences in wealth and geographical residence

This list of assumptions is controlled, reviewed and evaluated by an expert panel from MEDINTEL, Munich.

3.5. Ethical approval

For writing this report, and for the simulation model to be developed and performed, there is no need for an ethical approval.

4. Results

4.1. Objective 1: *Simulation model*

With the found visit-probabilities, sensitivity, specificity and timeliness a model is developed to test the ASTER system with a lower qualification level data enterer. This model is shown in figure 2 in the appendices and this figure will be used as illustrative for the following explanation:

The model is split up into two main flow charts. On the left side, the CHWs are used as data enterers, and on the right-side doctors are used as data enterers. The model starts with the amount of outbreak cases within the different population groups in a developing country. For each group, there is a specific probability that they will visit health care, resulting in a total amount of visits to health care both formal and informal. Secondly, the probability of recognizing the syndrome right, the sensitivity of the CHWs and Doctors, has to be taken into account. For CHWs a sensitivity of 70.3% was found, meaning that 70.3% of the health care visits, which are thus seen by the CHWs, will be recognized correct. This will finally result in a number of positive recognized syndromes which have to be put correctly in the questionnaires. To include the specificity as well, there is made use of a constructed hypothetical background noise, existing of four non-existing diseases (figure 3), wherein a certain amount of true positives and false positives are exhibited. The background noise is further explained in a paragraph hereafter.

Finally, the timeliness has to be taken into account as well. To do this, the background noise questionnaires will be virtually divided over 7 days. Next, the outbreak questionnaires will be added on day 1, 2 and 3. For the doctors, which are found to have a delay of 1-3 days by Konradsen et al. (2000) and Dunyo et al. (2000), the outbreak questionnaires have to be added on day 4, 5 and 6 (Dunyo et al., 2000; Konradsen et al., 2000). This variable will show the difference in timeliness between CHWs and Doctors as data enterers.

This model will result in an outbreak simulation wherein the system with CHWs, EMILIA and ASTER can be tested on its validity, reliability, objectivity and timeliness.

Background noise:

The background noise has to be introduced because it will scatter the gathered data from the CHWs. The CHWs will produce false-alarm cases, so-called false positives, due to their specificity. These false positives have to be added in the background noise. Hereafter the background noise will be theoretically explained. However, this background noise will not be used in the model due to its complexity and the added value for the model will be minimal.

For the theoretical background noise, there is assumed that a person is only capable of having one disease at the same time. With this, we assume that there are 2000 people visiting the CHWs in a week time period and having hypothetical diseases Alpha (15%), Beta (35%), Charlie (10%) or Delta (25%). 15% of these 2000 people will have no disease ('Nothing'), or have minor signs and symptoms, but although they seek care (figure 3). The calculations made for the background noise will be explained hereafter in a step-by-step proceeding.

1. CHWs will recognize every disease correct in 70.3% (*Sensitivity)* of the cases (*True positives:* TP), resulting in 29.4% *False Negatives* (FN) cases for each disease.
2. These FN will fill the 'Nothing'-pool, because CHWs will confuse these cases with other diseases and create *false positives* (FP) in 7.6% (*1 - Specificity)* of these cases.

3. These FP cases will fill the amount of ‘detected’ for every disease equally. This means; there will be 7.6% FP for each disease, equally distributed over the 4 other diseases.
4. In case of people having no disease, CHWs will recognize the *True Negatives* (TN) in 92.4% (*Specificity)* of these cases.
5. The resulting 7.6% of these ‘Healthy people’, which are not recognized as being a negative case, will again fill the FP pool, distributed equally over the 5 diseases (Alpha to Delta + the outbreak disease).
6. Now the background noise can be constructed under the header ‘detected’, by adding the TP of every disease with a fourth of the FP of every other disease.
7. The amount of ‘detected’ in the nothing group will consist of all TN, plus, the FN of each disease minus the amount of FP cases for each disease apart.
8. Concluding, there can be assumed that the amount of false positive outbreak cases, which will also have to be added in this background noise, can be calculated by taking all the FP of the other diseases, times 0.25. For the FP cases of the ‘Nothing’-group, one fifth has to be added.
9. This results in 15 FP outbreak cases for the outbreak disease in this simulation to be added in this background noise.

This shows that the amount of false positives produced by CHWs will only scatter the amount of detected outbreak cases in an event of a small outbreak (10 cases). However, when the outbreak evolves and the amount of outbreak cases expands, the number of true positive detected outbreak syndromes will instantly exceed the false positives, and the outbreak will be detected.

4.2. Simulation results

To test the hypothesis, 9 simulations have been carried out. In every group, with regard to household wealth and geographical residence, three different scaled outbreaks have been simulated (10, 50 & 100 outbreak cases). The rich urban group did not take part in these simulations, while they will not make use of CHWs. To make the simulations more feasible to run, and to prevent adding unnecessarily complex calculations in it, there is a final assumption wherein the above described background noise is excluded and there is assumed that the background noise in this simulation will be similar for both CHWs and doctors. A visualization of the results can be seen in figure 4 – 12 in the appendices. These simulations show clearly that especially the poor benefit from a system with a low qualification level data enterer, like the CHWs used in this model, for NRDS & EW systems. These outbreaks are detected earlier due to greater amounts of detected syndromes and due to the time savings achieved with CHWs as data enterer.

Due to the background noise, outbreaks cannot be detected in case of a small outbreak (10 infected persons). However, when the outbreak grows and the background noise remains the same, one is able to conclude that the detected outbreak-cases by CHWs are in most cases above the amount of detected cases within doctors. This means that the ASTER system will detect the abbreviation, achieved by this greater amount of detected outbreak cases with CHWs as data enterer, better than with doctors as data enterer.

4.3. Objective 2: *ASTER timeliness*

According to the information given by the WHO about the past Ebola outbreak in 2014, the first case was an 18-month-old boy on December 26th of 2013 in Guinea. In the weeks hereafter, several members of the boys’ immediate family developed similar illness followed by rapid death. The same was true for several midwives, traditional healers, and staff at a hospital in the city of Gueckedou (WHO/Global Alert and Response (GAR), 2015).

At March 14, 2014, HealthMaps´ automated text-processing algorithm was the first to be tracking the Ebola outbreak, after the Guinean news site Africaguinee.com reported “a strange fever”. This is the first traceable report about the onset of a haemorrhagic viral disease outbreak, albeit very rumour-based (Aissatou, 2014).

March 19, 2014; on this date ProMed gives a report for the first time about the event of several haemorrhagic viral fevers in Guinea, killing 23 people since February 2014. This report is already mentioning Ebola as a possible cause (ProMED-mail post, 2014b).

Marc 22, 2014; ProMed reports the confirmation of Ebola as the cause of the haemorrhagic fevers. From this moment the Ebola outbreak is no longer based on rumours, but based on facts (ProMED-mail post, 2014a).

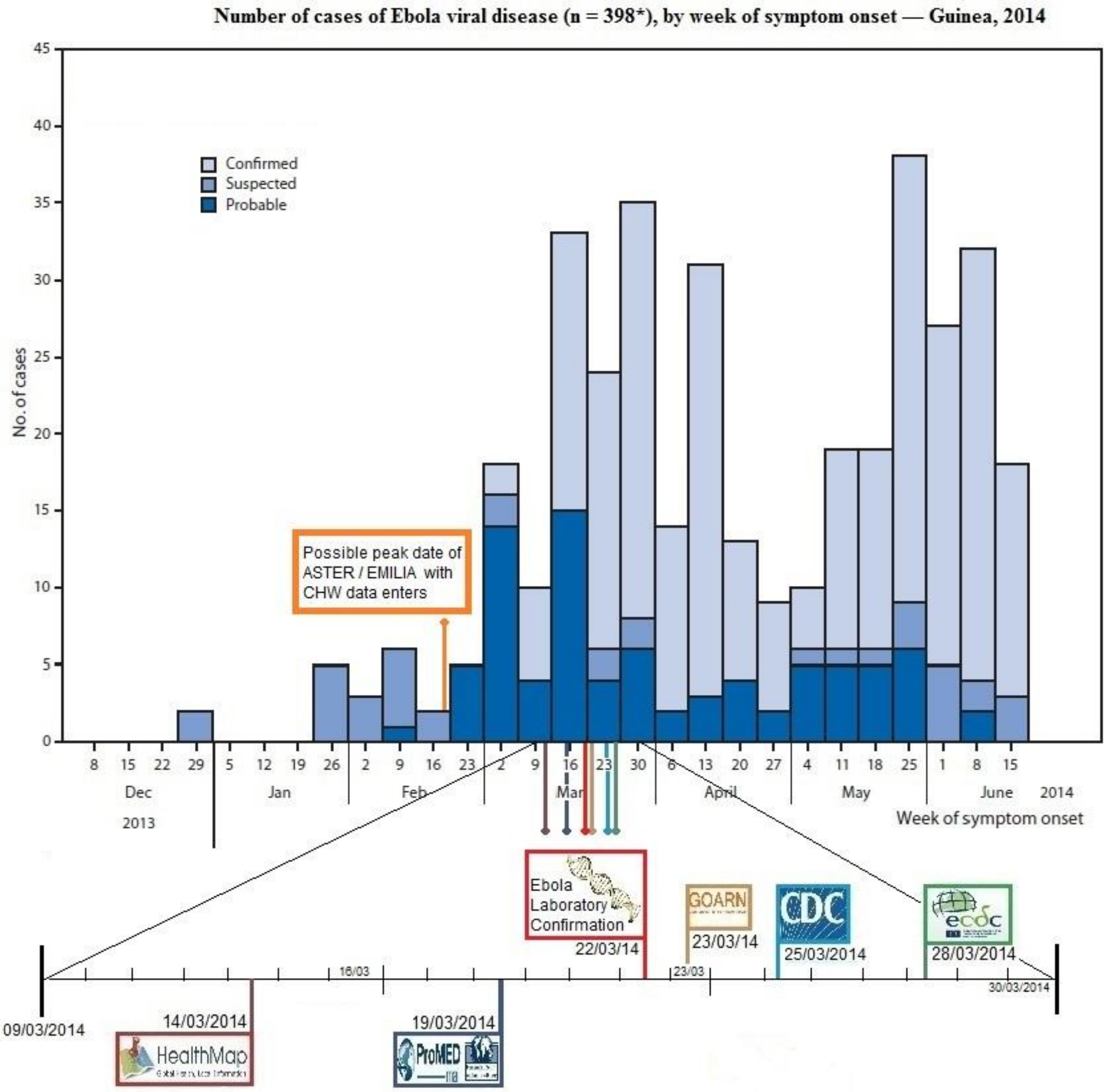


Figure 1: Chronology of the Ebola Viral Disease outbreak detection of several relevant agencies and the deduced moment of detection with the EMILIA / ASTER & CHWs system added. (Dixon & Schafer, 2014)

March 23, 2014; at this moment, WHO/GOARN confirms the outbreak of Ebola haemorrhagic disease in the south eastern parts of Guinea with a report on their internet site (WHO/Global Alert and Response (GAR), 2014). This was done because they were alerted by the government of Guinea about a confirmed, 'rapidly evolving' outbreak of Ebola virus disease.

With the data of Meynard, Chaudet et al. (2008) and Meynard et al. (2010), we are able to deduce that the ASTER system would have alerted the outbreak, 3 to 4 weeks before the conventional systems did (Meynard et al., 2008b; Meynard et al., 2009; Meynard et al., 2010). This, in combination with the data of Konradsen et al. (2000) and Dunyo et al. (2000), which claim that there can be achieved a time saving of 2-3 days after the introduction of CHWs in communities (Dunyo et al., 2000; Konradsen et al., 2000), results in a timeliness of the EMILIA / ASTER & CHWs system of an average of 3.5 weeks (figure 1).

4.4. Objective 3: *Sample representativeness*

Some articles revealed the differences in health-care seeking behaviour with and without the presence of CHWs in the community. These studies showed that there is a tremendous heightening in health seeking behaviour due to the implementation of CHWs in the local communities. Konradsens' study (2000) for example, observed a change of health seeking behaviour of a community in Sri Lanka. Before the introduction of a village treatment centre, 16% of the villagers sought help with private practitioners against 78% using any governmental facility. After the introduction, 70% of the villagers sought help with the local village centre and the use of private practitioners declined to 3% (Konradsen et al., 2000). Seidenberg et al. (2012) found preference for CHWs by about one-half of the mothers in rural Zambia with first health seeking actions, against more or less 40% for health facilities (Seidenberg et al., 2012). Yansaneh et al. (2014) stated in their report *"CHWs influence care-seeking behaviour and improve access to appropriate treatment of common childhood illnesses, particularly in hard-to-reach and poor areas."* (Yansaneh et al., 2014). They found an increase of more or less 10% in care seeking behaviour in comparison with no CHWs in the surrounding neighbourhood within the borders of Sierra Leone. These results show the influence CHWs have on health seeking behaviour, and in what sense their sample representativeness will be better.

With regard to health care accessibility, Rossmann (2009) shows us that the overall health care accessibility in Djibouti is in general very poor for displaced and marginalised people. However, for poor rural people and non-citizens the access to health care is even worse in terms of geographical disadvantages and the lack of financial resources; accessibility and affordability (Rossmann, 2009)**.**

While we focus on Liberia, there is found some specific information about health care service usage of the Liberian population. Kruk et al. (2011) found that people living in rural areas, over a period of one year, had 3 visits to formal health care providers, and 10 visits to informal health care providers, like black baggers (traveling pharmacist) and traditional healers. These findings have been found after they have interviewed 1434 Liberian rural inhabitants and asked for their health care usage and experiences (M. Kruk et al., 2011). They could be placed in perspective by the results of Johnson et al. (2008), considering different barriers in Health care accessibility.

In the report of Johnson et al. (2008) is stated that 97.5% of the Liberian inhabitants experience significant barriers to Health care. The main barriers seemed to be the ´Lack of payment ability´ (58%; affordability) and ´Health care too far away´ (18%; accessibility) (Johnson et al., 2008). This can be confirmed with the study of Rossmann (2009) wherein the same barriers are found for people in Djibouti (Rossmann, 2009).

The ´Health care too far away´-barrier can furthermore be confirmed with the finding that 41% of all Liberian households and 66% of rural households are more than one hour away from the nearest health care facility (Lee et al., 2011).

Moreover, this is showed to be worse in the results by Kruk et al. (2011). They state that their sampled population was on average 7.2 km or 136.1 min away from the nearest health facility. In addition, they also report a 2% increase in informal care use for each additional day of poor physical and mental health. This clearly shows that the poorer, most vulnerable individuals and the people with the greatest health need are high users of informal care providers (M. Kruk et al., 2011).

With implementation of CHWs in the Liberian health care system, the rural health delivery gap can be overcome. As Lee et al. (2010) states it in their paper; '*A corps of community health workers that is equipped, trained, well supported and recognized as a formal cadre within the County Health Teams can link dispersed populations to services and facilities at reasonable cost, and should form the backbone of Liberia's rural health delivery strategy'* (Lee et al., 2011). When this gap is overcome, the sample group which is taken by the CHWs and entered in the NRDS & EW system will not only be much larger than the sample taken by official doctors in government health care facilities. But due to above stated facts the sample of CHWs will also be much more representative in comparison with the doctors' sample.

4.5. Objective 4: *Validity & objectivity*

Three studies testing Integrated Management of Childhood Illnesses (IMCI)-algorithms with use of CHWs as data enterers concluded sufficient sensitivities and specificities comparing to physicians (Perkins et al., 1997; Simoes et al., 1997; Weber et al., 1997). In certain cases the sensitivity and specificity of CHWs outcompeted the results of physicians; detecting high fever (≥37.5°C) with 'touching the forehead' was 89% sensitive and 92% specific by health workers, compared to 91% sensitive and 77% specific for physicians (Perkins et al., 1997). Most of the deteriorating results of CHWs' performances in these studies were attributed to a lack of clarity and objectivity of the algorithms used (Darmstadt et al., 2009; Simoes et al., 1997) and experienced difficulties in classifying certain signs (e.g. of swelling) (Mullany et al., 2006).

The collected data from different reports are put in the excel sheet of Neyeloff et al. (2012), which can be found in table 8 & 9 of the appendices. With this, there is found a CHW-sensitivity of 70.3% and a specificity of 92.4% (Darmstadt et al., 2009; Hadi, 2003; Källander et al., 2006; Mullany et al., 2006; Otieno-Odawa & Kaseje, 2014; Perkins et al., 1997; Simoes et al., 1997; Weber et al., 1997). This data analysis is controlled, reviewed and evaluated by an expert panel from MEDINTEL, Munich.

4.6. Objective 5: *Reliability*

The found data about the inter observer agreement between CHWs and their golden standard is used for constructing an average kappa value. This data is summarized in table 10 in the appendices. The aggregated Cohens´ kappa value exhibits that there is on average slight to moderate agreement (k=0.38; 95% CI -0.05 – 0.80) in collected and measured data between CHWs and controls/golden standards (Darmstadt et al., 2009; Mullany et al., 2006; Otieno, Kaseje, & Githae, 2012). For the aggregated average, the negative scores within these studies have been left out: These scores were conflicting due to subjective and unclear questions within the algorithm worked with (Darmstadt et al., 2009) and contradictory measles' vaccination registration, due to a local outbreak at the time of the study (Otieno-Odawa & Kaseje, 2014).

Due to statements from several authors and various positive findings regarding reliability of CHWs in the found literature (Hadi, 2003; Källander et al., 2006; Mullany et al., 2006; Otieno et al., 2012; Perkins et al., 1997; Simoes et al., 1997; Weber et al., 1997) and based on the positive Cohens' kappa value we found, there can be concluded that CHWs are able to collect reliable data that can be used for early detection of communicable diseases.

4.7. Hypothesis

The hypothesis of this thesis was: *"The use of Community Health Workers as data enterers into a Near-real time disease surveillance system gives a higher reliability, validity, objectivity and timeliness in detecting outbreaks of communicable diseases, than the prevailing medical qualified health workers as data enterers".* With regard to the results of the presented simulation model, and under consideration of the proposed assumptions, this hypothesis can be confirmed.

4.8. Feasibility of the project to achieve the goal & purpose

The goal of this project was to examine the possibility of a low qualification level data enterer for a Near-real time disease surveillance system with the preservation of the conventional objectivity, validity and reliability.

According to the results of this thesis there can be concluded that the low qualification level data enterer has a higher degree of sample representativeness and timeliness. However, results show as well that there is a lowered sensitivity and specificity, resulting in missed outbreak cases and false alarms. Despite this fact, the model shows that the amount of detected cases is likely to be higher in case of outbreaks in poor populations. With this, the project seems to be feasible based on the findings of this thesis.

The purpose of this project is to develop a tool in order to warn earlier of future outbreaks of infectious diseases, and lower morbidity and mortality of possibly affected vulnerable populations in developing countries.

More time and effort should be put in the development of a tool in order to warn for future outbreaks. With the results of this thesis one is able to consider that data coming from low qualification level data enterers are as valid and reliable, and even more timely and representative, as data from doctors. However, to develop the tool for disease outbreak warnings and with which CHWs will be able to collect and gather data, wherein EMILIA and ASTER can be used as templates, there is need for further research, time and effort.

5. Discussion

5.1. Summary and critical review of results

The findings of this thesis confirm that, under the particular assumed circumstances, the use of lower qualification level data enterers into a NRDS & EW system (e.g. CHWs into ASTER via EMILIA) is likely to give a higher validity, reliability and objectivity in the detection of future outbreaks. This is, despite the lower sensitivity and specificity of the CHWs, due to their heightened representativeness of the sample group and timeliness. The results show that especially the poor population, which is 90% of the population of a developing country, benefits from this system. The results show that in case of an outbreak in ´PoorRural´ or ´PoorUrban´ conditions, and with the assumed circumstances, the CHWs will realize an earlier and clearer abbreviation of outbreak cases within ASTER via EMILIA than the doctors will do with a similar amount of outbreak cases.

Every aspect of the proposed model will specifically be discussed hereafter:

Timeliness

Due to a lack of literature about implementation of military based syndromic surveillance systems into civil conditions, it is hard to give concrete probabilities of timeliness of the ASTER system. But due to the literature available, a certain amount of timeliness can be considered. However, this timeliness is an estimated guess and could noticeably deviate enormously after the system is introduced.

According to the report from Konradsen et al. (2000) the time savings established by the CHWs might even be higher as proposed in this thesis. They state in their report that due to seasonal patterns (e.g. crucial agricultural periods) and economic reasons the waiting time for health-seeking behaviour could increase the delay up to 5-7 days. Also the elderly and handicapped persons, depending on help from someone to take them to health care, were found to have a similar high degree of delay in health seeking behaviour (Konradsen et al., 2000). When these people achieve to visit the CHWs with this time saving, the CHWs will have the chance to inject the syndrome data into ASTER via EMILIA with this same time saving compared to doctors.

Sample representativeness and simulation assumptions

The geographic and financial statuses of the population are used as the parameters of representativeness due to the outcomes of the studies from Kruk et al. (2011), Lee et al. (2011), Johnson et al. (2008) and Rossmann (2009). According to this literature, there are far more determinants for people in developing countries in whether or not retrieving formal or informal health care. However, geographical (urban vs. rural) and financial (poor vs. rich) parameters have shown to have the greatest impact in this and are used in the simulation assumptions (Johnson et al., 2008; M. Kruk et al., 2011; Lee et al., 2011; Rossmann, 2009).

Geldsetzer et al. (2014) confirms these assumptions with an extensive literature study concluding that geographical factors are of great influence on health care seeking behaviour. They also state that caregivers in urban areas are more likely to seek health care than care givers in rural areas.

The paper of Geldsetzer et al. (2004) is, on the other hand, less affirmative on the socio-economic aspects we used in our assumptions. They cited several studies wherein cost is given as a reason for not seeking appropriate care. On the other hand, they found a similar amount of papers stating there is no significant association between socio-economic status and health seeking behaviour. Above all, they present other disturbing results concerning CHW usage, derived from different study-results. In certain cases, CHW usage is found to be very low due to the perceived low status of CHW in the communities, and a lack of supplies and medication (Geldsetzer et al., 2014).

The amounts of informal and formal visits per capita are probably higher than they in reality would be. A report from the OECD, Health at a glance 2013, shows that on average, globally, there are 7 annual doctor visits per capita, with highest amount of visits in Korea (14.6) and the least amount of annual visits in South Africa (2.5) (Organization for Economic Cooperation and Development (OECD) Staff, 2013). Compared with the 26.5 informal visits of poor urban people one could say, this amount of informal visits is unrealistic. However, the exact numbers are not used in the model, but the ratio between formal and informal visits is used. This means, that we do not meant to show each urban poor person is annually visiting informal health care 26.5 times, but that this person is more likely to visit informal health care than formal health care.

The next assumption made is about the rural gap which will be overcome entirely by CHWs after they are implemented in the communities, and that they will adopt all former informal visits of the Liberian rural people. Within this assumption cultural and religious rationale are taken into account. In addition, this assumption can partially be confirmed by the results of Yansaneh et al. (2014), which is stating a reduced reliance on traditional treatments in rural Sierra Leone after CHW implementation in these areas (Yansaneh et al., 2014).

Furthermore, in the study of Konradsen et al. (2000) is found that the introduction of a local village treatment in rural Sri Lanka reduced private practitioner visits from 16% to 3% (Konradsen et al., 2000).

Again, similar results were found in a study from Kisia et al. (2012). 26% of the respondents in hard-to-access, poor villages in Kenya were using ´other health care advice/treatment´ (e.g. shop keepers) before the introduction of CHWs in the community. At the endline of this study, the usage of this ´other´ source of health care advice/treatment declined to 2% and the use of CHWs rose from 2% to 35% (Kisia et al., 2012).

Also Seidenberg et al. (2012) confirms our assumptions with their findings. They state that after the introduction of CHWs in rural Zambia home-treatment of several illnesses is reduced from 9.2% to 2%. More striking was their result that the use of traditional/spiritual healers was completely reduced from 3.4% to 0% after CHW introduction (Seidenberg et al., 2012). These numbers gives insight in the capacities of CHWs in reducing the informal health care usage, and the resulting induced usage of CHWs. With this higher usage of CHWs comes the opportunity to collect more representative data about the sample group compared to doctors.

Interesting and ambivalent results are reported in a study from Stekelenburg et al. (2003). Entirely inconsistent with the results from Seidenberg et al. (2012), they found poor performances of CWHs in rural Zambia; CHWs were underutilised and by-passed in case of serious diseases. However, on contrary, they indicate positive appreciation and recognition of CHWs by the communities. They conclude that the poor performances of CHWs are due to the erratic and inconsistent drug supply to CHWs and inadequate, incomplete equipment (Stekelenburg, Kyanamina, & Wolffers, 2003).

In Southwest rural Uganda, the effect of implementation of CHWs seemed to have beneficial results on combined prevalence of several diseases and diarrhoea, resulting in reduced child death outcomes and decreased mortality (Brenner et al., 2011). Also this finding shows the capacities of the

CHW with respect to their ability to reach people in hard-to-access, poor areas in developing countries and implement disease-related data about these people in the EMILIA / ASTER system.

Background noise

The background noise within the simulations is assumed to be similar for CHWs and Doctors. However, there is found that the specificity, resulting in a certain amount of false negatives in this background noise, is different for CHWs or doctors. In addition, also the difference in amount of people reached by CHWs and doctors has an effect on the background noise. Nonetheless there is chosen to use similar background noises for both groups to create a workable and sufficient enough simulation model wherewith it is possible to show the capabilities of CHWs as NRDS & EW system data enterers.

Validity, objectivity and reliability

Preferably the data enterers of a NRDS & EW system should have specificity- and sensitivity-rates as high as possible. However, these values are always in between a trade-off. When sensitivity is heightened, specificity will decline and vice versa. In case of a NRDS & EW system for infectious diseases, it could be argued that great amounts of undetected ill people (a low sensitivity with high degree of undetected cases) will have a disastrous impact on the efficacy of the system by missing outbreaks. However, when specificity is high enough, there are few false positive cases registered. This means, when there is a positive case registered; this case is probably a real one. In addition, if the screened population sample is large and representative enough and the threshold of the system to detect the outbreak is set correctly, a deviation in the amount of positive cases will certainly be detected.

After the estimation of the sensitivity and specificity of CHWs, one could conclude that there is a lack of sensitivity. However, as elucidated above, together with the high specificity and the sample representativeness, this does not have to be a problem. However, the low sensitivity we calculated will miss outbreaks! It cannot be claimed that this sensitivity, which is still a predictive value, is sufficient and good enough. Further research should find out the real sensitivity and specificity based on the questionnaire of EMILIA and the algorithm of ASTER. Interestingly, that the sensitivity and specificity we calculated is quite close to the values found in the report by Darmstadt et al. (2009) for CHWs performances in rural Bangladesh. They found a sensitivity of 73% and a specificity of 98% in classifying VSD by CHW (Darmstadt et al., 2009). This could be a reason to suspect the found values in this thesis to be lower than they will be in reality. It can be considered to be more challengeable for a CHW to recognize a VSD in a new-born child, compared to e.g. recognizing fever in an adult.

Apart from this, it is necessary to improve and maximise sensitivity among CHWs. Hadi (2003) found out that a minimum amount of training and some supervision has improving effects on the sensitivity and specificity of CHW. Supervision has especially great effects on heightening the sensitivity and specificity (Hadi, 2003).

Kelly et al. (2001) made a comprehensive analysis for the depressing results of CHWs with respect to sensitivity and specificity. With these findings taken into account, one is able to maximize CHW sensitivities and specificities. First they state, the complexity of guidelines, must be kept as low as possible. They found out that CHWs had difficulties in managing sick children due to 6 pages long guidelines which contained ambiguities in the algorithm and discrepancies in the drug dosing chart. This resulted in complaints from the CHWs and depressing results with regard to the sensitivity and specificity. The second problem reported in the paper of Kelly et al. (2001), and this can be confirmed with the above statement of Hadi (2013), concerns supervision. They found that only fewer than half of the CHWs had received one-on-one supervision in their study. Next to this, there was found out that the used supervisors in this study did not significantly performed better in tests than CHWs. The third problem was about the fact that CHWs expressed concerns about criticism they received from both care-givers and supervisors. As a result, CHWs were influenced in their performances. The fourth problem they state is the lack of confidence in the guidelines by CHWs themselves (Kelly et al., 2001). Apart from sufficient training, materials & equipment, all the by Kelly et al (2001) stated problems have to be taken into account as well, when there will be made use of CHWs within the EMILIA / ASTER disease outbreak systems.

Simoes et al. (1997) underlines also the importance of bright, clear and objective guidelines. They report for instance depressed sensitivities due to confusion between axillary and rectal temperature thresholds (Simoes et al., 1997).

A study from Mullany et al. (2005) found similar conclusions considering the necessarily objective and clear guidelines. Within a study regarding omphalitis recognition among CHWs, they found out a reduced reliability and validity of CHW-results due to a heightened complexity and subjectivity (e.g. distinguish between grades of swelling) of algorithms (Mullany et al., 2006).

Källander et al. (2006) also stated interesting findings. They found that of the 21% respiratory rate misclassifications of the CHW, approximately one-half still counted a rate of 5 breaths from the golden standard. Most of them used wrong cut-off thresholds, showing that more emphasis on the cut-off rates could have improved the classification (Källander et al., 2006). This is again an evident example for the importance of clear and objective thresholds and questions to optimize CHWs´ performances.

For the quantification of reliability of CHWs, there is constructed a Cohens´ kappa value from different values of several studies; wherein each study contains different cultural and socio-demographical aspects. By using all these values and put them together, with no regard to these different cultural and socio-demographical characteristics, an average Cohens´ kappa value is created. The potential Liberian CHWs will probably have an aberrant kappa value than this average, but due to a lack of knowledge about CHWs in Liberia, there is made use of this average to make a reasonable model simulation.

This average can be confirmed with different findings from different studies. For instance, Otieno-Odawa et al. (2014) found that CHWs in Kenya were able to collect data that had a slight to moderate agreement with their golden standard; data collected by research assistants. These results were registered even better in rural areas compared to peri-urban areas. They found positive kappa values between 0.04 and 0.76, meaning there was agreement. One exception of -0.97 was found. This was explained as it was due to a local measles outbreak at the time of this study (Otieno-Odawa & Kaseje, 2014). In a study of Darmstadt et al. (2009), sensitivity and specificity of CHWs using different algorithms were tested: they found 73% for sensitivity and 98% for specificity with, in the vast majority, Cohens' Kappa values above zero, which thus implies there is agreement between physicians' results and results of CHWs (Darmstadt et al., 2009). Together with the following statement of Otieno-Odawa (2014): "*This means that trained CHWs from communities can collect reliable data, especially on maternal and child health indicators. They are therefore a reliable, alternative source of data collection for community based studies*" (Otieno-Odawa & Kaseje, 2014), one could conclude that the data collection, done by CHWs in rural and urban areas, for community based studies, can be considered as reliable.

5.2. Limitations of the research

Within this thesis it was chosen to make use of an outbreak simulation model, which is based on a list of assumptions and wherein the ASTER-system detects the outbreaks. This is done because there is insufficient time to wait for outbreaks to happen and to be detected by the proposed ASTER / EMILIA system. In this respect, simulating multiple outbreaks is a more feasible approach for testing the lower qualification level data enterers for NRDS & EW systems. However, because it is a simulation, the reality may differ from the proposed. In which amount this will differ, is hard to say. Future research should find out if the proposed matter in this thesis is comparable with reality after implication of this system in a developing country. Within this simulation an abundance of assumptions are made. To make the model feasible and usable there is made use of assumptions which tend to be realistic. However, some assumptions have been used to limit the models complexity. Due to insufficient time to spend on the development of this model, and with the usability of the model in mind, this model tends to be sufficient enough to test the CHWs EMILIA / ASTER system. To use a quote of George E.P. Boxer to strengthen this conclusion; “Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful”.

To quantify the representativeness of the sample group taken by the CHWs, there is made use of only two different determinants. According to the literature and as stated above (Geldsetzer et al., 2014; Johnson et al., 2008; Rossmann, 2009), there are far more determinants which influences health seeking behaviour and thus the possible use of CHWs. Again, future research should discover what determinants influences peoples´ health care seeking behaviour for CHWs explicitly and the ranges wherein CHWs can provide in this behaviour.

The values for specificity and sensitivity are compiled with different reports about validity and reliability of CHWs covering a large variable of cultural, social and background characteristics. Furthermore, the values were considering the recognition of different diseases, signs or symptoms. To reveal the actual sensitivity and specificity of CHWs´ sign and symptom recognition, in the theatre of rural and urban areas within a developing country, should as well be investigated by future research.

5.3. SWOT-Analysis implementing proposed approach

To evaluate the possibilities and limitations of the pilot study a strategic marketing planning process, also known as an established project management tool, will be applied on this thesis´ results. For this, there is chosen to perform a SWOT analysis, known as an effective and clear management tool extensively used in project management and marketing planning processes (Ayub, Razzaq, Aslam, & Iftekhar, 2013).

Strengths & Weaknesses;

The available prototype of the smart phone application EMILIA, together with the fact that in the most African countries the vast majority of the population is cellular or mobile subscribers[1] (superscripts refers to statements in table 6), is a great strength in this thesis (Leo, Morello, & Ramachandran, 2015). In addition, this number of mobile or cellular subscribers is raised enormously in the past decade in African countries and will further rise in the upcoming future (Mungai, 2015). E.g. mobile phone coverage among the Liberian population has increased in a time span of 7 years from 5% to 58%. In Mali it raised from 5.8% to 87.5% in this same period (Leo et al., 2015). Together with the rise in attention for phone network coverage in rural Africa by some major Asian telephone companies, a high rate of mobile connectivity in rural Africa is established[2] (IBTimes Staff Reporter, 2013; Mungai, 2015).

The use of CHWs can also be considered as a notable strength. CHWs are low qualified, non-professional volunteers. They live in the communities of rural and urban parts of a country and are available to collect reliable and valid data. This makes them easy to gather and to train, resulting in a high degree of availability of data enterers[3] (Van Lerberghe, 2008).

The owners of the EMILIA application (MEDINTEL, Germany) and the ASTER system (Meynard, Marseille) must agree and cooperate when these systems will be integrated and evaluated extensively[4].

A major point of attention was the necessity to make various assumptions in order to create a useful and workable simulation model. These assumptions were necessary to make the simulation model workable and feasible and most of the assumptions approach reality. However, some assumptions are not entirely akin the truth, but this was done due to make the model more workable[5]. Other weaknesses can be based on for instance, the inadequate electricity coverage of rural parts of the

Strengths	**Weaknesses**
• The availability of the prototype **EMILIA application**. • [1]**Mobile phone coverage** in Africa • [2]**Phone network** coverage Africa • [3]**Availability of data enterers** • **Feedback:** CHWs can receive feedback via the EMILIA application to improve their performances or to react to local events. • **Timeliness**: Is heightened with the CHWs as data enterers • **Representativeness**: Of the sample group of CHWs will be higher	• [4]**Agreement and cooperation of the owners of both systems** • **Reliability:** Is lower than the prevailing medical qualified data enterers • **Sensitivity:** Is lower than the prevailing medical qualified data enterers • **Specificity:** Is lower than the prevailing medical qualified data enterers • [5]**Assumptions:** Qualitative & Quantitative • [6]**Electricity coverage** • [7]**Financial resources** • [8]**Can EMILIA be linked to ASTER?** • **Physical reachability** of CHWs for e.g. supervision or follow-up training
Opportunities	**Threats**
• [9]**Roll out** in Africa after a successful pilot-study and sufficient evaluation • **Prevent future outbreaks** and effectively protect susceptible and vulnerable groups in developing post-conflict countries of the bottom billion	• **Failing results** of CHWs´ competences regarding reliability, sensitivity, specificity and sample representativeness • [10]**Resignation/retirement** of CHWs after training period or after introduction in the communities • **Lack of sponsors or partners**, resulting in a lack of money to effectively train and implement CHWs in the communities with the EMILIA application to fill the ASTER system.

Table 6: Overview of SWOT-analysis of this thesis and the overall proposed project

African continent[6] (Leo et al., 2015). However, due to today's´ high complex technological developments there can be thought of mobile devices for solar charge or wind energy to solve this problem. In case of unavailability of technical solutions, there can as well be made use of old fashioned diesel generators to generate electric power.

Another point of attention for the implementation of this approach will be concerning the availability of financial resources. The logistics, education, training, supervision and materials for CHW equipment (e.g. thermometers) require certain amounts of financial capacities. For the development of a successful pilot-study and in further future, the roll-out in Africa, there must be thought of a major source of money or sponsor[7].

This thesis is built upon the assumption that the prototype application EMILIA can be integrated to the ASTER system. In consultation with one of the co-founders of EMILIA it is mentioned that this is possible. The extent to which this is possible and how this should be done has still to be found out by IT-specialists[8].

Opportunities & Threats;

Assuming a successful pilot-study in Liberia and Guinea, with clear positive outcomes regarding the overall competences of the system, it can be considered to establish a roll-out in all African countries in order to be able to protect a great part of the susceptible and vulnerable population of the African continent[9].

Threats that have to be minimized and prevented include the resignation/retirement of trained and implemented CHWs. Mehnay et al. (1997) describes high amounts of CHWs that resign after they are introduced in the communities (Mehnaz, Billoo, Yasmeen, & Nankani, 1997). A high retirement rate will result in wasted money and effort, and finally in an inoperable, incomplete CHW network[10].

5.4. Discussion of Public Health/One Health implications

Bravata et al. (2007) describes three main features required for bioterrorism surveillance systems. These systems are able to detect possible bioterrorism attacks, but they are mainly used for disease outbreak surveillance. The concerned features these systems certainly need to contain exist of: Timeliness, high specificity and sensitivity, and routine analysis and presentation of the data (Bravata et al., 2004). This thesis shows that systems like the ASTER/EMILIA system with use of low qualification level data enterers are able to fulfil in all of these features in a certain high extent.

The need for such a system is stressed by Bill Gates in a letter to the New England Journal of Medicine. Herein, it is actively asked for cooperation between military forces and civil organizations. Time should be spend on the development of a readily available task-force, able to prevent and control future outbreaks. This in reaction to what happened within the Ebola outbreak of 2014 (Gates, 2015). With the results of this thesis, there is made a clear example of the possible fruitful cooperation between civil and military apparatus and personnel in the detection and control of imminent future disease outbreaks of infectious diseases.

In further future perspective, there could also be thought of a veterinarian application of this system. Animals, for instance cattle and poultry, are of great importance for rural societies regarding financial and cultural status. There is much and intensive contact with these animals, resulting in a high degree of potential exposure and the availability for diseases to spread easily. A veterinary NRDS & EW system could result in an even more timeliness and sensitive system, due to the fact that most infectious diseases are zoonoses. Zoonoses are pathogens with the ability to spread and replicate among animals, and have the possibility to spread to humans (Jones et al., 2008). In epidemiological considerations, the human incubation time is normally an unusable and problematic period (due to the possibility to spread among the population without being detected) wherein diseases will not be noticed nor detected. With use of a veterinarian application of the proposed system it will be able to detect possible threatening infectious diseases in animals. With this, the diseases will be detected before they reach the human population and have the possibility to infect and spread among people.

The representativeness of the sample group of CHWs found in this thesis also emphasizes the importance of Primary Health care in developing countries for the more vulnerable group of people (Van Lerberghe, 2008). As stated by Ruger & Kim (2006) the poorest people are the most affected by a lack of access to health care (Ruger & Kim, 2006). In addition, several authors report rural people have a lower accessibility to health care (Johnson et al., 2008; M. Kruk et al., 2011; Lee et al., 2011; Rossmann, 2009). With this approach of CHWs implementation into communities of developing countries, this rural-health gap, as stated by Lee et al. (2011), can be overcome and the more vulnerable people will have better access to health care.

5.5. General conclusion of the study

With regard to the found results and taken the discussed limitations into account, this study is generalizable for implication in West Africa. The assumptions made in this thesis´ model were reviewed and evaluated by an expert panel from MEDINTEL in Munich and Veterinary Medicine of the Utrecht University containing years of considerable experiences with regard to tropical and veterinary medicine, epidemiology, common knowledge about (West-) Africa, Post-Conflict health and One-Health sciences. According to this expert panel the assumptions and the model turned out to be rather complete, realistic and workable.

In general, the overall conclusion of this thesis considers the confirmation of the validity, reliability and objectivity of CHWs as data enterers in a NRDS & EW system. Within these systems, there can be made use of in-field low qualification level data enterer (e.g. CHWs), within the assumed circumstances, to properly detect and report outbreak cases. With CHWs as data enterer, a valid, reliable and objective NRDS & EW system will be created with a higher timeliness in detecting outbreaks. With the application of this EMILIA / ASTER system in developing (post-conflict) countries (e.g. Liberia), their vulnerable and susceptible populations can be protected against imminent future outbreaks.

5.6. Way ahead

Findings of this study could be tested in a pilot study before a comprehensive study and a possible roll-out in order to test the feasibility of this approach in the praxis. The approach could, for example, be tested and compared in two different settings like Guinea and Liberia which showed different epi-curves as well as political and socio-cultural dynamics during the 2014 Ebola-outbreak. This study should be performed over a one-year period to include all seasonal dimensions. Primarily, a short pre-pilot study should be conducted to assess the SWOT-analysis in the previous section of this paper. In this pre-pilot there should be focused on the possibility to train the personnel sufficiently and the ability to maintenance the hardware. Also, the possibility and sustainability of the proposed mobile devices in the field should be tested, especially considering the poor electricity services and the mobile phone network coverage.

In order to do so, there should be developed a clear, objective questionnaire first. This questionnaire, with which it is possible to import required data from the field into the ASTER system, should be developed, tested and evaluated. CHWs will be able to fill in these questionnaires via the EMILIA application, developed by the German military armed forces. As discussed before, this questionnaire should be kept as objective as possible and the questions have to be clear and self-explanatory. This could be achieved by using simple tasks only and clear thresholds. Furthermore, there should be made use of closed questions, wherein only two answer possibilities are given (e.g. yes or no). There could also be thought of instruction images or videos for difficult but necessary tasks to be performed. Only when all these aspects are taken into account, every CHW is able to work with the questionnaire.

6. Recommendations

In general

NRDS & EW systems, for instance ASTER, can be used for the detection of future outbreaks of infectious diseases. With a lower qualification data enterer, e.g. CHWs, it will be possible to make these systems more valid and reliable, due to a higher representativeness and timeliness and declined, but sufficient enough, levels of sensitivity and specificity. Altogether, this EMILIA / ASTER system with Community Health Worker data enterers will have a heightened validity, reliability and objectivity due to the sample group representativeness and timeliness. The integration of these systems should be a first priority, before further research can be carried out.

This study

The approach and results of this study should be reviewed and reconsidered by external parties. In a next step, the simulation proposed in this thesis will be reviewed and where necessary improved and expanded. A mathematician student from Hamburg will achieve in this in the following period and will try to get these simulations running. After this, the approach could be tested in further research within a pilot study as described in earlier paragraphs. Therefore, partners have to be found with varying capacities in the field of conducting such a one-year pilot study in developing post-conflict countries like Liberia and Guinea.

West Africa

The literature research done about representativeness revealed different voids in the health care system and its accessibility for the Liberian population. With the Ebola outbreak of 2014 etched in memory, these voids in health care will result in further outbreaks with diseases like malaria, measles and typhus. New outbreaks are already occurring and the result of failing vaccination programs and distribution of bed nets due to the Ebola outbreak (Walker et al., 2015). To protect the population of the by the Ebola outbreak affected countries for further miserable and mortalities, quick effective actions are required in the near future.

7. References

African Development Bank. (2014). *Millennium development goals (MDGs) report 2014.* (MDG report).African Development Bank Group.

Aissatou, B. A. H. (2014, 03/14/2014). Santé : Une étrange fièvre se déclare à macenta, plusieurs cas de morts signalés…. *Africaguinee.Com - Site Officiel D'Informations Sur La Guinée Et L'Afrique*

Ayub, A., Razzaq, A., Aslam, M. S., & Iftekhar, H. (2013). A conceptual framework on evaluating SWOT analysis as the mediator in strategic marketing planning through marketing intelligence. *European Journal of Business and Social Sciences, 2*(1), 91-98.

Bravata, D. M., McDonald, K. M., Smith, W. M., Rydzak, C., Szeto, H., Buckeridge, D. L., . . . Owens, D. K. (2004). Systematic review: Surveillance systems for early detection of bioterrorism-related diseases. *Annals of Internal Medicine, 140*(11), 910-922. doi:10.7326/0003-4819-140-11-200406010-00013

Brenner, J. L., Kabakyenga, J., Kyomuhangi, T., Wotton, K. A., Pim, C., Ntaro, M., . . . Kayizzi, J. (2011). Can volunteer community health workers decrease child morbidity and mortality in southwestern uganda? an impact evaluation. *PLoS ONE, 6*(12), e27997. doi:10.1371/journal.pone.0027997

Carneiro, H., & Mylonakis, E. (2009). Google trends: A web-based tool for real-time surveillance of disease outbreaks. *Clinical Infectious Diseases, 49*(10), 1557-64. doi:10.1086/630200

Collier, P. (2004). *Development and conflict.* ().Centre for the Study of African.

Collier, P. (2007). *The bottom billion: Why the poorest countries are failing and what can be done about it* Oxford University Press.

Dailey, L., Watkins, R. E., & Plant, A. J. (2007). Timeliness of data sources used for influenza surveillance. *Journal of the American Medical Informatics Association : JAMIA, 14*(5), 626-631. doi:M2328 [pii]

Darmstadt, G. L., Baqui, A. H., Choi, Y., Bari, S., Rahman, S. M., Mannan, I., . . . Chang, S. (2009). Validation of community health workers' assessment of neonatal illness in rural bangladesh. *Bulletin of the World Health Organization, 87*(1), 12-19. doi:10.1590/S0042-96862009000100009

Daumerie, D., Savioli, L., Crompton, D. W. T., & Peters, P. (2010). *Working to overcome the global impact of neglected tropical diseases: First WHO report on neglected tropical diseases* World Health Organization.

Degefie, T., Marsh, D., Gebremariam, A., Tefera, W., Osborn, G., & Waltensperger, K. (2009). Community case management improves use of treatment for childhood diarrhea, malaria and pneumonia in a remote district of ethiopia. *Ethiopian Journal of Health Development, 23*(2) doi:10.4314/ejhd.v23i2.53227

Delacollette, C., Van der Stuyft, P., & Molima, K. (1996). Using community health workers for malaria control: Experience in zaire. *Bulletin of the World Health Organization, 74*(4), 423-30.

Dixon, M. G., & Schafer, I. J. (2014). Ebola viral disease outbreak—West africa, 2014. *MMWR Morb Mortal Wkly Rep, 63*(25), 548-551.

Dunyo, S. K., Afari, E. A., Koram, K. A., Ahorlu, C. K., Abubakar, I., & Nkrumah, F. K. (2000). Health centre versus home presumptive diagnosis of malaria in southern ghana: Implications for home-based care policy. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 94*(3), 285-8.

Feldmann, H., & Geisbert, T. W. (2011). Ebola haemorrhagic fever. *The Lancet, 377*(9768), 849-862. doi:10.1016/S0140-6736(10)60667-8

Flahault, A., Blanchon, T., Dorléans, Y., Toubiana, L., Vibert, J. F., & Valleron, A. J. (2006). Virtual surveillance of communicable diseases: A 20-year experience in france. *Statistical Methods in Medical Research, 15*(5), 413-21.

Gates, B. (2015). The next Epidemic—Lessons from ebola. *New England Journal of Medicine, 372*(15), 1381-1384.

Geldsetzer, P., Williams, T. C., Kirolos, A., Mitchell, S., Ratcliffe, L. A., Kohli-Lynch, M. K., . . . Campbell, H. (2014). The recognition of and care seeking behaviour for childhood illness in developing countries: A systematic review. *PLoS ONE, 9*(4), e93427. doi:10.1371/journal.pone.0093427

Ginsberg, J., Mohebbi, M. H., Patel, R. S., Brammer, L., Smolinski, M. S., & Brilliant, L. (2009). Detecting influenza epidemics using search engine query data. *Nature, 457*(7232), 1012-1014. doi:10.1038/nature07634

Giorgetti, C. (2012). International health emergencies in failed and failing states. *Geophysical Journal International, 44*, 1347.

Gomes, M. F. C., Pastore Y Piontti, A., Rossi, L., Chao, D., Longini, I., Halloran, M. E., & Vespignani, A. (2014). Assessing the international spreading risk associated with the 2014 west african ebola outbreak. *PLoS Currents, 6* doi:10.1371/currents.outbreaks.cd818f63d40e24aef769dda7df9e0da5

Gostin, L. O., & Friedman, E. A. (2015). A retrospective and prospective analysis of the west african ebola virus disease epidemic: Robust national health systems at the foundation and an empowered WHO at the apex. *The Lancet, 385*(9980), 1902-1909. doi: http://dx.doi.org.proxy.library.uu.nl/10.1016/S0140-6736(15)60644-4

Hadi, A. (2003). Management of acute respiratory infections by community health volunteers: Experience of bangladesh rural advancement committee (BRAC). *Bulletin of the World Health Organization, 81*(3), 183. doi:10.1590/S0042-96862003000300008

Haken, N., Messner, J. J., Hendry, K., Taft, P., Lawrence, K., Brisard, L., & Umaña, F. (2014). *Fund for peace; fragile states index 2014.* (Annual ranking report No. July-August). Washington: Foreign People.

Heymann, D. L., Chen, L., Takemi, K., Fidler, D. P., Tappero, J. W., Thomas, M. J., . . . Rannan-Eliya, R. P. (2015). Global health security: The wider lessons from the west african ebola virus disease epidemic. *The Lancet, 385*(9980), 1884-1901. doi:http://dx.doi.org.proxy.library.uu.nl/10.1016/S0140-6736(15)60858-3

IBTimes Staff Reporter. (2013, 29/08). Rural africa, meet 3G: Asian telecoms using satellites to increase coverage on continent. *International Business Times*

Jafarpour, N., Precup, D., Izadi, M., & Buckeridge, D. (2013). Using hierarchical mixture of experts model for fusion of outbreak detection methods. *AMIA ...Annual Symposium Proceedings, 2013*, 663-9.

Jefferson, H., Dupuy, B., Chaudet, H., Texier, G., Green, A., Barnish, G., . . . Meynard, J. B. (2008). Evaluation of a syndromic surveillance for the early detection of outbreaks among military personnel in a tropical country. *Journal of Public Health (Oxford, England), 30*(4), 375-383. doi:10.1093/pubmed/fdn026 [doi]

Johnson, K., Asher, J., Rosborough, S., Raja, A., Panjabi, R., Beadling, C., & Lawry, L. (2008). Association of combatant status and sexual violence with health and mental health outcomes in postconflict liberia. *The Journal of the American Medical Association, 300*(6), 676-690. doi:10.1001/jama.300.6.676

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., & Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature, 451*(7181), 990-993.

Källander, K., Tomson, G., Nsabagasani, X., Sabiiti, J. N., Pariyo, G., & Peterson, S. (2006). Can community health workers and caretakers recognise pneumonia in children? experiences from western uganda. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 100*(10), 956-963. doi:10.1016/j.trstmh.2005.11.004

Kelly, J. M., Osamba, B., Garg, R. M., Hamel, M. J., Lewis, J. J., Rowe, S. Y., . . . Deming, M. S. (2001). Community health worker performance in the management of multiple childhood illnesses: Siaya district, kenya, 1997-2001. *American Journal of Public Health, 91*(10), 1617-24.

Kisia, J., Nelima, F., Otieno, D. O., Kiilu, K., Emmanuel, W., Sohani, S., . . . Akhwale, W. (2012). Factors associated with utilization of community health workers in improving access to malaria treatment among children in kenya. *Malar J, 30*(11), 1.

Konradsen, F., Amerasinghe, P. H., Perera, D., Van der Hoek, W., & Amerasinghe, F. P. (2000). A village treatment center for malaria: Community response in sri lanka. *Social Science & Medicine, 50*(6), 879-889. doi:10.1016/S0277-9536(99)00378-0

Kruk, M. E., Rockers, P. C., Williams, E. H., Varpilah, S. T., Macauley, R., Saydee, G., & Galea, S. (2010). Availability of essential health services in post-conflict liberia. *Bulletin of the World Health Organization, 88*(7), 527-534. doi:10.1590/S0042-96862010000700012

Kruk, M., Rockers, P., Varpilah, S. T., & Macauley, R. (2011). Which doctor?: Determinants of utilization of formal and informal health care in postconflict liberia. *Medical Care, 49*(6), 585-91. doi:10.1097/MLR.0b013e31820f0dd4

Lee, P. T., Kruse, G. R., Chan, B. T., Massaquoi, M. B. F., Panjabi, R. R., Dahn, B. T., & Gwenigale, W. T. (2011). An analysis of liberia's 2007 national health policy: Lessons for health systems strengthening and chronic disease care in poor, post-conflict countries. *Globalization and Health, 7*(37)

Leo, B., Morello, R., & Ramachandran, V. (2015). *The face of african infrastructure: Service availability and citizens´ demands.* (Working Paper No. 154).AfroBarometer.

Lober, W., Karras, B., Wagner, M., Overhage, J. M., Davidson, A., Fraser, H., . . . Tsui, F. (2002). Roundtable on bioterrorism detection: Information system-based surveillance. *Journal of the American Medical Informatics Association, 9*(2), 105-15.

Lombardo, J. S., Burkom, H., & Pavlin, J. (2004). ESSENCE II and the framework for evaluating syndromic surveillance systems. *Morbidity and Mortality Weekly Report,* , 159-165.

Lori, J. R., & Boyle, J. S. (2011). Cultural childbirth practices, beliefs, and traditions in postconflict liberia. *Health Care for Women International, 32*(6), 454-473. doi:10.1080/07399332.2011.555831

MacNeil, A., & Rollin, P. E. (2012). Ebola and marburg hemorrhagic fevers: Neglected tropical diseases? *PLoS Neglected Tropical Diseases, 6*(6), e1546.

Mehnaz, A., Billoo, A. G., Yasmeen, T., & Nankani, K. (1997). Detection and management of pneumonia by community health workers--a community intervention study in rehri village, pakistan. *Journal of the Pakistan Medical Association, 47*(2), 42-5.

Meynard, J., Chaudet, H., Green, A., Jefferson, H., Texier, G., Webber, D., . . . Boutin, J. (2008a). Proposal of a framework for evaluating military surveillance systems for early detection of outbreaks on duty areas. *BMC Public Health, 8*, 146. doi:10.1186/1471-2458-8-146

Meynard, J., Chaudet, H., Texier, G., Ardillon, V., Ravachol, F., Deparis, X., . . . Boutin, J. (2008b). Value of syndromic surveillance within the armed forces for early warning during a dengue fever outbreak in french guiana in 2006. *BMC Medical Informatics and Decision Making, 8*, 29. doi:10.1186/1472-6947-8-29

Meynard, J., Chaudet, H., Texier, G., Dupuy, B., Queyriaux, B., Pellegrin, L., . . . Boutin, B. J. (2009). Advantages and limits of real-time epidemiological surveillance during military deployments: The experience of the french armed forces. *Military Medicine, 174*(10), 1068-1074. doi:10.7205/MILMED-D-04-7408

Meynard, J., Chaudet, H., Varcol, C., Decker, E., Andresen, S., Holterm, H., . . . Maza, J. P. (2010). Evaluation of the NATO disease surveillance system by its users in kosovo in 2008. *Military Medicine, 175*(7), 466-468. doi:10.7205/MILMED-D-09-00122

Mubila, M., Lannes, L., & Ben Aissa, M. S. (2012). *Briefing notes for AfDB's long-term strategy.
Briefing note 5: Income inequalty in africa.* (Briefing Note No. 5).African Development Bank Group.

Mullany, L. C., Darmstadt, G. L., Katz, J., Khatry, S. K., LeClerq, S. C., Adhikari, R. K., & Tielsch, J. M. (2006). Development of clinical sign based algorithms for community based assessment of omphalitis. *Archives of Disease in Childhood.Fetal and Neonatal Edition, 91*(2), F99-104. doi:10.1136/adc.2005.080093

Mungai, C. (2015, 03/03). The mobile phone comes first in africa; before electricity, water, toilets or even food. *Mail & Guardian Africa*

Neyeloff, J. L., Fuchs, S. C., & Moreira, L. B. (2012). Meta-analyses and forest plots using a microsoft excel spreadsheet: Step-by-step guide focusing on descriptive data analysis. *BMC Research Notes, 5*, 52-0500-5-52. doi:10.1186/1756-0500-5-52 [doi]

Office for the Coordination of Humanitarian Affairs (OCHA), U.N. (2014). Ebola virus disease outbreak-overview of needs and requirements. 16 september 2014.

Organization for Economic Cooperation and Development (OECD) Staff. (2013). *Health at a glance 2013: OECD indicators* OECD.

Otieno, C. F., Kaseje, D., & Githae, M. N. (2012). Reliability of community health worker collected data for planning and policy in a peri-urban area of kisumu, kenya. *Journal of Community Health, 37*(1), 48-53. doi:10.1007/s10900-011-9414-2

Otieno-Odawa, C. F., & Kaseje, D. O. (2014). Validity and reliability of data collected by community health workers in rural and peri-urban contexts in kenya. *BMC Health Services Research, 14*(Suppl 1), S5. doi:10.1186/1472-6963-14-S1-S5

Pagnoni, F., Convelbo, N., Tiendrebeogo, J., Cousens, S., & Esposito, F. (1997). A community-based programme to provide prompt and adequate treatment of presumptive malaria in children. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 91*(5), 512-7.

Pandey, M. R., Daulaire, N. M. P., Starbuck, E. S., Houston, R. M., & McPherson, K. (1991). Reduction in total under-five mortality in western nepal through community-based antimicrobial treatment of pneumonia. *The Lancet, 338*(8773), 993-997. doi:10.1016/0140-6736(91)91847-N

Pellegrin, L., Gaudin, C., Bonnardel, N., & Chaudet, H. (2010). Collaborative activities during an outbreak early warning assisted by a decision-supported system (ASTER). *International Journal of Human-Computer Interaction, 26*(2-3), 262-277. doi:10.1080/10447310903499062

Penchansky, R., & Thomas, J. W. (1981). The concept of access: Definition and relationship to consumer satisfaction. *Medical Care, 19*(2), 127-140.

Perkins, B. A., Zucker, J. R., Otieno, J., Jafari, H. S., Paxton, L., Redd, S. C., . . . Campbell, C. C. (1997). Evaluation of an algorithm for integrated management of childhood illness in an area of kenya with high malaria transmission. *Bulletin of the World Health Organization, 75 Suppl 1*, 33-42.

ProMED-mail post. (2014a, 22/03/2014). UNDIAGNOSED VIRAL HEMORRHAGIC FEVER - GUINEA (02): EBOLA CONFIRMED.

ProMED-mail post. (2014b, 19/03/2014). UNDIAGNOSED VIRAL HEMORRHAGIC FEVER - GUINEA: (NZEREKORE) REQUEST FOR INFORMATION.

Rossmann, K. (2009). *Acces to health care in djibouti for displaced and marginalised people.* (Unpublished MSc in Public Health in Developing Countries). London School of Hygiene & Tropical Medicine, London.

Ruger, J. P., & Kim, H. J. (2006). Global health inequalities: An international comparison. *Journal of Epidemiology and Community Health, 60*(11), 928-936. doi:60/11/928 [pii]

Seidenberg, P., Hamer, D., Iyer, H., Pilingana, P., Siazeele, K., Hamainza, B., . . . Yeboah Antwi, K. (2012). Impact of integrated community case management on health-seeking behavior in rural zambia. *The American Journal of Tropical Medicine and Hygiene, 87*(5 Suppl), 105-10. doi:10.4269/ajtmh.2012.11-0799

Simoes, E. A., Desta, T., Tessema, T., Gerbresellassie, T., Dagnew, M., & Gove, S. (1997). Performance of health workers after training in integrated management of childhood illness in gondar, ethiopia. *Bulletin of the World Health Organization, 75 Suppl 1*, 43-53.

Stekelenburg, J., Kyanamina, S. S., & Wolffers, I. (2003). Poor performance of community health workers in kalabo district, zambia. *Health Policy, 65*(2), 109-118. doi:10.1016/S0168-8510(02)00207-5

The Lancet. (2015). Rural health inequities: Data and decisions. *The Lancet, 385*(9980), 1803. doi:http://dx.doi.org.proxy.library.uu.nl/10.1016/S0140-6736(15)60910-2

Tulloch, O., Theobald, S., Morishita, F., Datiko, D. G., Asnake, G., Tesema, T., . . . Yassin, M. A. (2015). Patient and community experiences of tuberculosis diagnosis and care within a community-based intervention in ethiopia: A qualitative study. *BMC Public Health, 15*(1), 187. doi:10.1186/s12889-015-1523-x

UNICEF. (2013). UNICEF, at a glance: Liberia. statistics. Retrieved from http://www.unicef.org/infobycountry/liberia_statistics.html

Van Lerberghe, W. (2008). *The world health report 2008: Primary health care: Now more than ever* World Health Organization.

Walker, P. G., White, M. T., Griffin, J. T., Reynolds, A., Ferguson, N. M., & Ghani, A. C. (2015). Malaria morbidity and mortality in ebola-affected countries caused by decreased health-care capacity, and the potential effect of mitigation strategies: A modelling analysis. *The Lancet Infectious Diseases,*

Weber, M. W., Mulholland, E. K., Jaffar, S., Troedsson, H., Gove, S., & Greenwood, B. M. (1997). Evaluation of an algorithm for the integrated management of childhood illness in an area with seasonal malaria in the gambia. *Bulletin of the World Health Organization, 75 Suppl 1*, 25-32.

WHO/Global Alert and Response (GAR). (2014, 23/03/2014). Ebola Virus Disease in guinea - disease outbreak news. Retrieved from http://www.who.int/csr/don/2014_03_23_ebola/en/

WHO/Global Alert and Response (GAR). (2015). Origins of the 2014 ebola epidemic - one year into the ebola epidemic - january 2015. Retrieved from http://www.who.int/csr/disease/ebola/one-year-report/virus-origin/en/

World Health Organization. (2014). *Atlas of african health statistics 2014: Health situation analysis of african region* World Health Organization.

Yansaneh, A. I., Moulton, L. H., George, A. S., Rao, S. R., Kennedy, N., Bangura, P., . . . Diaz, T. (2014). Influence of community health volunteers on care seeking and treatment coverage for common childhood illnesses in the context of free health care in rural sierra leone. *Tropical Medicine & International Health, 19*(12), 1466-1476. doi:10.1111/tmi.12383

Acknowledgements

I would like to thank…

Dr. Joris Wijnker, for suggesting this thesis subject and giving me the opportunity to participate in this project. And of course for the tremendous amount of effort he put in reviewing this thesis as a supportive and very valuable enthusiastic personal tutor.

Dr. Katalyn Rossmann, for broadening my perspective of One-Health enormously and introducing me into the topic of Conflict & Health. Also a great pillar in the evolution of the subject of this thesis and the thesis itself and furthermore always an interesting and devoted partner of discussion. Next to Katalyn I would like to thank **Freia** for her, sometimes annoying, but certainly most of the times bright and happy faces and noises.

Dr. Christian Janke, for having the missing mathematical insight needed to complete this thesis and always be the one available to extensively control, discuss and challenge the made assumptions, calculations and interpretations. Furthermore for introducing me to ASTER and to the world of syndromic surveillance and Near-real time disease surveillance systems.

Dr. Jacob Boreel, for being the man that kept our ideas rational and pragmatic within the first developments of this thesis and the overall project. Additionally, for the valuable tips to finalize this thesis with (hopefully) good result.

Dr. Armin Fügenschuh, for travelling to Munich to discuss the mathematical problems encountered during this thesis and helping to solve them.

Silke Ruhl, for being a nice and cheerful roommate within the offices of MEDINTEL.

Dennis Kergl, for travelling to Munich to discuss and to solve the IT-related problems encountered during this thesis.

Robin Mathea, for travelling to Munich to help to solve the difficult mathematical calculations and critically reviewing the simulation model and background noise.

Department MEDINTEL, Munich; Yasmine, Nadine, Uli, Andreas and others for the always pleasant, social breakfasts in the morning, the delicious lunches made in the afternoon and for the support were it was needed during my time in Munich. And also **Bertie,** for the comprehensive ASTER introduction and explanation.

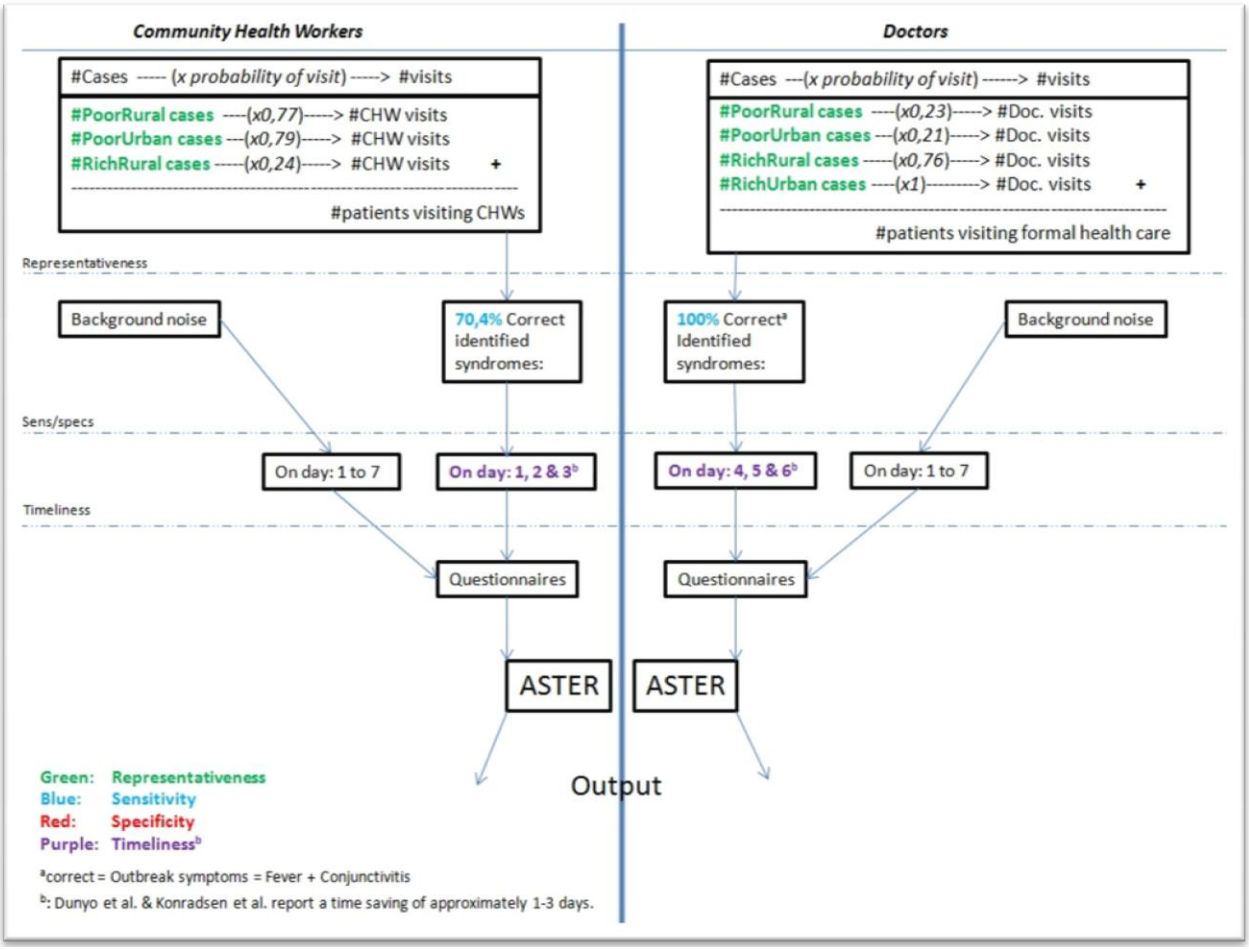
Maaike Mourik, for everything; too many to list it all.

8. Appendices

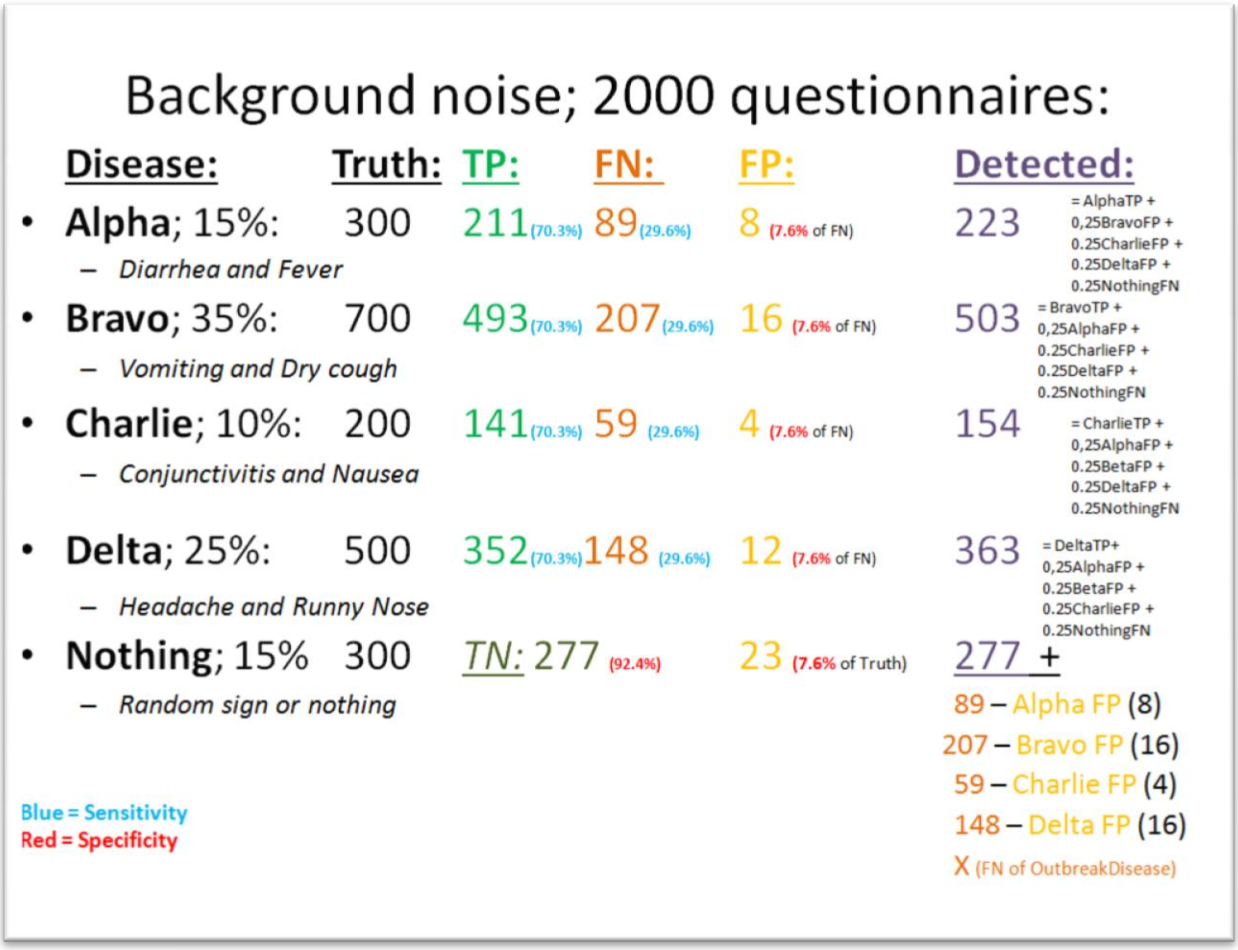
APPENDIX A: *Table 7*, literature overview used in the mini meta-analysis for composition of CHWs sensitivity and specificity:

First Author	Second Author	Title	Year of publication	Journal	Used for:
Weber, W.M.	Mulholland, E.K.	Evaluation of an algorithm for the integrated management of childhood illness in an area with seasonal malaria in the Gambia	1996	Bulletin of World Health Organization	Sensitivity & Specificity
Simoes, E.A.F.	Desta, T.	Performance of health workers after training in integrated management of childhood illness in Gondar, Ethiopia	1997	Bulletin of World Health Organization	Sensitivity & Specificity
Perkins, B.A.	Zucker, J.R.	Evaluation of an algorithm for integrated management of childhood illness in an area of Kenya with high malaria transmission	1997	Bulletin of World Health Organization	Sensitivity & Specificity
Hadi, A.	-	Management of acute respiratory infections by community health volunteers; experience of Bangladesh Rural Advancement Committee	2003	Bulletin of World Health Organization	Sensitivity & Specificity
Mullany, L.C.	Darmstadt, G.L.	Development of clinical sign based algorithms for community based assessment of omphalitis	2006	Archives of Disease in Childhood. Fetal and Neonatal Edition	Sensitivity
Källander, K.	Tomson, G.	Can community health workers and caretakers recognize pneumonia in children	2006	Transactions of the Royal Society of Tropical Medicine and Hygiene	Sensitivity & Specificity
Darmstadt, G.L.	Baqui, A.H.	Validation of community health workers' assessment of neonatal illness in rural Bangladesh	2009	Bulletin of World Health Organization	Sensitivity & Specificity
Otieno-Odawa, C.F.	Kaseje, D.O.	Validity and reliability of data collected by community health workers in rural and peri-urban contexts in Kenya	2014	BMC health services research	Sensitivity & Specificity

APPENDIX B: ***Figure 2*, Flow chart overview of outbreak simulation model**



APPENDIX C: ***Figure 3,*** **overview concerning background noise for outbreak simulation model**



APPENDIX D: ***Figures 4 – 12*****, visualization of outbreak simulation and detection.**

Figure 4, Simulation of an outbreak (10 cases) in a poor rural area.

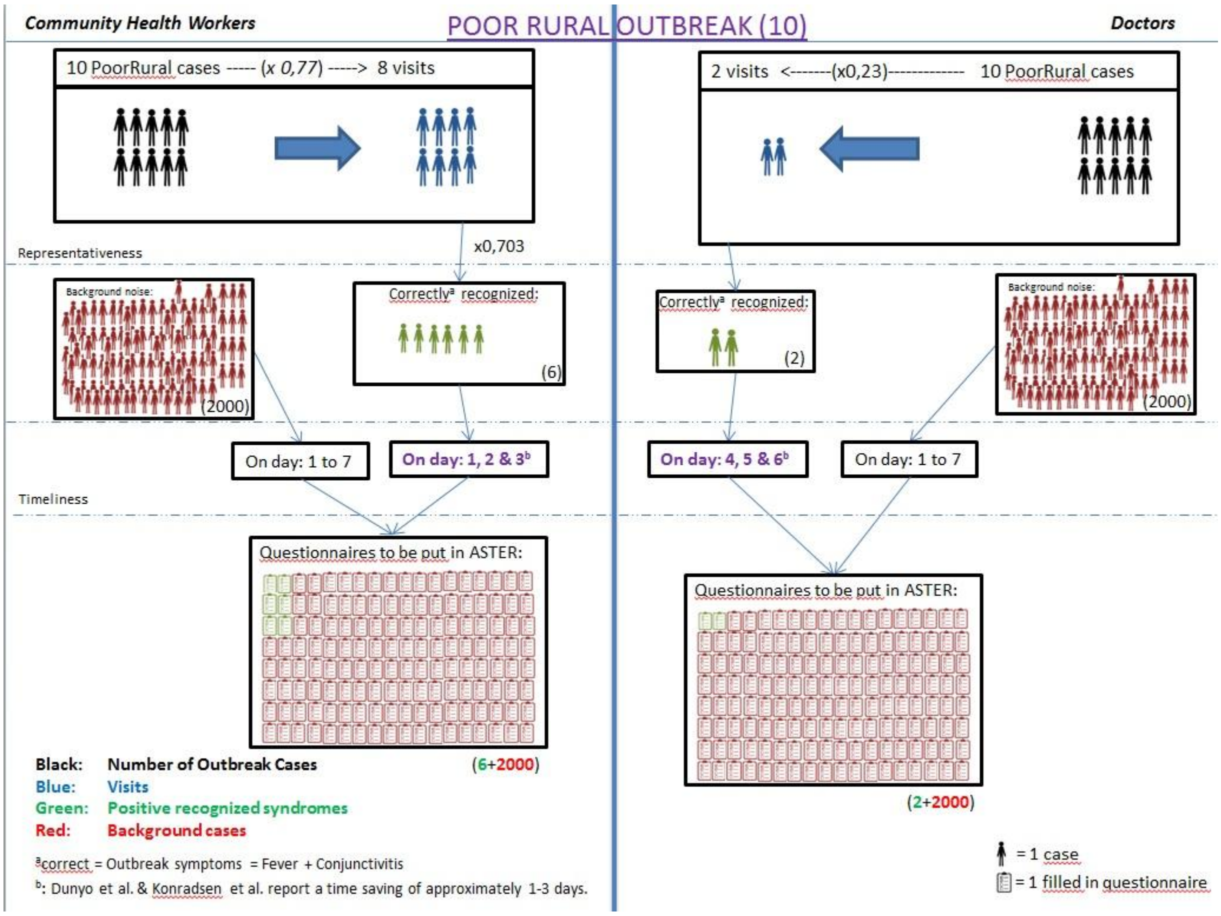


Figure 5, Simulation of an outbreak (50 cases) in a poor rural area.

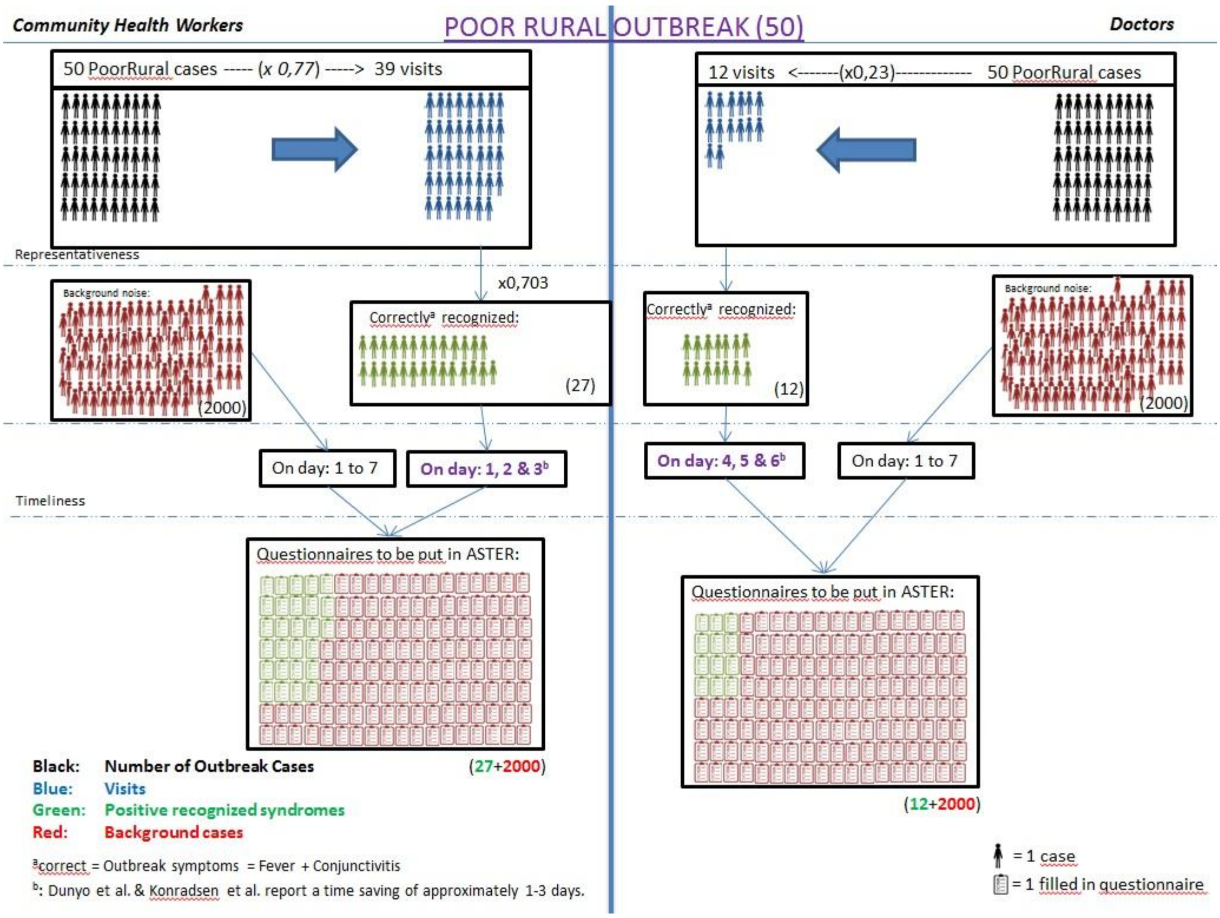


Figure 6, Simulation of an outbreak (100 cases) in a poor rural area.

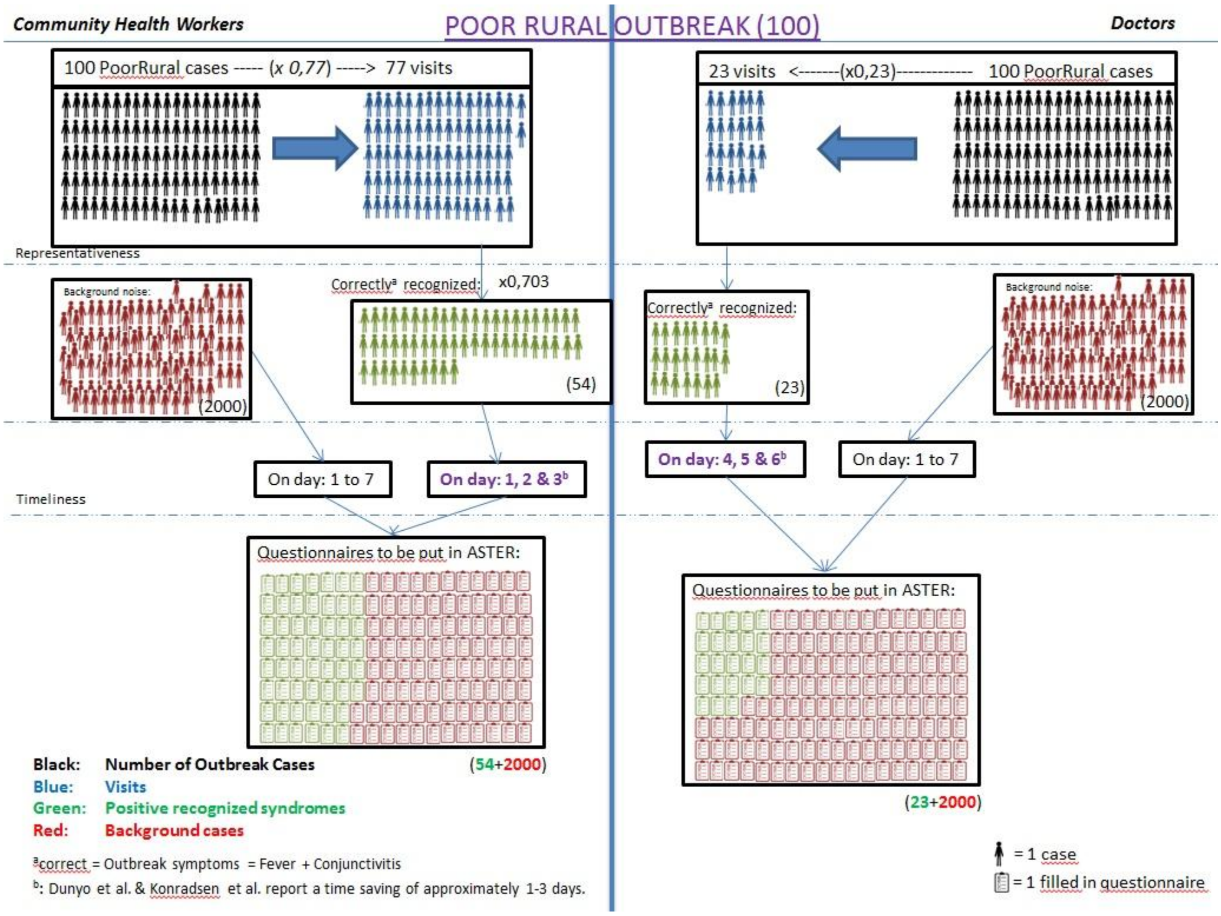


Figure 7, Simulation of an outbreak (10 cases) in a poor urban area.

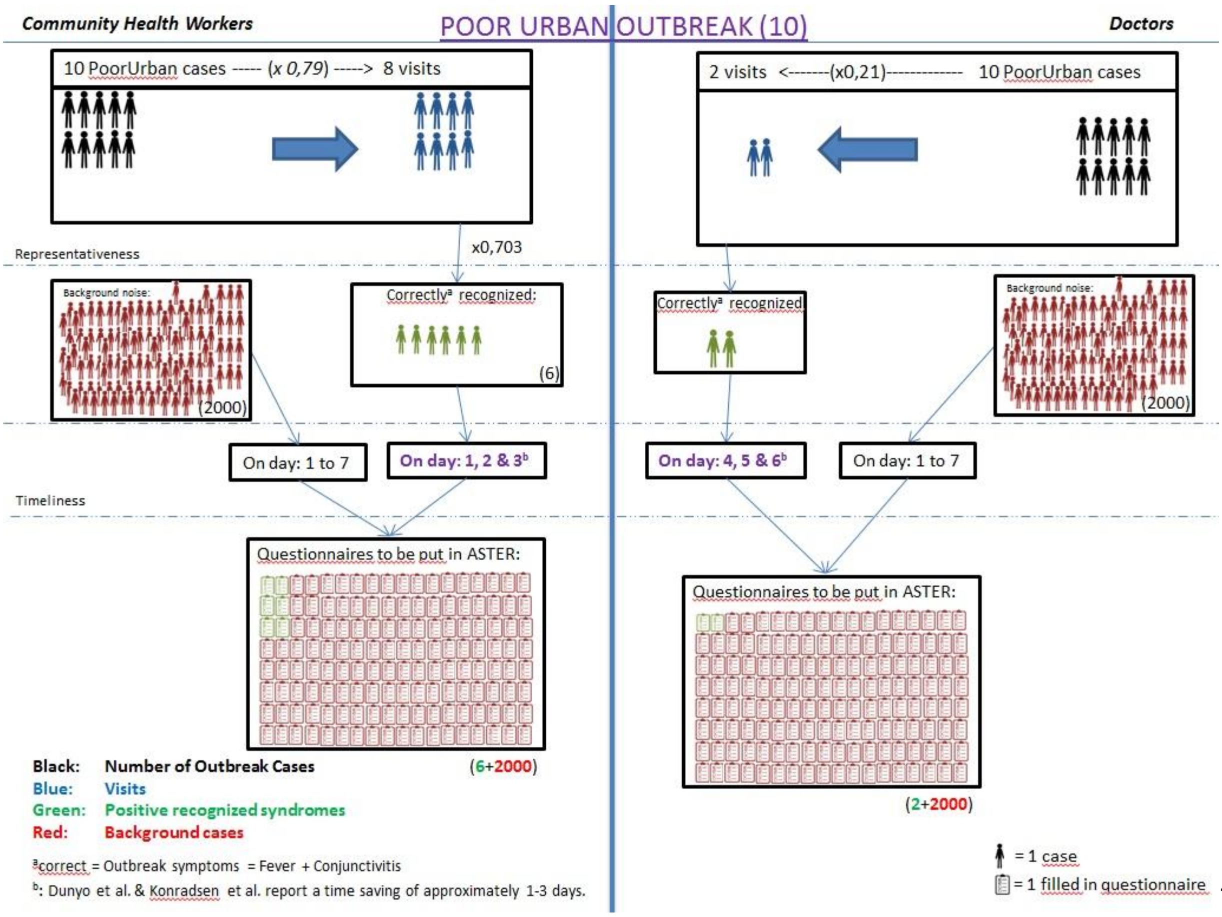


Figure 8, Simulation of an outbreak (50 cases) in a poor urban area.

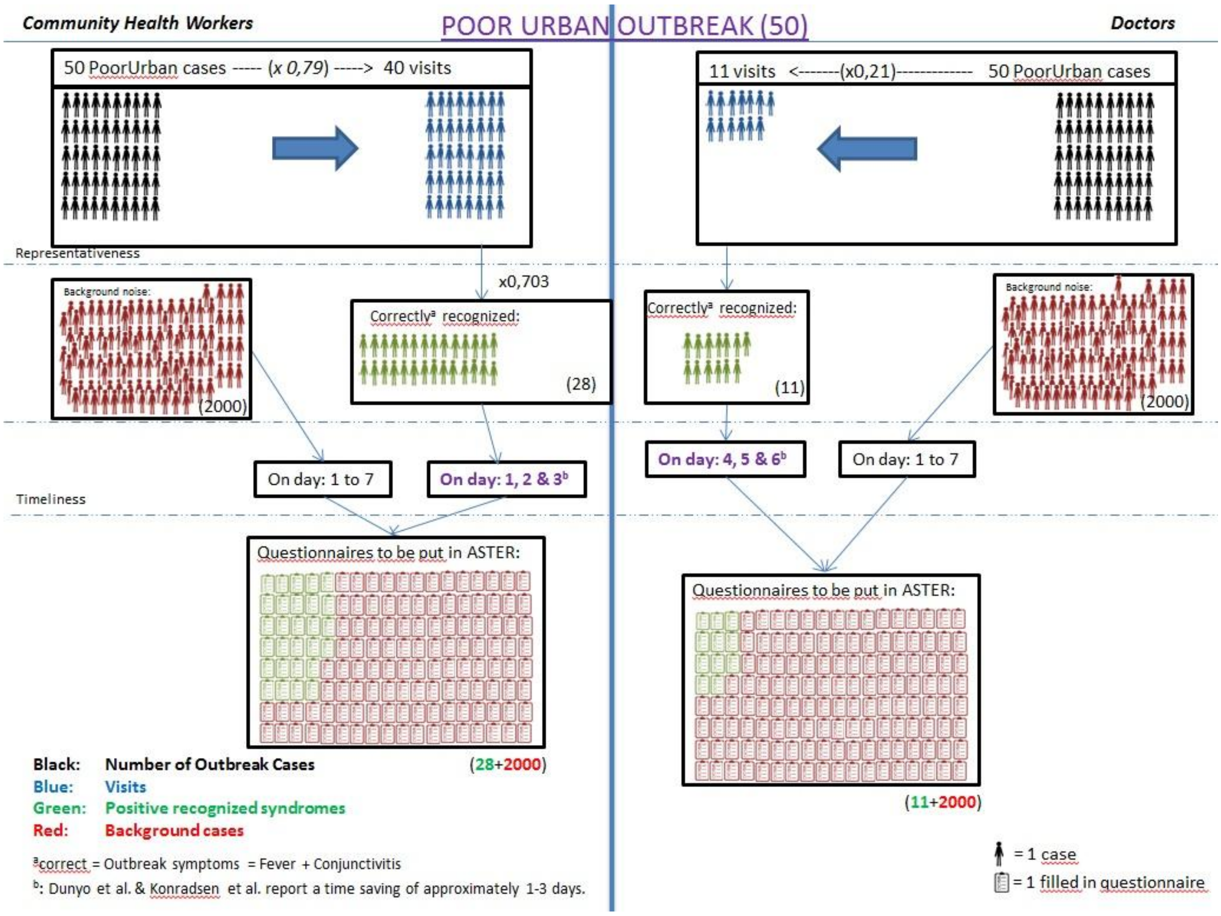


Figure 9, Simulation of an outbreak (100 cases) in a poor urban area.

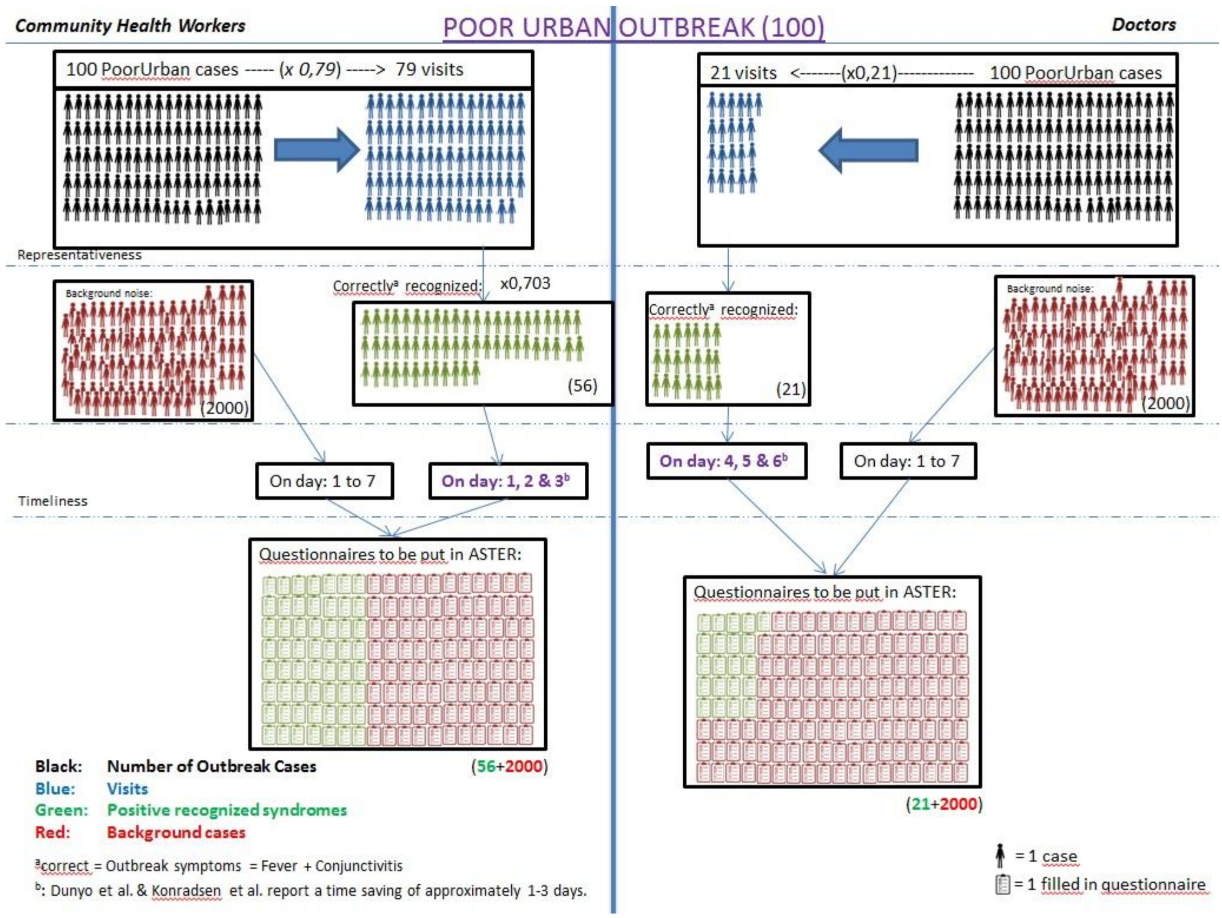


Figure 10, Simulation of an outbreak (10 cases) in a rich rural area.

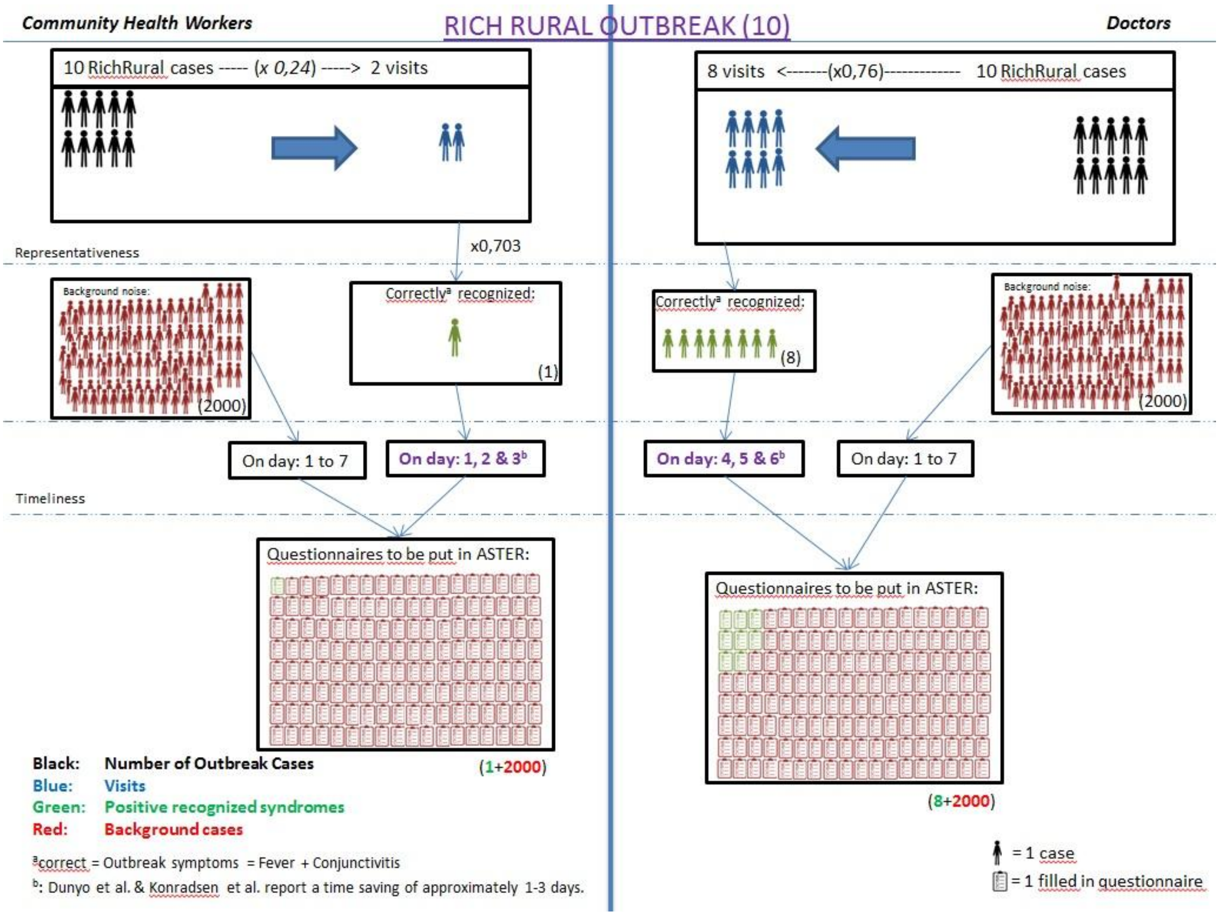


Figure 11, Simulation of an outbreak (50 cases) in a rich rural area.

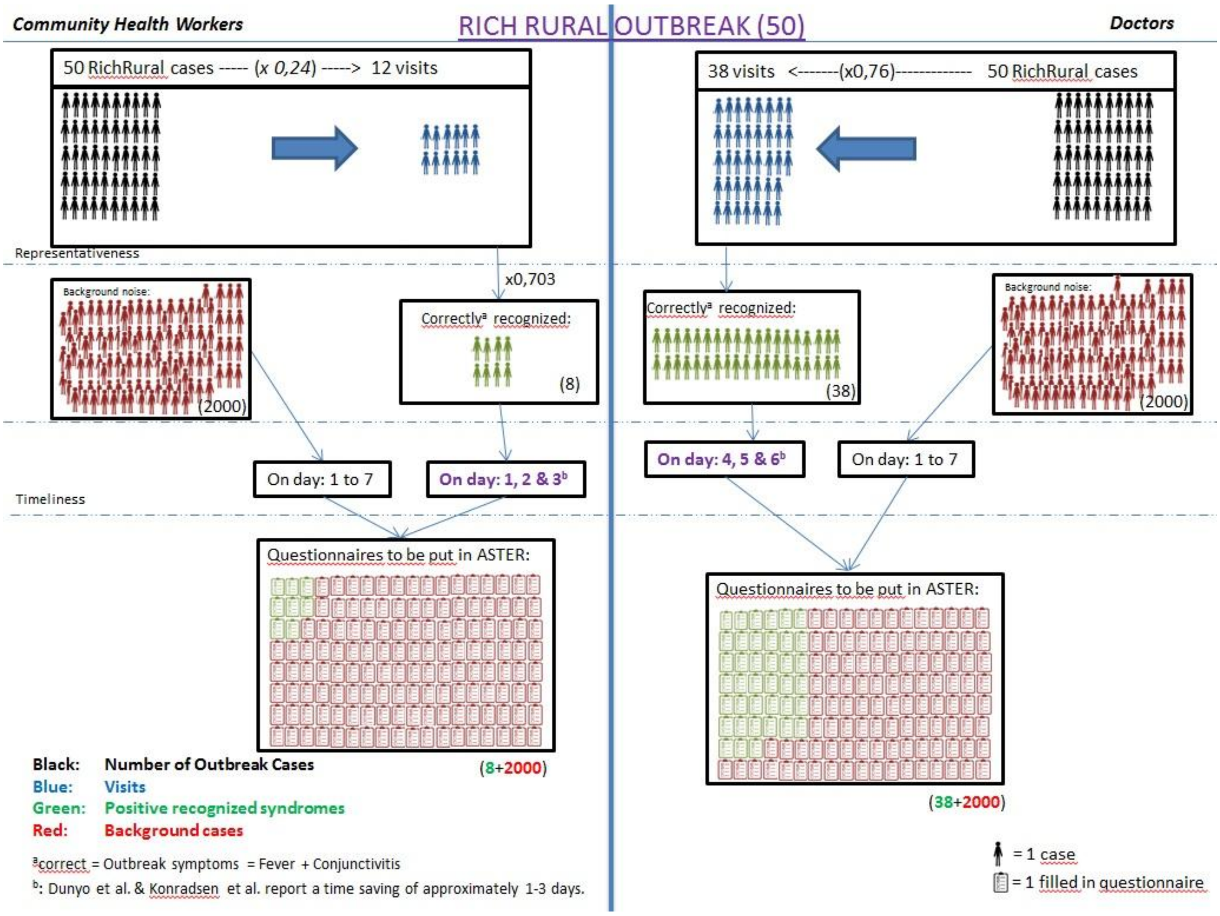
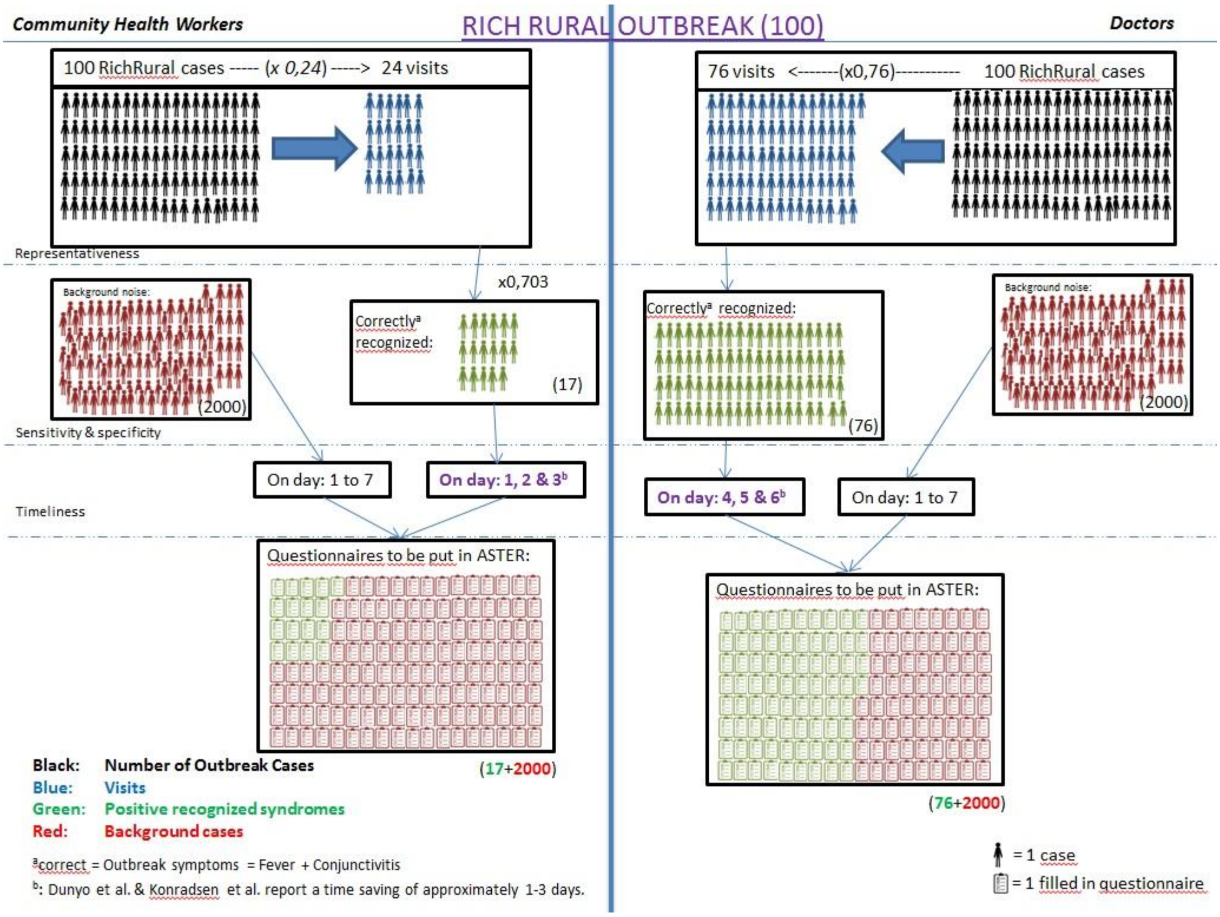


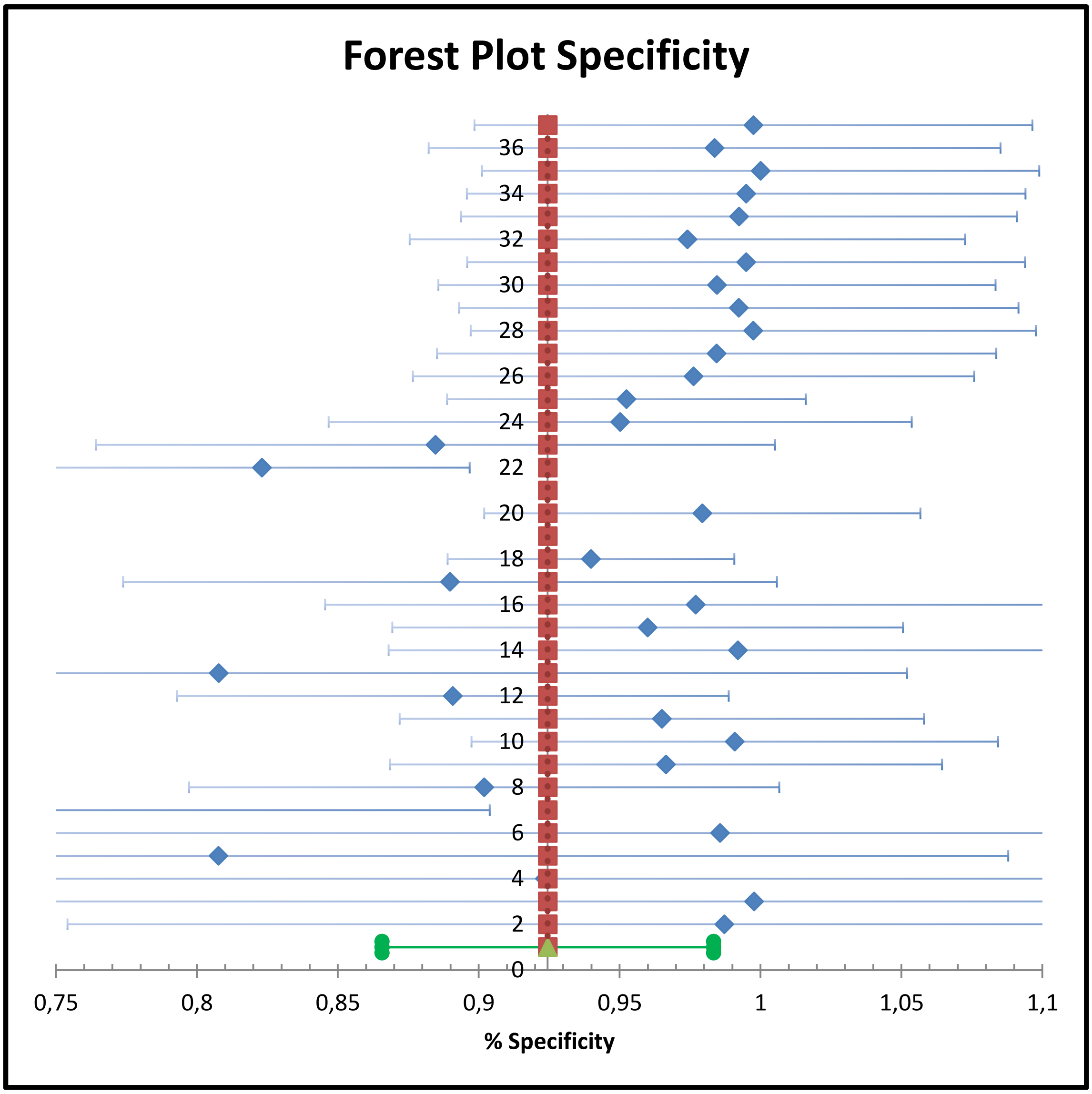
Figure 12, Simulation of an outbreak (100 cases) in a rich rural area.



APPENDIX E: *Table 8*, overview of collected data about specificity of Community health workers, in a Meta-analysis lay out:

Specificity of Community Health Workers			
Name	**Rate (TP/n)**	**Weight**	**Specificity (95% CI)**
Darmstadt, 2008			
RespRate >70	390/391	3,00%	0,997 (0,898-1,096)
RespRate 60-69	361/367	2,98%	0,983 (0,882-1,085)
Severe fever	393/393	3,00%	1 (0,901-1,099)
Moder. Fever	387/389	3,00%	0,994 (0,896-1,094)
Sever hypoth.	389/392	3,00%	0,992 (0,894-1,091)
Moder. Hypoth	375/385	3,00%	0,974 (0,875-1,073)
lethargic	388/390	3,00%	0,995 (0,896-1,094)
skin pustules	381/387	3,00%	0,984 (0,886-1,083)
umbilicus disch.	384/387	3,00%	0,992 (0,893-1,091)
jaundiced palms	380/381	2,99%	0,997 (0,897-1,098)
very severe dis.	378/384	3,00%	0,984 (0,855-1,084)
local infection	369/378	2,99%	0,976 (0,877-1,076)
Hadi, 2003			
non-acute Resp. Infection	860/903	3,15%	0,952 (0,889-1,016)
without basic training	324/341	2,97%	0,950 (0,847-1,054)
Irregular supervision	207/234	2,88%	0,885 (0,764-1,005)
Källander, 2006			
Pneumonia Recognition	479/582	3,12%	0,823 (0,749-0,897)
Perkins, 1997			
Pneumonia	420/858	3,21%	0,490 (0,442-0,536)
Diarrhoea with dehydr.	615/628	3,10%	0,979 (0,901-1,057)
Nutritional status	838/1269	3,21%	0,660 (0,616-0,705)
Need for referral	1311/1395	3,20%	0,940 (0,889-0,991)
Simoes, 1997			
Tachypnoea	226/254	2,91%	0,890 (0,774-1,006)
Diarrhoea with dehydr.	212/217	2,81%	0,977 (0,845-1,108)
Malnutrition	431/449	3,04%	0,960 (0,869-1,051)
Febrile illnesses	246/248	2,86%	0,992 (0,868-1,116)
Ear Problems	42/52	2,09%	0,808 (0,563-1,052)
Weber, 1996			
Pneumonia	318/357	3,00%	0,891 (0,793-0,989)
Dehydration	413/428	3,03%	0,965 (0,872-1,058)
Measles	432/436	3,03%	0,991 (0,897-1,084)
Otitis Media	374/387	3,00%	0,966 (0,868-1,064)
Malnutrition	285/316	2,97%	0,902 (0,797-1,007)
Otieno-Odawa, 2014			
ANC 4+ (peri-urban)	14,5/24,3	1,73%	0,597 (0,290-0,904)
Measles vaccine recieved (peri-urban)	34,2/34,7	1,61%	0,986 (0,655-1,316)
Skilled attendant delivery (peri-urban)	31,9/39,5	1,88%	0,808 (0,527-1,088)
ANC 4+ (rural-site)	20,5/22,2	1,30%	0,923 (0,524-1,323)
Measles vaccine recieved (rural-site)	42,8/42,9	1,78%	0,998 (0,699-1,297)
Skilled Attendant delivery (rural-site)	68,9/69,8	2,16%	0,987 (0,754-1,220)
Effect Summary		100	0,924 (0,866-0,983)
I^2: 0%; Q: 15,06; df: 35			

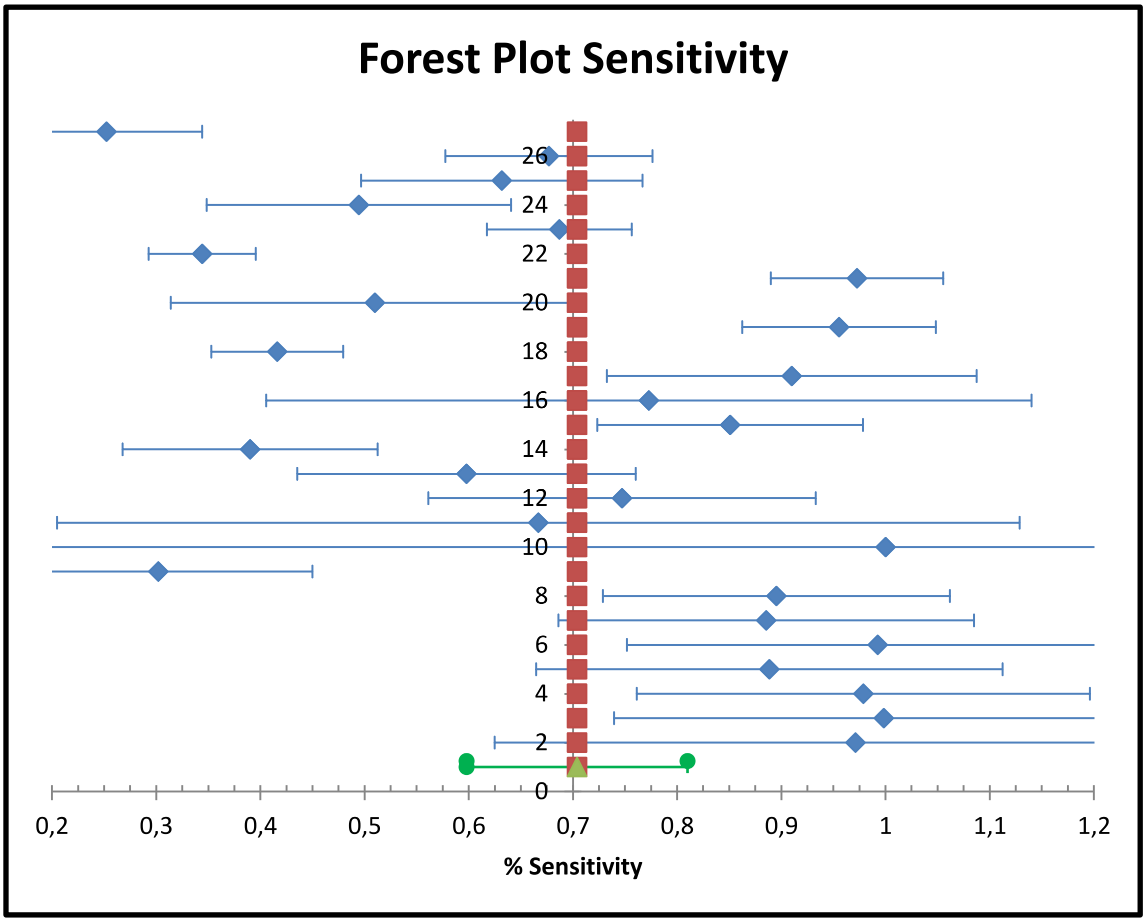
APPENDIX F: ***Figure 13*****, Forest plot of data from table 2:**



APPENDIX G: Table 9, overview of collected data about sensitivity of Community health workers, in a Meta-analysis lay out:

Sensitivity of Community Health workers			
Name	**Rate (TP/n)**	**Weight**	**Sensitivity (95% CI)**
Darmstadt, 2008			
Neonatal disease signs (aggregated)	29/115	4,37%	0,252 (0,160- 0,344)
Hadi, 2003			
non-acute Resp. Infection	178/263	4,35%	0,677 (0,577-0,776)
without basic training	84/133	4,21%	0,632 (0,497-0,767)
Irregular supervision	44/89	4,17%	0,494 (0,348-0,640)
Källander, 2006			
Pneumonia Recognition	375/546	4,44%	0,687 (0,617-0,756)
Mullany, 2005			
Omphalitis recognition	172/500	4,47%	0,344 (0,293-0,395)
Perkins, 1997			
Pneumonia	531/546	4,40%	0,973 (0,890-1,055)
Diarrhoea with dehydr.	26/51	3,92%	0,510 (0,314-0,706)
Nutritional status	406/425	4,37%	0,955 (0,862-1,048)
Need for referral	166/399	4,45%	0,416 (0,353-0,480)
Simoes, 1997			
Tachypnoea	101/111	4,01%	0,910 (0,732-1,087)
Diarrhoea with dehydr.	17/22	2,93%	0,773 (0,405-1,140)
Malnutrition	171/201	4,24%	0,851 (0,723-0,978)
Febrile illnesses	39/100	4,27%	0,390 (0,268-0,512)
Ear Problems	52/87	4,09%	0,598 (0,435-0,760)
Weber, 1996			
Pneumonia	62/83	3,97%	0,747 (0,561-0,933)
Dehydration	8/12	2,43%	0,667 (0,205-1,129)
Measles	4/4	0,93%	1,000 (0,02-1,98)
Otitis Media	16/53	4,16%	0,302 (0,154-0,450)
Malnutrition	111/124	4,07%	0,895 (0,729-1,062)
Otieno-Odawa, 2014			
ANC 4+ (peri-urban)	75,7/85,5	3,90%	0,885 (0,686-1,085)
Measles vaccine recieved (peri-urban)	65,3/65,8	3,67%	0,992 (0,752-1,233)
Skilled attendant delivery (peri-urban)	60,5/68,1	3,76%	0,888 (0,665-1,112)
ANC 4+ (rural-site)	77,8/79,5	3,80%	0,979 (0,761-1,196)
Measles vaccine recieved (rural-site)	57,1/57,2	3,56%	0,998 (0,739-1,257)
Skilled Attendant delivery (rural-site)	30,2/31,1	3,05%	0,971 (0,625-1,317)
Effect Summary		100	0,704 (0,598-0,890)
I^2: 0%; Q: 19,89; df: 25			

APPENDIX H: Figure 14, Forest plot of data from table 3:



APPENDIX I: Table 10, overview of collected Kappa values considering the reliability of Community health workers:

Cohens´ kappa values concerning inter observer agreement of Community Health Workers	
Character	**Kappa value**
Darmstadt, 2008	
Respiratory rate ≥70 bpm	0,33
Respiratory rate 60–69 bpm	0,08
Severe fever: temperature >(38.3 °C)	0,67
Moderate fever: temperature (37.8–38.3 °C)	0,39
Severe hypothermia: temperature <(35.3 °C)	0,66
Moderate hypothermia: temperature (35.3–36.4 °C)	0,16
Weak, abnormal or absent cry	-0,01
Lethargic or less than normal movement	0,24
Unable to feed or suck, or not attached	0,50
Skin pustules	0,23
Umbilicus discharging pus	0,42
Umbilical redness not extending to skin	-0,01
Jaundiced palms and soles after the day of birth	0,32
Ulcer or white patches inside the oral cavity	0,40
Very severe disease	0,63
Possible very severe disease	0,33
Local infection	0,35
Mullany, 2006	
Pus	0,77
Redness (binary)	0,48
Swelling (binary)	0,13
Alg-04: (Redness or swelling)	0,45
Alg-05: (Redness and swelling)	0,11
Alg-06: Pus and (redness or swelling (moderate or severe))	0,36
Alg-07: Pus and redness (moderate or severe)	0,39
Alg-08: Pus and (redness and swelling (any degree))	0,35
Alg-09: Pus and (redness and swelling (moderate or severe))	0,06
Alg-10: (Pus and moderate redness) or (severe redness)	0,35
Otieno-Odawa, 2014	
Age (peri-urban)	0,66
ANC 4+ (peri-urban)	0,5
Measles vaccine received (peri-urban)	-0,97
Skilled attendant delivery (peri-urban)	0,75
Age (rural-site)	0,12
ANC 4+ (rural-site)	0,16
Measles vaccine received (rural-site)	0,76
Skilled Attendant delivery (rural-site)	0,04

Average Kappa Value	0,380
Standard deviation	0,212
95% confidence interval	-0,0452 - 0,8046