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**Evaluating communicable disease surveillance in
resource-poor settings:
A new approach applied to meningitis
surveillance in Chad**

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Declaration

I, Ngozi Adaeze Erondu, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

Date:

Full name: Ngozi Adaeze Erondu

Abstract

Background

The costs of improving surveillance systems in resource-poor settings are largely unknown. Though several communicable disease surveillance systems have been evaluated, they rarely provide precise evidence to facilitate decision making or support appeals to increase and sustain surveillance system investments. This thesis seeks to empirically test the potential benefit of a novel evaluation approach, which assesses both cost and performance of surveillance.

Methods

The thesis and PhD research comprises four components: 1) a structured literature review to describe and examine evaluation methods of communicable disease surveillance systems; 2) an application of the ingredients costing approach to retrospectively determine meningitis surveillance costs in Chad in 2012; 3) a work-process analysis structured evaluation and identification of performance gaps through interviews at health facilities and at each administrative level across seven districts in southern Chad; and 4) an estimation of the costs to upgrading and implementing a more sensitive system to assess the long term impact of the newly introduced serogroup A meningococcal conjugate vaccine in Chad.

Results

The literature review highlighted the necessity of granular evaluation methods in low-resource settings where surveillance data at supra-peripheral levels are less reliable. In Chad, optimal surveillance was severely hampered by limited resources. Only four percent of probable meningitis cases had a known outcome. Missing and unreliable data affected case detection; in three of the districts, zero meningitis cases were reported during 2012. In the other four districts, reported cases varied between 11 and 149 per 100,000 populations. The total costs of meningitis surveillance in Chad were estimated at US\$ 393,000, equivalent to US\$ 0.03 per capita. The work-process analytic

approach was used to detail an upgrading plan of resources and inputs and a 123% incremental increase in annual costs was estimated as needed to upgrade meningitis surveillance to an optimal standard. Sentinel district case-based surveillance was recommended as the most feasible and sustainable strategy.

Conclusion

The systematic approach for assessing performance gaps and the associated costs provided rich data that stakeholders found useful for policy and programme change. This approach underscores the benefit of understanding specific contexts in order to yield the most relevant and meaningful evidence for surveillance system strengthening.

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Abbreviations

AMP	Agence de Médecine Préventive
CBS	Case based surveillance
CDC	US Centres for Disease Control and Prevention
CDSS	Communicable disease surveillance system
CSF	Cerebral spinal fluid
CSSI	Centre du Support en Santé International
ES	Enhanced epidemic meningitis surveillance
EPI	Expanded programme on immunisation
EWARS	Early warning alert and response system
FETP	Field epidemiology training program
IB-VPD	Invasive bacterial vaccine preventable diseases laboratory network
IDS	Integrated disease surveillance
IDSR	Integrated disease surveillance and response strategy
IHR (2005)	International Health Regulations (2005)
LDC	Least developed countries
LMIC	Low and middle income countries
M&E	Monitoring and Evaluation
MoH	Ministry of Health
MDS	Multiple disease surveillance
MSP	Ministère de la santé publique du Tchad
MSS	Meningitis surveillance system
PHSS	Public health surveillance system
RCS	Responsable du centre de sante
SSA	Sub-Saharan Africa
T-I	Trans-isolate medium
USA/US	United States of America
UNICEF	United Nations Children's Fund
WHO	World Health Organization
WHO AFRO	World Health Organization – African Regional Office

Useful Terminology

Active case detection	Health staff reach out to the community and systematically screen the population to find cases of meningitis.
Aggregated reports	Aggregate data gives a quick summary of the magnitude of the problem but are not detailed enough to enable case tracking. Aggregate reports summarise the total number of cases of several reportable diseases reported on one disease surveillance report form.
Attack rate	Number of new cases of a specified condition in a population at the start of an epidemic period (1).
Case definition	The clinical criteria used to screen an individual for a suspected disease or health related event; used when determining whether someone is a suspected, potential or confirmed case during an outbreak.
Case-fatality rate	Also called death-to case ratio or case-fatality ratio. Defined as the number of new cases who die from a specific condition in a given time interval (1).
Case reports	Reports that provide details of individual cases of persons with a suspected reportable disease. Often used for diseases that 1) require urgent public health action or, 2) are subject to accelerated disease control goals or, 3) during suspected outbreaks of epidemic-prone diseases.
Carriage (of meningococci)	Colonisation of meningococci microorganism to the mucosal surface of the human nasopharynx. Carriage is an immunising event associated with meningococcal disease incidence and protective immunity against the organism (2).
Communicable disease	An illness due to a specific infectious agent or its toxic products that arises through transmission of that agent or its products from an infected person, animal or inanimate reservoir to a susceptible host; either directly or indirectly through an intermediate plant or animal host, vector or the inanimate environment (3).

Endemic disease	The constant presence of a disease or infectious agent within a given geographic area or population group. It may also refer to the usual prevalence of a given disease with such area or group.
Epidemiology	Study of health and illness of populations and the application of findings to improve local and community health (4).
Expanded Programme on Immunisation	A WHO programme established in 1974 to develop and expand immunisation programmes throughout the world.
Health system	All organisations, people and actions whose primary intent is to promote, restore or maintain health (5).
Health system strengthening	Building capacity in critical components of health system to achieve more equitable and sustained improvements across health services and health outcomes (5).
Hyper-endemic disease	A disease that is constantly present at a high incidence and/or prevalence rate and affects all groups equally.
Incidence rate	Number of new cases per population at risk of a specified condition in a given time (1).
International Health Regulations (2005)	Internationally upon agreed rules aimed to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risk.
Logic model	Also referred to as an <i>analytic</i> or <i>casual</i> framework. A diagram that depicts the inter relationships among population characteristics, intervention components and future outcomes. Used in programme planning to assist in designing, implementing, and evaluating effective interventions (4).
Line list	A convenient means for consolidating data acquired from case investigation forms on a number of cases of the same disease; it includes more detail than an aggregated report.
MenAfriCar	An international consortium that aims to increase understanding of how meningococcal infections are transmitted in Africa, and to document the impact of a new meningococcal conjugate vaccine on transmission of the infection (6).

MenAfriNet	A regional meningitis surveillance network to evaluate the impact of MenAfriVac [®] introduction in the African meningitis belt (7).
Operational standard [for a disease surveillance system]	The comprehensive set of surveillance activities that comply with international standards and local guidelines, customised to a country's circumstances. This can be graphically depicted with a logic model.
Plan of action	National strategic plan based on the findings of an assessment. Contains planned programme activities and targeted objectives over a specified time period. Should be monitored to ensure timely implementation of activities, efficient and rational use of available resources (8).
Reportable diseases	Also referred to as <i>notifiable diseases</i> . A disease considered to be of great public health importance to a particular country or sub-region. These diseases are legally mandated to be reported to authoritative health officials upon diagnosis.
Surveillance [public health]	The ongoing systematic collection, analysis, and interpretation of outcome-specific data for use in the planning, implementation, and evaluation of public health practice (9).
System	A set of elements or components that work together in relationships for the overall objectives/vision of the whole (10).

1 Introduction

Early detection is fundamental to containing and controlling emerging, re-emerging, and novel infectious diseases (11). To ensure global health security, the world must predict, monitor, and quickly respond to human and animal disease occurrences (12). An unfortunate illustration of the threat of re-emerging diseases can be seen in the 2014 Ebola virus disease (Ebola) outbreak in West Africa. This tragic event provided a painful reminder that outbreaks know no boundaries and that improving public health systems is critical to mitigate future global health security risks (13).

Scientific commentaries have attributed many factors to the cause of the Ebola epidemic, including: high movement across porous and uncontrolled borders, critical shortage of health care workers due to existing shortfalls, ignorance and misconception of the disease within the population due to a lack of health education programmes, inadequate financing for health systems, poor or disjointed communication and information systems, and inexperienced leadership (14, 15). The equivocal concept, 'fragile health system', was used to contain all the deficiencies in the health system that prevented early detection of the disease and led to a delayed coordinated effort to contain what became an international emergency (16).

Historically, public health surveillance systems (PHSS) have been the vessel used to detect disease events, trigger interventions to prevent transmission, and reduce morbidity and mortality (17). Public health surveillance is widely considered the cornerstone function of public health practice and is classically defined as the "ongoing systematic collection, analysis, interpretation and dissemination of health data for the planning, implementation and evaluation of public health action" (1). Essentially, an effective surveillance system should provide epidemiologic intelligence that prompts and informs public health action.

In high-income countries in Europe, North America, Australia, and some parts of Asia, surveillance systems have progressively evolved from monitoring infectious diseases and cataloguing epidemics to examining interactions among biological, social, psychological, and environmental factors in order to support health promotion, inform intervention programmes, and guide prevention efforts of non-communicable disease and mental illness (18). However, despite these impressive advances and the ensuing societal benefits enjoyed by richer nations, surveillance systems in low-income countries remain a neglected and strained public health function and the continuing challenge is to create effective systems that combat communicable diseases.

Amid the many functions of public health surveillance, detecting epidemics and monitoring changes in communicable diseases are critical to health protection in low-income countries where emerging pathogens are most likely to occur (12). Today, too few low- and middle-income countries have a functioning and effective surveillance and response infrastructure, which includes the local capacity to perform core public health functions. Persisting factors, such as an insufficient and inadequately skilled workforce, suggests that it is unlikely to change unless a deliberate, capacity-focused strengthening programme is initiated on a global scale (19). In sub-Saharan Africa, where human and animal health are inextricably linked, an effective surveillance and response system must include a network of animal and human health community sources, which feed into a national early warning and outbreak surveillance response system (15). It must also harness the resources and collaboration of national, regional, and international stakeholders and policy makers to ensure the development and success of customised effective intervention measures.

In the wake of the Ebola tragedy and other global health scares, the international community is now placing greater scrutiny on the use of donor aid and funding for sustainable health systems in under-resourced countries and regions of the world (5). While this fresh refocus on health infrastructure is encouraging, one must be wary of the international proclivity towards hurried reactions and often unhelpful solutions

(20). This PhD intends to promote a different solution: that sustainable changes to disease surveillance systems are products of steady and systematic assessment, review, and then precise repair of system parts and processes.

The research problem for this thesis was conceived from first-hand observations of disease surveillance in rural African health communities as well as experiences working with intermediate and high levels of staff in ministries of health (MoHs) and international non-governmental organisations (NGOs) to budget, plan, and evaluate surveillance programmes. These settings often require operational assessments and programme evaluation. Local health workers frequently present international consultants with system obstacles that prevent successful surveillance processes. Many times the consultants convey these messages to the health ministries and donor agencies, but in many cases the response is unsatisfactory and no programmatic change or resource redirection occurs. From a top-down perspective, the information discovered through these assessments rarely provides evidence that can be used to determine what part of the system should be prioritised and which resources are needed the most. Most surveillance system evaluations that I have reviewed provide descriptions of the problem and demand more resources without explaining where exactly these resources should be allocated. It is understandable that MoHs and donor agencies would be hesitant to invest more resources without a clear understanding of how and where it would be used. In this thesis, I will examine the existing frameworks and guidance for evaluating surveillance systems and the type of information generated by their use. My research builds upon existing methods of surveillance evaluation and explores the usefulness of including a cost assessment. The aim is to design evaluations that produce better evidence to advocate for adequate resources to improve and support surveillance programmes.

In the 2010 book *Principles and Practice of Public Health Surveillance*, the US Centers for Disease Control (CDC) surveillance pioneer, Dr. Stephen Thacker, argues for a growing appreciation of higher standards for surveillance practice, which can be assured

through frequent quality evaluations of PHSS. He compellingly adds that once the concept of 'data for decision making' is prioritised and successfully translated, public health surveillance will be recognised at a higher level of importance (1). The importance of sustainable and effective surveillance systems is also inherent in the World Health Organisation's (WHO) International Health Regulations (2005) ([IHR (2005)] and regional-specific strategies. These policies urge countries to meet the challenge of generating data to improve their own disease monitoring and response policies, predict health-related adverse events, and inform interventions and programmes to improve the health of communities and countries.

This thesis is grounded in the belief and shared commitment in data for decision-making and sustainable surveillance systems, and presents one way to achieve these goals. The work presented in this thesis aims to shift the emphasis of the global discussion from *why surveillance systems fail* to *what can make them succeed* as well as to highlight the benefit of local led remedies to scientifically defined problems. My core belief is that finding the best evidence-for-advocacy is critical to equip the valuable individuals who are the first line of defence in detection and control of epidemic-prone diseases.

Structure of the thesis

This thesis is divided into 10 chapters. Chapter 1 contains an introduction to the global state of PHSS, and underscores the sub-Saharan Africa (SSA) context and the opportunity to better align evaluation findings with programme planning and advocacy activities. Chapter 2 provides a background to the main themes of the PhD: 1) Public health surveillance of communicable diseases (also referred to as communicable disease surveillance system [CDSS]), 2) communicable disease surveillance systems in SSA, 3) the research context of meningococcal disease and Chad, and 4) the costs of communicable disease surveillance systems.

Chapter 3 presents a critical review of the empirical literature of surveillance performance evaluations. The review identifies the methods and recommendations of the studies and highlights methodological gaps in the existing work. The findings of the review informs one of the aims of the thesis: the development of a process-centred evaluation approach for optimizing surveillance in low-income countries in an economical and sustainable way.

Chapter 4 further presents the aims, objectives and conceptual framework of the thesis. Chapter 5 begins with an introduction of the work process analysis (WPA) framework as a useful and systematic CDSS evaluation approach and demonstrates its application in the Chad meningitis surveillance evaluation study. This chapter also provides an overview of the general methods for the evaluation study.

Chapters 6 thru 9 describe the results for the Chad meningitis surveillance evaluation study. Chapter 6 explains the Chad meningitis and integrated disease surveillance system using the WPA tools to analyse and organise the information. Chapter 7 presents the results of the performance assessment. The surveillance-related cost estimates are presented in Chapter 8. Chapter 9 concludes the results with a presentation of the incremental costs to achieve recommended upgraded system components for optimal surveillance in Chad.

Chapter 10 provides a summary of the research findings and compares them to findings in the existing literature. An empirical validation of the WPA approach is also presented in this chapter, which concludes with discussions on strengths and weaknesses, reflections on potential applications of the thesis findings, and insights for further study and research.

2 Background

This introductory chapter contains background information on the field of public health surveillance of communicable diseases and is essential to the understanding of systematic practices, which my research seeks to improve. Section 2.1 explains the objectives of the basic surveillance strategies used to collect epidemic-prone population health data and other notifiable diseases, and summarises the frameworks and guidelines widely used to evaluate CDSS. Section 2.2 provides an overview on the history of epidemic prone and emerging disease surveillance in sub-Saharan Africa and explains the regional strategy used to implement surveillance. In section 2.3, the study specific context of meningococcal disease in Chad is described. Lastly, section 2.4 explains the key costs concepts related to CDSS and discusses issues identified in the literature, which are specifically associated to collecting costs in low-income countries.

2.1 Background to evaluation of public health surveillance

2.1.1 The concept of disease surveillance for public health practice

“Surveillance, when applied to a disease means the continued watchfulness over the distribution and trends of incidence through the systematic collection, consolidation, and evaluation of morbidity and mortality reports and other relevant data. Intrinsic in the concept is the regular dissemination of the basic data and interpretation to all who have contributed and all others who need to know.” (21)

- Alexander Langmuir (1963)

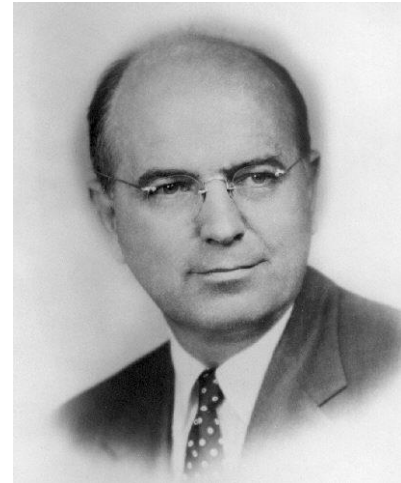
The crude functions of observing, recording, and collecting facts and then analysing and interpreting them to inform corrective actions was observed as early as in the 17th century in the Western world (22). William Farr first noted in the 19th century that natural laws govern occurrence of disease and codified the public health functions of collecting, evaluating and reporting relevant health-related facts by person, place, and time (23). Surveillance as a practice applied to public health detection and control of

disease, however, is a relatively new field. Former CDC Chief Epidemiologist, Alexander Langmuir is often credited with establishing modern day surveillance practices and distinguishing the concept of surveillance as a separate activity from disease control activity or epidemiologic research. His 1963 definition (quoted at the top of this section) provided the systematic components of surveillance, i.e. 'ongoing', 'systematic', 'data collection', 'mortality, morbidity and other relevant data', 'data analysis', 'interpretation' and 'dissemination'(18). Since the 1968 World Health Assembly first recognised surveillance as an essential function of public health practice, contributions to Langmuir's definition continue to refine and nuance the concept of surveillance, particularly in regards to its purpose. There has been a shift from a singular disease control function to a fundamental and integral function of public health systems used to inform public health action (such as disease control activities), planning, implementation and evaluation of practice (18). Today, the widely accepted definition of public health surveillance is: "The ongoing systematic collection, analysis, and interpretation of outcome-specific [health] data for use in the planning, implementation, and evaluation of public health practice [and action]" (9, 18). Data which feed surveillance systems are collected from an array of sources, and include clinical and laboratory diagnosis, vaccination status, mortality, and other pertinent information needed to understand disease characteristics within a population (24).

Figure 2.1 “Fathers” of modern public health surveillance



William Farr (1807-1883)
Medical statistics pioneer



Alexander Langmuir (1910 -1993)
Founder of CDC Epidemiologic
Intelligence Service

Langmuir (and several others after him) ardently separated the practice of surveillance from the research and programmes that surveillance information informs. The purposes of public health surveillance systems can be summarised into four areas: (1) To assess health status and trends of a population; (2) To prioritize public health needs and allocate resources for planning; (3) To assess programme effectiveness and; (4) To stimulate basic, applied, and operational research (18). The uses of public health surveillance data are listed below (22)

- Estimate the magnitude of a problem
- Determine geographic distribution of illness
- Show the natural history (historical trend) of a disease
- Detect epidemics/define a [health] problem
- Generate hypotheses, stimulate research
- Evaluate programmes and control measures
- Detect changes in health practices and behaviour
- Facilitate planning

Public health surveillance has evolved from monitoring contacts of persons with communicable diseases, such as small pox, to a breadth of other conditions, such as those listed in Table 2.1.

Table 2.1 Examples of conditions for which surveillance is used

Communicable diseases
Chronic disease (e.g. cancer, malnutrition)
Occupational injuries
Other injuries <ul style="list-style-type: none"> Intentional injuries (e.g. suicide, homicide) Unintentional injuries (e.g. falls)
Health effects of toxic exposures
Personal health practices (e.g. smoking, sexual behaviour, drug use, alcohol)

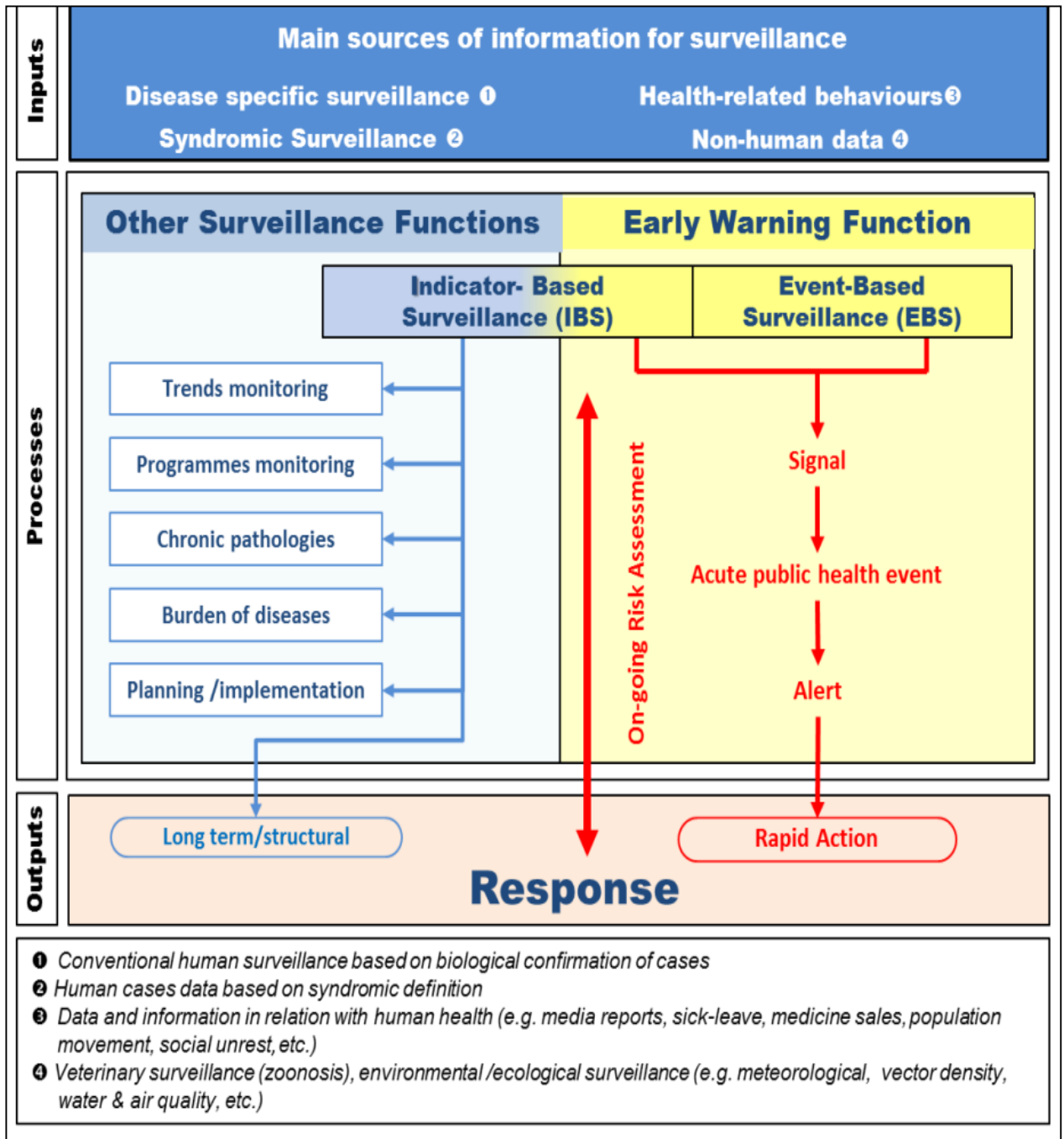
The IHR (2005) aims to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risks (25). These newly revised regulations have pushed surveillance to become more comprehensive and collaborative on a global scale, adding a degree of complexity to its functionality and uses. Surveillance must interface with novel public health methods and technology, balance coverage and intensity with resources, and respond rapidly and collaboratively to rapid global changes, which may constitute a threat to human health.

More developed countries are able to fluidly navigate between and in concert with multiple sources of data, various activities and functions, and tailored response abilities. The sophisticated picture of surveillance illustrated in Figure 2.2 provides an all hazards approach to public health surveillance, which reflects the IHR (2005) obligations, but is arguably built on the shoulders of well-functioning CDSS as well as

other systems, such as a stable government, an organized healthcare structure, and an established and accepted classification system for disease and illness (22).

In contrast, conventional surveillance based on communicable and epidemic-prone diseases are still represented in their most basic form in low-income countries, which cradle the world's burden of communicable diseases. The model presented in Figure 2.2 is what is currently regarded as the optimum for producing epidemiologic intelligence and protecting health populations. For many low-income countries this is a lofty, but desirable goal—the first step is strengthening communicable disease surveillance to gather useful information for early warning and rapid control of epidemics and for the monitoring of endemic communicable diseases (26). As developing countries modernize, many are already experiencing epidemiological transition in disease burden from infectious (e.g. diarrhoeal disease, meningitis, pneumonia) to chronic ailments (e.g. heart disease, stroke, cancer). These shifts inevitably require established CDSS to evolve and expand in order to provide data that addresses new questions about national public health.

Figure 2.2 Overview of all hazard public health surveillance and response functions



Source: World Health Organisation (27)

2.1.2 Types of communicable disease surveillance

Communicable disease surveillance (CDS) is essential to every public health system. Though it represents just one type of surveillance area, it is essential in African and other low-income contexts where infectious and epidemic-prone diseases overwhelmingly represent national priority diseases. In these settings CDS is often used interchangeably with PHS. CDS can encompass multiple parallel disease systems (the vertical approach) or take an integrated approach where multiple diseases are monitored under one system with similar structures, processes, and personnel (the horizontal approach) (18). CDS is essential for detecting and responding quickly to health threats, especially in low-income countries where emerging disease threats can be exacerbated by poor health systems and slow or inexistent response efforts.

National surveillance programmes identify priority diseases and adverse health events that significantly impact the health of their population. An appropriate surveillance strategy and accompanying surveillance activities are implemented based on the specific disease attributes and control programme objectives. Disease control objectives can be linked to national, regional or global goals and have one (or more) of three outcomes: 1) to keep the disease/event under control in the population, 2) to eliminate the disease/event from the population, or 3) to eradicate the disease/event from the population. Table 2.2 defines these concepts in the context of surveillance and national communicable disease control programmes. Surveillance activities are generally classified under three types of surveillance: active, passive, and sentinel surveillance.

Passive Surveillance

Passive surveillance is performed through a data reporting hierarchy and depends on the cooperation of health providers or stakeholders (e.g. health facilities, laboratories, hospitals, private clinics, community organizations, NGOs). This method is also referred to as *routine* surveillance. Almost every country in the world has a national, passive public health surveillance system to monitor and track local notifiable (i.e.

reportable) diseases. Passive surveillance is efficient, relatively inexpensive and requires fewer resources. However, it can be difficult ensuring complete and timely data of high quality; especially in resource-constrained settings.

Table 2.2 Definitions of control, elimination, and eradication of infectious diseases

Control	The reduction of disease incidence, prevalence, morbidity or mortality to a locally acceptable level as a result of deliberate efforts; continued intervention measures are required to maintain the reduction. Example: diarrhoeal diseases, diphtheria, pertussis
Elimination	Reduction to zero of the incidence of a specified disease in a defined geographical area as a result of deliberate efforts; continued intervention measures are required. Example: neonatal tetanus.
Eradication	Permanent reduction to zero of the worldwide incidence of infection caused by a specific agent as a result of deliberate efforts; intervention measures are no longer needed and also the complete interruption of transmission and the extinction of the causative agent so that it no longer exists in the environment. Example: smallpox.

Source: CDC (28)

Passive surveillance is usually employed through weekly and monthly reporting so that specific disease indicators and trends can be captured – this is referred to as indicator-based surveillance (IBS). But it can also function through event-based surveillance (EBS), which is the organised and rapid capture of information about events that are a potential risk to public health. This includes rumours and other ad-hoc reports transmitted through formal (i.e. established routine reporting systems) and informal channels (i.e. media, health workers and nongovernmental organisations reports) (27). The breadth and diversity of sources allow EBS to detect rare and high-impact outbreaks or emerging or novel diseases.

EBS should be implemented through integration with IBS and should not be a parallel system as it enhances and extends the reach of traditional surveillance. EBS uses

unstructured descriptions and reports for data collection and relies on careful analysis of information by epidemiologists or other qualified health scientists.

Sentinel surveillance

A sentinel surveillance system is used to collect intensive, high-quality data about a particular disease or condition that cannot be obtained through a passive system. A limited number of reporting units (e.g. health workers or health facilities) are selected based on the general criteria that, 1) the site is willing to participate, 2) there is a high probability of encountering cases, 3) there is access to good laboratory facilities, and 4) there are qualified and experienced staff who can identify and report on the disease. This method is often employed through a network of large hospitals to collect high quality data and understand characteristics of less common diseases and causative organisms, for instance invasive bacterial disease, such as caused by meningococcus.

Active surveillance

Active surveillance makes up for the shortcomings of passive surveillance, and is most useful when the disease programme objective includes identification of all cases. This method is defined as a special effort to collect data and confirm diagnoses. In practice, active surveillance attempts to identify cases by designated surveillance officials visiting health facilities and checking disease registers and medical records to see if a suspected case was missed and even speaking with health staff. This method also includes active searching for cases and contacts of cases (i.e. door-to door searching). Once the case is found, surveillance staff must investigate it and document clinical, epidemiological, and laboratory data.

Active surveillance is expensive and requires the alert participation of health stakeholders. Due to its resource intensity, this method is usually reserved for outbreaks to locate unreported cases or as a regular strategy for diseases that are targeted for elimination or eradication. It should complement but not replace passive surveillance. One example of active surveillance is the case-based surveillance (CBS)

strategy. CBS is used to collect data on each individual (i.e. suspected case) using a unique form to collect epidemiological information and capture microbiological information. Case-based data is used for immediate response and, as appropriate, case investigation and control measures (29). This strategy is used for the surveillance of acute flaccid paralysis for poliomyelitis eradication. CBS details of every suspected case are meticulously captured and sent with a stool sample. CBS allows for a very sensitive surveillance system, which aims to detect every case of polio and to interrupt poliovirus transmission through vaccination intervention. Table 2.3 provides a comparison of the advantages and disadvantages of the three surveillance types.

Table 2.3 Comparison of surveillance types

	Type of surveillance		
	Passive surveillance	Sentinel surveillance	Active surveillance
Population under surveillance	Entire country	Cases seen and treated at selected health facilities	All cases attending selected health facilities
Outcome measures	<ul style="list-style-type: none"> - Cases and deaths - Incidence rates - Epidemiological trends 	<ul style="list-style-type: none"> - Cases and deaths in selected health facilities 	<ul style="list-style-type: none"> - Cases and deaths in health facilities - Full case investigation details of each case
Advantages	<ul style="list-style-type: none"> - Less expensive than other strategies - Covers a wider area 	<ul style="list-style-type: none"> - High quality clinical, epidemiological and diagnostic data - Signal trends/ monitors disease burden of selected population 	<ul style="list-style-type: none"> - Improves timeliness and accuracy of case reporting - Directs eradication and elimination programmes - Rapid detection of outbreaks through close laboratory linkages - Enables timely action
Disadvantages	<ul style="list-style-type: none"> - Reporting is rarely complete and timely - Burden on health staff 	<ul style="list-style-type: none"> - Cannot be used to calculate incidence - Not representative - Ineffective for detecting rare diseases 	<ul style="list-style-type: none"> - Resource –intensive - Requires dedicated staff, transport, management

Early warning and response function of CDS

CDS is most valuable when it can produce a rapid response to health issues. The overarching objective of the system is that IBS and EBS work complementary to trigger the appropriate authorities as early as possible to respond to public health events. The Early Warning and Response (EWAR) functionality is a key requirement of the IHR (2005) and requires multiple diverse data services, an available workforce, existing community network, and most importantly the ability to minimize the negative health consequences under an acute public health event (27).

2.1.3 Guidelines for evaluation of PHSS

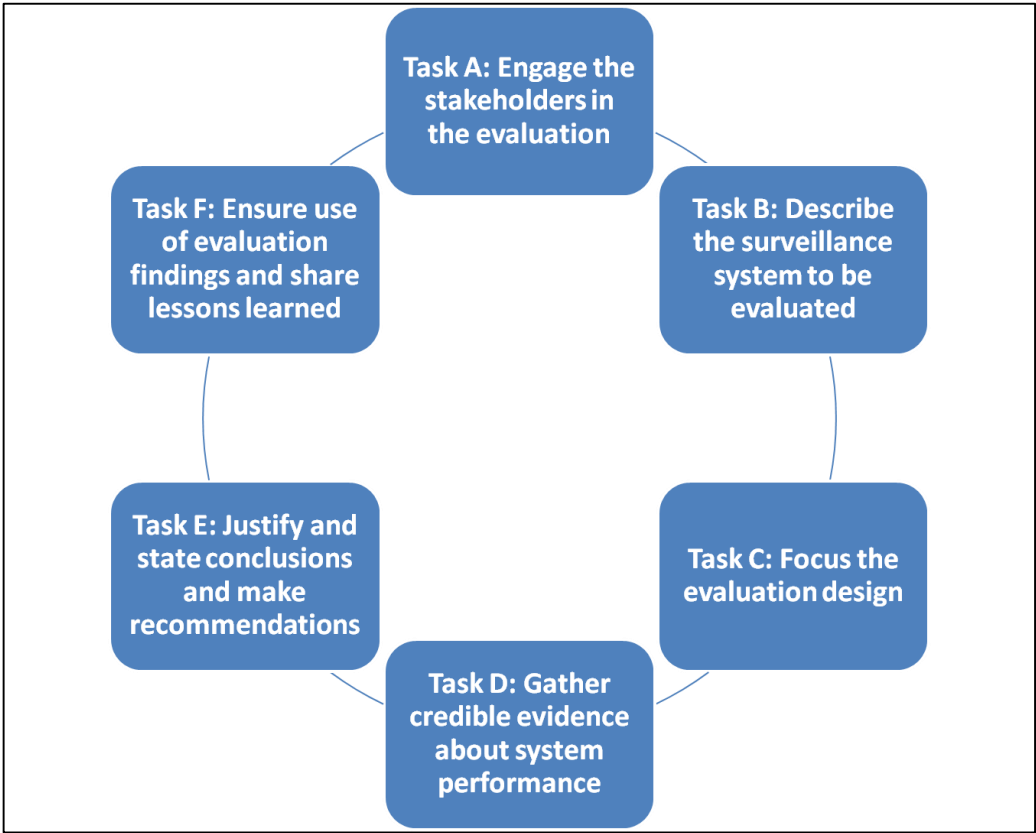
To ensure that health programmes are using quality health information to make decisions, there must be a quality surveillance systems in place (30). Evaluation of surveillance systems should be completed to determine whether the purposes of the surveillance system are met (1) and regularly assessed to ensure that appropriate and meaningful data is being captured for public health action and policy development. This section summarises the current guidelines for evaluating public health and communicable disease surveillance systems.

CDC's Updated guidelines for evaluating public health surveillance systems (31)

The CDC's '*Updated guidelines*' was published in 2001 to supplement the 1988 foundational version and identify the essential elements and attributes of an effective PHSS. Though not explicitly stated, the intended audience could be programme evaluators of US surveillance systems. This is assumed because examples provided throughout the document focus on the National Notifiable Disease Surveillance System and experiences of US state and local health departments. The guide summarises two main steps of evaluating PHSS by 1) describing the objective and elements of the system and 2) assessing performance according to key attributes (32). The report identifies six tasks that must be accomplished to satisfy these steps (Figure 2.3).

The guidelines also include the nine system attributes defined in Table 2.4. These attributes represent surveillance system characteristics that contribute directly to the system’s ability to achieve its specific objectives (1). Each attribute is described and general methods for collecting these from surveillance programme participants are suggested. The guidelines conclude with the recommendation that all PHSS be evaluated periodically and state that as technology and practice evolve, so should the guidelines for evaluating surveillance systems.

Figure 2.3 Tasks for evaluating public health surveillance systems



Source: CDC (31)

Table 2.4 CDC recommended attributes for evaluating the performance of PHSS¹

Attribute	Description	Selection of suggested evaluation measures and methods
Acceptability	<ul style="list-style-type: none"> ▪ Willingness of relevant entities to participate in PHSS² 	<ul style="list-style-type: none"> ▪ Assessment of entity (individual or organization) participation rate ▪ Completion and timeliness of reporting forms
Data Quality	<ul style="list-style-type: none"> ▪ The completeness and validity of the data recorded in the PHSS 	<ul style="list-style-type: none"> ▪ Calculating the percentage of “unknown” or “blank” response items on surveillance forms ▪ Comparison of data values recorded vs. true values
Flexibility	<ul style="list-style-type: none"> ▪ Ability of the PHSS to be adaptive and accommodating to changing information (e.g. new health related event) and needs with little resources. 	<ul style="list-style-type: none"> ▪ Usually evaluated retrospectively ▪ Subjective assessment of effort needed to change or retrofit a component of a system
Predictive value positive (PVP or PPV)	<ul style="list-style-type: none"> ▪ The proportion of reported cases that actually have the health-related event under surveillance 	<ul style="list-style-type: none"> ▪ Review of case investigation forms ▪ Review of external data to confirm cases (e.g. registries, medical records, death certificates)
Representativeness	<ul style="list-style-type: none"> ▪ Accurate PHSS description of the occurrences over time and its population distribution by place and person 	<ul style="list-style-type: none"> ▪ Compare the characteristics of reported events to all such actual events ▪ Calculate rates of health-related events in population (could include high risk or target populations) and use to measure trends over time (denominator source must be consistent)
Sensitivity	<ul style="list-style-type: none"> ▪ Proportion of cases of a disease (or other health-related event) detected by surveillance system (i.e. cases-suspected vs. confirmed/missed cases) 	<ul style="list-style-type: none"> ▪ Estimate the proportion of total number of cases in the pop under surveillance being detected by the system

¹ Communicable Disease Surveillance System

² Can refer to a specific CDSS or entire PHSS

Attribute	Description	Selection of suggested evaluation measures and methods
	<ul style="list-style-type: none"> • The ability to detect outbreaks and monitor changes in the number of cases over time 	
Simplicity	<ul style="list-style-type: none"> ▪ The degree of ease in operating the PHSS while still meeting its objectives (Closely related to acceptance, timeliness, and the amount of resources required to operate the system.) 	<ul style="list-style-type: none"> ▪ Amount and type of data needed to identify health condition ▪ Amount and type of data required on surveillance form ▪ Number of organizations or persons involved ▪ Data management including time spent on transferring, entering, and storing data
Stability	<ul style="list-style-type: none"> ▪ Reliability and availability of the PHSS 	<ul style="list-style-type: none"> ▪ Measures of costs involved with systems computer ▪ Percentage of time the system is operating fully ▪ Comparing the outcomes of the system with its stated purpose and objectives
Timeliness	<ul style="list-style-type: none"> ▪ The speed between steps in a PHSS 	<ul style="list-style-type: none"> ▪ The interval between the onset of a health-related event and it being reported to the public health entity Responsible for institution control measures
Usefulness ¹	Surveillance system contributes to the prevention, control, and discovery of adverse health-related events, including an improved understanding of the implications of such events	<ul style="list-style-type: none"> ▪ Review objectives of the system and consider the system’s effect on policy decisions and disease control programmes ▪ Survey key persons who use data from the system on the usefulness of the system

Source: Adapted from CDC’s Updated guidelines for evaluating public health surveillance systems (31).

¹ Usefulness is not listed as an original attribute, but more as an indicator of surveillance system performance which is reliant on the other attributes. However, this is often assessed in PHSS evaluations

WHO's Communicable disease surveillance and response systems: Guide to monitoring and evaluating (8)

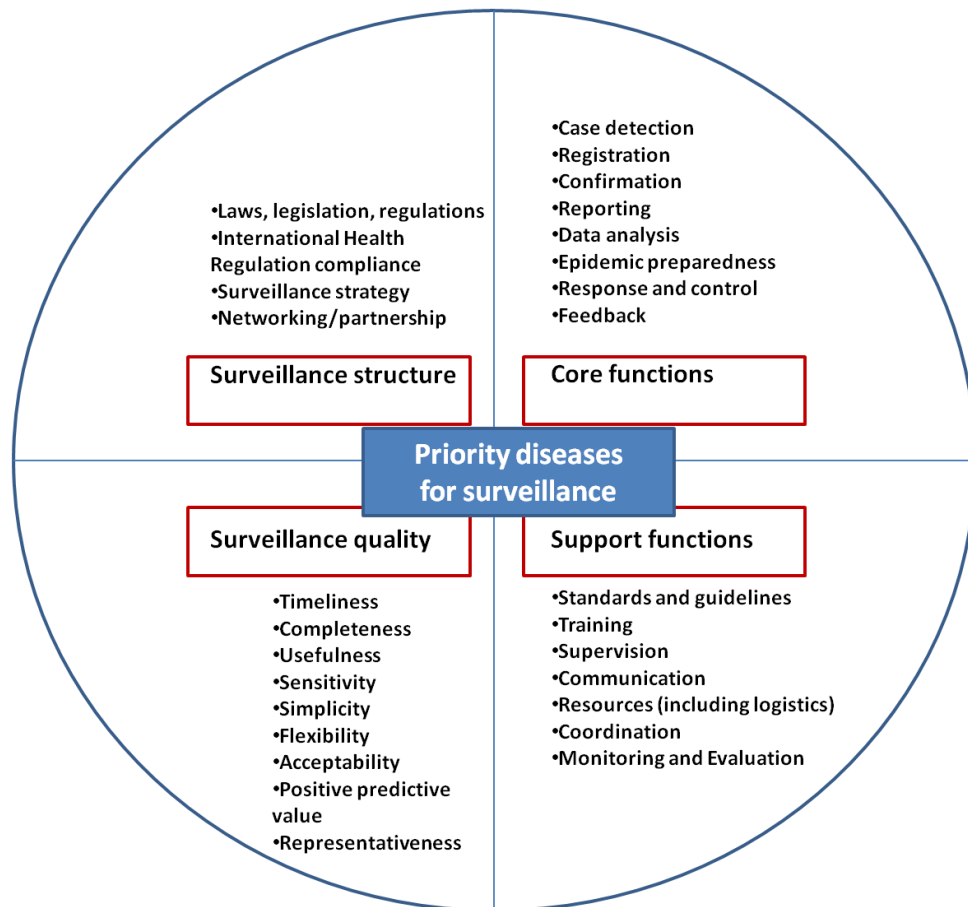
The World Health Organisation (WHO) guidelines for monitoring and evaluating (M&E) CDSS were published five years after the updated CDC guidelines in 2006, and were developed to support implementation of surveillance system strengthening activities. The guide makes mention of the IHR (2005) (released just one year prior to this guide) and its commitment to global security. The guide underscores the regulation requirement for all Member States to put in place an effective surveillance and response system. Communicable disease surveillance is selected as the mechanism to evaluate the impact of disease prevention and control projects. The structured activities proposed to strengthen national CDSS activities include:

- Assessment of communicable disease risks to identify major public health threats.
- Prioritisation of public health threats to ensure that surveillance is limited to the important public health events.
- Assessment of existing systems to review strengths, weaknesses, and opportunities for strengthening the systems.
- Development of a strategic plan of action based on the findings of the assessment.
- Implementation of activities planned to strengthen the systems.
- Monitoring progress in implementation of planned activities, the evolution and performance of the surveillance system.
- Evaluating outcomes and overall impact of the surveillance system.

The primary intended users are listed as Ministry of Health staff implementing surveillance and response systems. Beyond a description of the concepts for M&E of CDSS, the guidelines underscore indicators as tools for M&E and provide a list of sample indicators.

When describing the components of surveillance and response systems for M&E, the WHO introduces a new conceptual framework for measuring effectiveness of CDSS around priority diseases. The framework components include the CDC quality attributes, along with an expanded list of core and support functions delineated by McNabb *et al.* (33), and finally what they call surveillance ‘structural components’. Each of these components are defined and expanded upon in the guidelines with worksheets, examples, and suggested indicators provided throughout the document. Each component is illustrated in Figure 2.4.

Figure 2.4 Conceptual framework of surveillance and response systems for communicable disease



Source: Overview of the WHO framework for monitoring and evaluating surveillance and response systems for communicable diseases (34)

2.2 Background to communicable disease surveillance in Sub-Saharan Africa

2.2.1 The need for stronger disease surveillance of emerging and epidemic prone infectious diseases

Novel and re-emerging infectious diseases typically make headlines because they conjure scenes of devastating past epidemics, like the bubonic plague and the Spanish flu. The equally daunting reality is that many communicable diseases have serious impact on societies and economies and interfere with many aspects of daily life (35). Frightening diseases like Ebola, Middle East Respiratory Syndrome Coronavirus (MERS CoV), SARS and even the pandemic H1N1 have impacted high and middle-income countries very differently than low-income countries. In high-income countries established and sensitive health systems, cutting edge technology, and an ever-ready bioterrorism response unit can squelch a killer epidemic. Contrastingly, sub-Saharan African countries are perpetually vulnerable to sudden unknown disease occurrences, due to chronic shortages of doctors, medicine, health facilities, and medical equipment. These challenges are exacerbated in countries, which suffer from persistent economic constraints, civil war and conflict, and overwhelming poverty and disease (36, 37). Such disparities can be illustrated by the recent Ebola epidemic where the shortage of beds and facilities in West Africa to accommodate over 25,000 cases starkly contrasts the response to four imported cases in the U.S., such as the allocation of six billion dollars for the creation of 35 Ebola Centres (37).

Notably, SSA has made great strides in combating epidemic prone diseases, primarily from standing on the shoulders of public health triumphs, such as smallpox eradication and tangible progress of goals towards the eradication or elimination of poliomyelitis, dracunculiasis (guinea worm disease), measles and leprosy (38). One lesson that has proved effective is the combined strategy of enhancing population immunity through routine immunisation programmes and supplemental immunisation activities, alongside strengthening epidemiological surveillance (i.e. clinical and laboratory). This

strategy has led to a reduction in the global incidence of polio by 99% since 1988 (38, 39). Stronger coordination between EPI and surveillance also produced an 88% decrease in measles mortality in Africa in only 12 years (40). Other gains include significant decreases in meningitis epidemic response time due to faster identification of circulating serotypes for appropriate vaccine development and the establishment of a sophisticated polio laboratory network, which provides genetic tracking of viruses (41). In addition, the war on Guinea worm continues to take steps to being the second disease eradicated and has seen transmission interrupted in 17 out of 21 originally endemic countries (42). These successes have also brought to light the value of continuous commitment of financial and technical support from local and international stakeholders. The aforementioned achievements have been the products of the targeted strategies implemented through the Global Polio Eradication Initiative, WHO African Region (AFRO) Paediatric Bacterial Meningitis Surveillance Network, and the Guinea Worm Eradication Programme, respectively. These initiatives are global partnerships, often spearheaded by CDC, the WHO, and the United Nations Children's Fund (UNICEF).

Still, the disparity in the ability to prevent, control, and respond to infectious disease outbreaks remains between SSA countries and much of the rest of the world. Many SSA countries continue to struggle with executing basic surveillance activities. Failures in timely case detection, underreported cases, and opaque reporting to the international community, have resulted in uncontained spread of too many diseases. These activities ought to be buttressed by knowledgeable and watchful clinicians and well-equipped laboratories. Countries must firstly comply with the IHR mandate to develop functional early warning disease systems to combat innumerable preventable deaths due to outbreaks (25, 43). Countries also require widespread laboratory policy reforms to bolster quality assurance and training directives, and expand capacity and funding beyond disease-specific programmes — this could greatly decrease response efforts for disease outbreak crises (41).

The tried and true formula of strong routine immunisation plus enhanced surveillance must be decisively executed to see continued progress of disease control. The next section discusses the WHO-African Regional office solution to the second half of this equation: a systematic approach to disease surveillance in SSA.

2.2.2 Integrated disease surveillance and response strategy

In an effort to confront the challenges of limited resources in SSA, the integrated disease surveillance and response (IDSR) strategy was developed by the WHO-African Region in 1998. IDSR is a strategy for developing and implementing comprehensive and efficient public health surveillance and response systems in SSA (44, 45). The specific objectives are listed in Table 2.5. The IDSR strategy is used in surveillance of priority diseases as recommended by the WHO and selected by each country; this usually includes epidemic prone diseases and diseases marked for elimination and eradication (see Table 2.6).

This holistic, shared resource approach focuses on strengthening surveillance from district to regional to national levels, and has improved data collection, reporting, analysis and monitoring as well as strengthened the use of data for decision-making across all health levels (46). Additionally, IDSR provides a platform for countries to implement the IHR (2005) (47). IDSR implementation has contributed towards strides in sufficient immunisation coverage and attainment of global disease elimination and eradication goals by improving surveillance at the peripheral and district health levels through continuous investment in human capital and equipment (48). Of the 46 countries in the WHO African region (AFRO), 43 are implementing IDSR guidelines to improve their abilities to detect, confirm, and respond to high priority communicable and non-communicable diseases (43).

Table 2.5 Specific objectives of IDSR

1. Strengthen the capacity of countries to conduct effective surveillance
2. Integrate multiple surveillance systems for efficient use of resources
3. Improve the use of information to facilitate evidence-based response
4. Improve the flow of surveillance information between and within health jurisdiction levels
5. Strengthen laboratory capacity and involvement
6. Increase involvement of clinicians in surveillance system
7. Emphasize community participation, including event based surveillance
8. Use data thresholds to trigger epidemiological investigations

Source: WHO/ CDC (45)

The key feature of IDSR is that it is an integrated system. This means that all the surveillance activities are coordinated and streamlined, rather than separated and duplicated for different diseases. Integration includes the horizontal management of methods, software, data collection forms, standards and case definitions in order to prevent inconsistencies and standardise reporting of information by designated focal points at every health level. Integrating disease training, supervision, and feedback, which practically cuts down on the amount of trips and funds used to support such activities, efficiently uses resources. This also allows for the hiring of specific personnel and materials (e.g. vehicles, computers,) to perform exclusive surveillance-related activities (45).

Core activities and functions of a surveillance system

The IDSR guidelines provide a general reference for surveillance activities and functions for national public health management officials, relevant clinicians, health facility managers, partners, and community officers. The eight steps for completing the IDSR public health functions are listed below:

Step 1 – Identify cases and events

Step 2 – Report suspected cases or conditions to the next health level

Step 3 – Analyse and interpret data for trends

Step 4 – Investigate and confirm suspected cases, outbreaks or events

Step 5 – Prepare for response to potential outbreak

Step 6 – Respond

Step 7 – Provide feedback on outcomes to all levels that provided data

Step 8 – Evaluate to assess and improve the effectiveness of the system

Several of these activities occur across jurisdictional health levels (i.e. community, health facility/peripheral, intermediate, national) and others occur at specific levels only. The integrated system also includes laboratory services at some levels. IDSR has a specific focus on strengthening the intermediate or district level.

Table 2.6 Priority diseases, conditions and events for IDSR, 2010

Epidemic prone diseases	Disease targeted for eradication or elimination	Other major disease, events or conditions of public health importance
<p>Acute haemorrhagic fever syndrome*</p> <p>Anthrax Chikungunya</p> <p>Cholera</p> <p>Dengue</p> <p>Diarrhoea with blood (Shigella)</p> <p>Measles</p> <p>Meningococcal meningitis</p> <p>Plague</p> <p>SARI**</p> <p>Typhoid fever</p> <p>Yellow fever</p> <p>*Ebola, Marburg, Rift Valley, Lassa, Crimean Congo, West Nile Fever</p> <p>**National programmes may wish to add Influenza-like illnesses to their priority disease list</p>	<p>Buruli ulcer</p> <p>Dracunculiasis</p> <p>Leprosy</p> <p>Lymphatic filariasis</p> <p>Neonatal tetanus</p> <p>Noma</p> <p>Onchocerciasis</p> <p>Poliomyelitis*</p> <p>*Disease specified by IHR (2005) for immediate notification</p>	<p>Acute viral hepatitis</p> <p>Adverse events following immunisation (AEFI)</p> <p>Diabetes mellitus</p> <p>Diarrhoea with dehydration in children under 5 years of age</p> <p>HIV/AIDS (new cases)/Hypertension</p> <p>Injuries (Road traffic Accidents)</p> <p>Malaria</p> <p>Malnutrition in children under 5 years of age</p> <p>Maternal deaths</p> <p>Mental health</p> <p>Epilepsy</p> <p>Rabies</p> <p>Severe pneumonia in children under 5 years of age</p> <p>Sexually transmitted infections</p> <p>Trachoma</p> <p>Trypanosomiasis</p> <p>Tuberculosis</p>
	Diseases or events of international concern, as specified by the IHR	
	<p>Human influenza due to a new subtype</p> <p>SARS</p> <p>Smallpox</p> <p>Any public health event of international or national concern (infectious, zoonotic, food borne, chemical, radio nuclear, or due to unknown condition.)</p>	

Source: WHO-AFRO (49)

2.3 Research context of meningitis and Chad

This section contains background information on meningococcal meningitis with special attention given to the disease in sub-Saharan Africa. It also presents a brief overview to Chad and the rationale for selecting this disease and this country as the case study of my PhD research. The information summarised in this section is important to understanding methods and resources needed for meningitis surveillance.

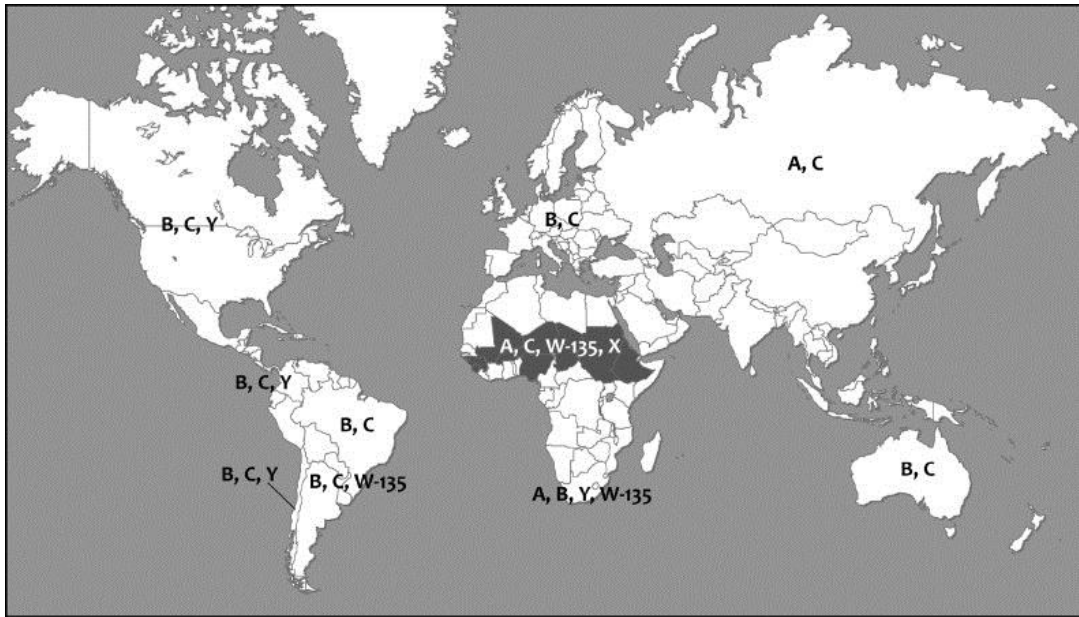
2.3.1 Meningococcal meningitis

While several agents can cause meningitis, including, bacteria, protozoa, viruses and fungi, meningococcal disease specifically refers to any illness caused by the gram-negative bacterium *Neisseria meningitidis* (also called the meningococcus) (50). The two primary clinical outcomes of meningococcal disease are meningococcal meningitis (one form of bacterial meningitis) and meningococcal septicaemia (meningococcaemia). Meningococcal disease generally occurs 1–10 days after exposure and presents as meningitis in more than 50% of cases (51). Meningococcal meningitis is clinically defined as an inflammation of the brain and spinal cord meninges, and requires immediate hospitalisation. It is the only form of bacterial meningitis that causes epidemics. The case-fatality rate of meningococcal disease is 9% to 12%, even with treatment; in resource poor countries fatality rates can reach 50% (52, 53). As many as 20% of survivors have permanent sequelae, such as hearing loss, neurologic damage, or limb amputation (54). Meningococcal septicaemia can be more severe with a fatality rate of 20% to 40% depending on timeliness of and access to treatment (53, 55)

Epidemiology

Six serogroups of *N. meningitidis* are known to cause life threatening disease (A, B, C, W, X and Y). Figure 2.5 depicts the serogroup distribution and predominant strains by world region.

Figure 2.5 Worldwide distribution of major meningococcal serogroups



Sub-Saharan African meningitis belt indicated by the dark shaded area.

Source: Harrison, LE *et al* (56)

Though epidemics can occur in any part of the world, the highest burden of this disease is in Africa, where epidemic and endemic rates are several times higher than those in industrialised nations. Serogroup A is the dominant strain Responsible for the recurring meningitis epidemics in Africa during the last century (2). Additionally, serogroups X, Y, and W emerge sporadically and have caused several African outbreaks in the last decade (56-60). Serogroups B and C are repeatedly Responsible for outbreaks in several industrialized nations. Table 2.7 explains the characteristics of each serogroup (61).

Table 2.7 Characteristics of disease due to meningococcal serogroups

Serogroup	Characteristics
A	Most prevalent serogroup in SSA and China Leading cause of epidemic meningitis worldwide Monovalent conjugate vaccine available
B	Major cause of endemic meningitis in Europe and the Americas Vaccines commercially available in several countries; will be introduced in the UK routine immunisation programme for infants in 2015
C	Major cause of endemic meningitis in Europe and the Americas Peaks of disease in adolescents and young adults Conjugate MenC vaccine was adopted into the UK immunisation schedule in 1999 Polysaccharide vaccines are still mostly used in SSA
Y	Infrequent worldwide Emerged in the US in mid 1990s Conjugate and polysaccharide tetraavalent vaccines (A, C, Y, W) available
W	Worldwide, some epidemics in SSA Associated with Hajj pilgrimage in 2000 and 2001 Conjugate and polysaccharide tetraavalent vaccines (A, C, Y, W) available
X	Infrequent worldwide Cause of local outbreaks in parts of SSA No vaccine is yet available to protect against serogroup X

In 2012 the global burden of invasive meningococcal disease was estimated to be at least 1.2 million, with 135,000 deaths (62). Meningococcal incidence trends are highly regional and are contingent on serogroup distribution (56). Meningococcal meningitis incidence is variable with ranges from 0.3 - 0.05/100,000 in industrialised countries to 1,000 per 100,000 population during severe African epidemics (2, 51). Meningococcal disease can occur year-round, but has a seasonal pattern, which varies by country. Generally, peak incidence occurs in late winter to early spring in countries with a temperate climate and during the dry season in SSA. High risk populations include infants, adolescents, and young adults. Other risk factors include travelling to an endemic area, closed populations (e.g. military personnel, Hajj pilgrims), recent upper

respiratory tract infections and smoking (2, 51). Because of this, local understanding of the epidemiology and burden of disease need to be facilitated through meningococcal disease surveillance.

The African meningitis belt

Epidemic meningitis in Africa dates back to more than 100 years ago (63). In 1963, Lapeyssonnie coined the term 'meningitis belt', which represents the geographic distribution of sub-Saharan African countries with the highest incidence of meningococcal disease. While the epidemiology of meningococcal disease varies greatly across geographic area and time, explosive meningitis epidemics occur in five to twelve year cycles in meningitis belt countries (2, 64). Generally, outbreaks and epidemics coincide with the dry *Harmattan* season (typically end of November to end of June). The African Meningitis Belt is comprised of 22-26¹ countries stretching from Senegal to Ethiopia, primarily in the semi-arid and sub-Saharan areas (Figure 2.6). Cumulatively, this represents an at-risk population of 430 million people (64). Before 2010, serogroup A was the predominant strain in this region, accounting for 80-85% of all cases (61). The most devastating of these outbreaks was the 1996-1997 epidemic—more than 250,000 cases and over 25,000 deaths were reported (65). Substantial outbreaks have also been due to serogroups C, W and X, though since 2002 these occurrences have generally decreased (59, 63, 66). The most recent large-scale meningitis epidemic in this region occurred in 2009 where more than 80,000 cases were reported and was due to serogroup A meningococcus (66).

Transmission and carriage

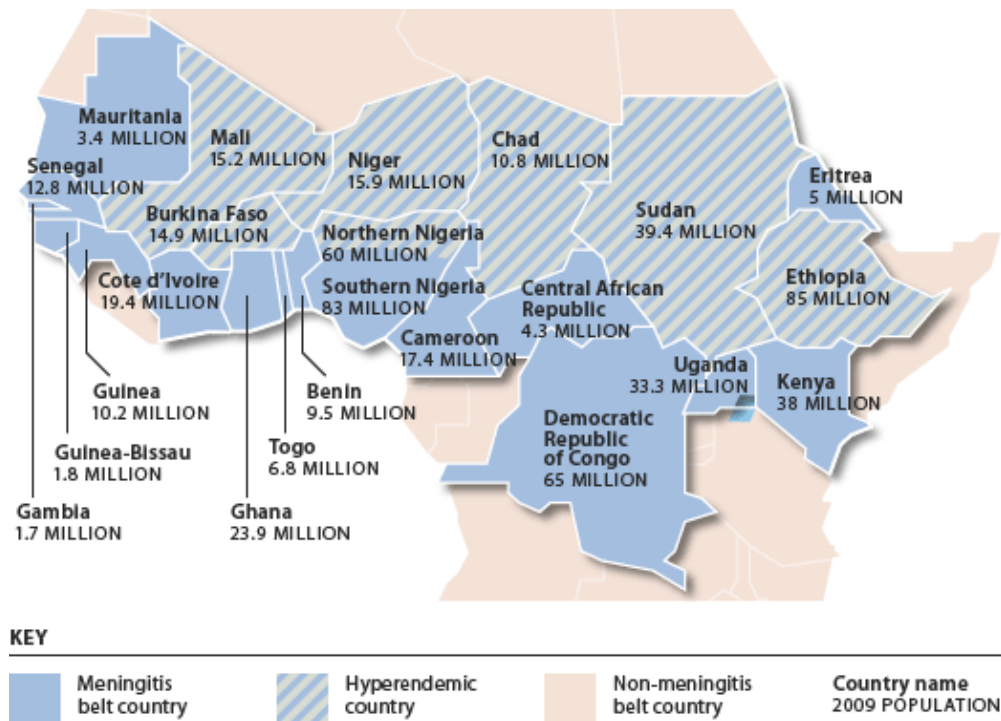
Humans are the only known reservoir for meningococcus and the disease is spread rapidly from person to person through the respiratory droplets of infected people (24). Thus, risk factors are associated with host characteristics and environmental factors. For example, people living in crowded and intimate living spaces, such as university

¹ Burundi, Rwanda, South Sudan, and Tanzania, are usually considered part of the *extended belt*

dormitories and army barracks, are at higher risk than people who do not live in these spaces (51).

N. Meningitidis commonly inhabits the mucosal membranes of the nose and throat and it is estimated that at any given time 5-25% of the population are asymptomatic carriers (2, 24, 51). Carriage has protective and immunising properties and non-carriers are considered high-risk for meningococcal disease (67), but a clear association between carriage and immunity and disease remains unclear, especially in the African context (2, 60). Carriage studies of pathogenic strains are occasionally undertaken to understand epidemic conditions and carriage reduction through vaccination with conjugate vaccines has been effective in interrupting transmission (63, 68, 69).

Figure 2.6 Sub-Saharan Africa meningitis belt countries



Source: PATH/MenAfriVac (70)

Diagnoses

Patients with meningitis present with symptoms such as: stiff neck, headache, and an abrupt onset of fever. These features can be accompanied by sensitivity to light, confusion, and vomiting (24, 51). Upon presentation of meningitis symptoms, a lumbar puncture is performed to obtain cerebrospinal fluid (CSF), which should undergo laboratory diagnostic testing for confirmation of meningitis and isolation of *N. meningitidis*. These include culture, gram stain, latex agglutination and rapid diagnostic tests (71). These methods can be performed in basic environments with limited laboratory facilities. During outbreaks, identification of the serogroup is essential to ensure use of the appropriate vaccine. Apart from culture, the reference standard for diagnosis is identification of meningococcal DNA using polymerase chain reaction (PCR) (72). PCR is used frequently in industrialised countries; however, the equipment and material resources needed to perform PCR can be difficult to obtain in resource-constrained settings (2, 63).

Treatment

Meningitis can be effectively treated with antimicrobial agents (e.g. penicillin). Early diagnosis and treatment is critical to halt the rapid progression of the infection and decrease the probability of death (50, 51). Treatment should ideally be administered after blood or CSF sample is obtained to ensure that bacteria can still be detected through laboratory testing.

Vaccines

Vaccines are integral to the prevention and control of meningococcal meningitis. Polysaccharide vaccines have been available since the 1970s for serogroups C, A, W, and Y. These vaccines are relatively inexpensive, safe and effective, and are most useful in mass vaccination campaigns, where they have been used extensively to control epidemics in African meningitis belt countries. Limitations of polysaccharide vaccines are: 1) they are less effective in young children, 2) they do not provide long-term protection (immunity lasts for 3-5 years), and 3) they have little or no effect on

carriage and thus no herd immunity (2, 51). Due to this final reason, these vaccines have not reduced the frequency of epidemics in hyper-endemic countries.

Conjugate vaccines were first successful for *Haemophilus influenzae* type B (Hib) and offer improvements over polysaccharide vaccines. These vaccines induce a strong and long-term immune response even in infants as young as two months old, and have been shown to reduce the frequency of *N. meningitidis* carriage and protect unvaccinated persons through herd immunity (51, 73, 74). The first meningococcal conjugate vaccine (serogroup C vaccine) to be licensed was introduced in the UK in 1999 where it demonstrated 90% vaccine effectiveness and significantly reduced the incidence of type C meningococcal disease (2, 74). Europe, Canada and the US subsequently introduced monovalent C conjugate vaccines into their routine immunisation programmes. Since 2005, tetravalent (A, C, W, Y) conjugate vaccine has been available in the United States and internationally.

The main limitation of conjugate vaccines is the high costs, for example in 2011 the US CDC price for tetravalent vaccine was USD \$85.12 per dose (75)-- an unattainable amount in SSA, which includes some of the poorest countries in the world. Due to this, countries in Africa continued using polysaccharide vaccines until 2010. Through the Meningitis Vaccine Project (a Bill and Melinda Gates funded collaborative effort between WHO and PATH), a novel meningococcal serogroup A polysaccharide–tetanus toxoid conjugate vaccine (PsA-TT) (MenAfriVac®) was developed. Before development started, the Serum Institute of India agreed to not charge more than 0.60 USD per dose. This new vaccine gives hope to achieving elimination of epidemic meningitis as a public health problem in SSA (76). Chapter 5 will further discuss the introduction of this vaccine into SSA and Chad.

2.3.2 Surveillance in the African meningitis belt

The WHO-AFRO IDSR strategy is meant to be implemented across all disease surveillance programmes in Africa, including meningitis. Under this strategy, the district level is the focus of most of the six activities (44) (26):

1. Detection and notification of health events;
2. Collection and consolidation of pertinent data;
3. Investigation and confirmation (epidemiological, clinical and/or laboratory) of cases or outbreaks;
4. Routine analysis and creation of reports;
5. Feedback of information to persons providing data;
6. Feed-forward (i.e. the forwarding of data to more central levels).

Since 2009 the WHO has provided the *Standard Operating Procedures for Enhanced Meningitis Surveillance in Africa* (77), to African meningitis belt countries for supplemental guidance. This document provides technical meningitis-specific information such as case-definitions, intervention thresholds, and vaccine choice guidance. It also explains the recommended meningitis surveillance methodologies for African meningitis belt countries, which are defined below.

Enhanced epidemic meningitis surveillance

Since 2002, enhanced epidemic meningitis surveillance (ES) has been the baseline surveillance strategy for countries in the African meningitis belt. This passive approach uses population-based aggregated counts of suspected cases of all ages (according to the standard case definition) to compute weekly incidence at the district level. When district meningitis rates exceed 10 cases per 100,000 populations in a single week, reactive campaigns using a polysaccharide meningococcal vaccine are recommended and implemented (78). With ES, laboratory confirmation is required only for the first several cases, which serves to identify the pathogen Responsible for the outbreak. This means that under ES, health facility personnel only perform a few lumbar punctures

and send few samples to the laboratory. These samples should be accompanied with a standard IDSR form with the details of the case. After the serogroup is confirmed, health facilities are not required to capture further detailed information or perform lumbar punctures on suspected cases. All suspected cases however continue to be captured using a line list.

Because this method relies on aggregated data and calls for limited laboratory confirmation, it has an incomplete capacity to respond to the new epidemiological needs and questions that have arisen from introduction of the new conjugate vaccine, including the impact of the new vaccine on serogroup circulation and epidemic patterns, as well as vaccine efficacy (78, 79).

Case-based surveillance

Unlike aggregated surveillance approaches, case-based surveillance collects information at the individual level. It requires all suspected cases of meningitis to be investigated individually and for all epidemiological information to be documented. Additionally, microbiology data from the individual are linked with their epidemiological information by a unique identifier. This active approach is resource intensive, but it also provides the most informative data and it is the only surveillance method for providing vaccine efficacy information (77). Due to resource constraints, case-based surveillance may be difficult to implement in all areas where the new conjugate vaccine has been introduced. Hence, making trade-offs regarding both the amount of information that can be expected and the amount of resources available is necessary to decide on the most appropriate surveillance strategy and its scale.

The WHO guidelines, *Epidemic meningitis surveillance in the African meningitis belt: Deciding on the most appropriate approach* (80), outline the scope of potential meningitis surveillance strategies in the context of the post- MenAfriVac® introduction. It provides Meningitis belt countries with an overview of surveillance objectives (Table 2.8) and

describes information on practical considerations for each strategy (Table 2.9). Three types of case-based surveillance have been identified (81):

1. ***Comprehensive case-based outbreak documentation:*** Active and systematic collection of detailed epidemiological and bacteriological information on each meningitis case during an epidemic.
2. ***Sentinel case-based surveillance:*** Uses data systematically collected in a sample of high-quality sites across the country, which are purposely selected to bring forth valuable information and answer specific epidemiological questions. This approach is particularly relevant when resources are too sparse to implement nationwide effective surveillance. While a sentinel system will not at once answer all the epidemiological questions associated with the introduction of the conjugate vaccine, it is possible to combine different strategies to reach a satisfying level of information and meet the surveillance goals set for meningococcal meningitis. The proposed sentinel surveillance strategies for meningitis are:
 - a. ***Paediatric case-based surveillance:*** Relies on same principles as paediatric bacterial meningitis surveillance (i.e. collects clinical and diagnostic data on children <5 years at sentinel hospitals which primarily serve children)
 - b. ***Hospital case-based surveillance:*** Implemented in a selection of hospitals where meningitis suspected cases are treated
 - c. ***District case-based surveillance:*** Implemented in all health facilities in a particular district. It is a population-based approach where information at the individual level of suspected cases is collected. In some countries, this involves referral of suspected cases to a district level facility for lumbar puncture procedure.
3. ***Nationwide case-based surveillance:*** All health facilities in a country are included in the surveillance system. A population-based approach where information at the individual level is collected on each suspected case

(microbiological and epidemiological). It is the widest and most comprehensive approach to case-based surveillance.

Table 2.8 Meningitis surveillance strategies and associated objectives

Surveillance Objectives	Surveillance Strategies					
	Enhanced epidemic surveillance	Comprehensive case-based outbreak documentation	Pediatric case-based surveillance	Hospital case-based surveillance	District case-based surveillance	Nationwide case-based surveillance
1. Detect and confirm outbreaks, launch appropriate response strategies	X				X ¹	X
2. Assess the case burden and incidence trends in time, place, and persons of meningococcal meningitis and other acute bacterial meningitis	X					X
3. Monitor the circulation, distribution and evolution of Nm serogroups and other pathogens	X	X	X	X	X	X
4. Monitor the circulation, distribution and evolution of Nm strains (sequence-type)	X	X	X	X	X	X
5. Monitor the antibiotic resistance profile of Nm	X	X	X	X	X	X
6. Evaluate the control strategies	X	X			X	X
7. Evaluate the impact of the conjugate meningitis A vaccine on the number of cases and outbreaks, on epidemic patterns, and on circulating serogroups		X	X	X	X	X
8. Estimate the efficacy of the meningitis A conjugate vaccine		X	X	X	X	X

Source: WHO (80)

¹ Using incidence thresholds in the districts involved in sentinel case-based surveillance

Table 2.9 Breakdown of incremental resources needed per surveillance strategy

Surveillance Strategies	Types of incremental resources							
	Human resources	Laboratory capacity	Specimen handling shipment	Training	Laboratory materials	Lumbar puncture kits	Complex preparation	Complex implementation
<i>Baseline: enhanced surveillance (used as reference)</i>								
Comprehensive case-based outbreak documentation	Light	Light	Light	Light	Moderate	Light	Light	Light
Paediatric case-based surveillance	Light	Light	Light	Light	Light	Light	Light	Light
Hospital case-based surveillance	Light	Light	Light	Light	Light	Light	Light	Light
District case-based surveillance	Moderate	Light	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Nationwide case-based surveillance	Heavy	Moderate	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy

Note: These resources reflect the needs to operate baseline surveillance and serve as reference for the assessing the incremental resources required to run the other strategies.

For sentinel strategies, the total amount of resources needed will depend on the number of sites or district selected.

Source: WHO (80)

2.3.3 Chad

Chad is a land locked country in central Africa bordered by Libya and Sudan to the North East, Niger and Nigeria to the West, and Cameroon and Central African Republic to the South. It is an ethno-linguistic mosaic of more than 256 language groups. The two official languages are French and Arabic. It is among the poorest countries in the world and ranked 184th out of 186 countries on the 2012 UNDP Human Development Index. Around 55% of the population live below the poverty line and about 36% live in extreme poverty (29). Poverty is primarily concentrated in rural areas where 87% of the country's poor live. Socio-demographic indicators are summarised in Table 2.10.

Table 2.10 Chad socio-demographic indicators

Indicator	Chad
2013 population	12,661,091
Area (million sq km)	1.284
2012 Gross Domestic Product per capita	US\$ 1,006
Life expectancy at birth (years)	50
2011 mortality per 1,000 children < 5 years	169
Infant mortality per 1,000 live births	94
2010 maternal mortality per 100,000 births	1,100
Percent population under 18 years	57%
Percent female population	51%
Percent literacy of entire population	34.5%

Sources: Chad MoH documents, CIA World Fact-book (last updated 15/5/15) and the International Monetary Fund

Chad has suffered from conflict and instability since its independence in 1960. President Idriss Déby's administration has been in place since 1990, and in 1996 was officially designated during the country's first pluralist elections. In 2003, Chad became an oil producing nation, and its gross domestic product per capita rose from an estimated US\$ 253 in 2002 to US\$ 1,006 in 2012 (82). Recently, Chad has become an important

regional actor and safe haven for asylum seekers. It is the temporary home to thousands of Sudanese, Central African, and Nigerian internally displaced persons who have fled violent conflict in their home countries, these include thousands of Chadian migrant returnees (83, 84). Additionally, the Chadian Armed Forces have been influential in peace-keeping missions in Mali and Central African Republic, and has militarily intervened in terrorists attacks in Northern Nigeria (85).

Chad is politically decentralised and regulated by four levels of administrative and territorial demarcations: rural communities, communes, departments and regions. Decentralisation is primarily implemented through regional delegations (i.e. regional action committees) (86). Health areas include regions (see Figure 2.7), districts and zones; MoH authorities are stationed at each level. Health facilities are assigned to specific zones.

Chad's epidemiologic profile is characterised by both endemic and epidemic-prone diseases. The leading causes of morbidity in the population are attributed to malaria, tuberculosis, acute respiratory infections, HIV/AIDS, and diarrheal diseases (87). Child malnutrition rates are the highest in West Africa, with parts of the country experiencing persistent "food crises" since 2012 (88). Like many sub-Saharan countries children and women are the most vulnerable groups in the population.

Recent history of meningococcal meningitis epidemics in Chad

Chad is one of the six SSA countries that are hyper-endemic (i.e. Constant high incidence rates that affects all age groups equally) for meningococcal meningitis (66, 89). For several decades, epidemics have persisted in Chad despite extensive use of polysaccharide vaccines in reactive vaccination campaigns (73). During 1966-2001, Chad reported meningitis cases to WHO almost every year, but there were three, distinct epidemic waves (90). The first phase was between 1970 and 1974, the second between 1988 and 1990, and a third phase between 1998 and 2001. In these epidemics,

between 4,000 and 6,000 cases were reported per year and the case fatality rate was around 10% (90).

Figure 2.7 Regional map of Chad by administrative health divisions



Source: Chad Ministère de la santé publique

During the 2009 epidemic season, cases were primarily detected in the capital N'Djamena with smaller outbreaks in three southern regions, Mandoul, Chari-Baguirmi and Mayo-Kebbi Ouest (91). A total of 1,299 cases and 140 deaths were reported in 2009 (case fatality rate of 10.8%), with about half of the cases caused by NmA and the other half by serogroup W135 (91). In 2010, 3,228 suspected cases and 248 deaths were reported from 11 epidemic districts. The cases were again NmA and W135. In 2011,

there were 5,935 suspected cases, with 269 deaths in 17 epidemic districts. In 2012, 3,874 cases and 163 deaths were reported from 12 epidemic districts. NmA was also the predominant bacteria in these two most recent outbreaks.

MenAfriVac[®] was introduced through mass vaccination campaigns in 2011 and 2012. The campaigns targeted all 1-29 year olds and were conducted in three phases. Three regions (N'Djamena, Chari Baguirmi and Mayo Kebbi Est) had vaccination campaigns during December 2011 where approximately 1.8 million individuals aged 1-29 were vaccinated. Most other regions had campaigns between June and December 2012. However, some districts, such as Oum Hadjer and Moissala, had campaigns a little earlier than this in response to the 2012 epidemic (92). At this time, all regions in Chad were implementing passive surveillance. To date, since the introduction of MenAfriVac[®], there have been no meningitis outbreaks in Chad.

2.3.4 Rationale for MenAfriVac[®] and Chad as research case study

I chose to embrace the public health landmark of the introduction of MenAfriVac[®] in my thesis because I believe it provides a remarkable opportunity to test a new evaluation approach and to improve surveillance of an epidemic prone disease. In addition, the commitment of partners, such as the Bill and Melinda Gates Foundation and the WHO, to use the research from our Chad study to support other meningitis belt countries in identifying the most appropriate surveillance aligned with my aims of sustainable health systems and evidence-based policy development. Finally, the in-depth observations presented in this thesis has value to the government, health care workers, and the population of Chad—this information will benefit these most important stakeholders through improved understandings of the issues.

2.4 Background to cost of communicable disease surveillance systems

A cost study, or economic costing, is a health economic technique which determines the costs of a health intervention or health programme and can underline its importance considered alongside its impact on population health (93). Information about costs can be derived from a cost analysis, which can also be used to compare the costs of two or more approaches or elucidate the economic burden. Cost studies can provide value-for-money information to assist decision makers in efforts to appropriately allocate resources and prioritise investments for specific disease threats (11, 94, 95).

Cost is a commonly reported barrier to communicable disease surveillance system maintenance and thus, performance. However, it is rarely calculated or assessed, revealing a major gap in knowledge to improve disease surveillance programmes, which are chronically underfunded, especially in low-income countries (96). In 2005, the WHO published the guidance document *Evaluating the Costs and Benefits of National Surveillance and Response* (97). Since then, there has been some surveillance research that include a cost analyses. A 2012 systematic literature review of 99 public health surveillance evaluations found that only 21 human health studies included a cost or cost-effectiveness component (98). The objective of this section is to provide a background to the design of costing studies by summarising applied costing methods and detailing key components for conducting a CDSS cost study (99-106). The following subsections are categorised using concepts presented in the aforementioned WHO guidelines.

2.4.1 Methods of CDSS costing exercises

Study objectives

CDSS cost studies are usually undertaken to estimate incremental costs of additional surveillance components. Researchers capitalise on opportunities to assess newly adopted surveillance strategies (102, 105, 106), a new outbreak control programme, (99) or an electronic data-collection system (103). Studies are also conducted to estimate costs associated with a certain event, such as a community outbreak of meningococcal disease (104). While most studies have aimed to provide a cost-outcome description of the system, one study assessed disability-adjusted life years (DALYs) needed to be averted to determine cost-effectiveness of an early warning system (102).

Time horizon

The costs study time horizon, or the period of time for which the costs are measured in the analysis, is generally set to capture two reference points. Studies that include new system components are often defined as “preparatory phase” and “implementation/routine operation phase”. Researchers may choose to use more explicit terms to define their time horizon. For example, Baly *et al.* defined time horizon as “transmission” and “non-transmission” periods to capture attributable cost drivers during dengue outbreaks (99). Time horizon definitions generally correspond with retrospective data collection.

Resource valuation

Resource valuation is usually based on the notion of ‘opportunity costs’. Opportunity costs, are the cost of an alternative that must be forgone in order to pursue a certain action. Put another way: opportunity costs represent the cost of using resources for some purpose and measures their value in the proposed alternative usage (93). The purpose of this notion is to define the value of scarce resources in health care interventions – this is primarily a social-economic theoretical concept (107, 108). An example of an opportunity cost for CDSS is volunteer time for community based

surveillance activities. Economic costs consider opportunity costs, while financial costs do not.

Cost perspective and total costs

A cost perspective is a decision of which social or institutional entities' costs incurred will guide the identification of resource inputs to be included in the study; it must be established at the beginning, as the perspective determines the entire costing process (93). The choice of perspective is derived from the research question and study objective(s). The most comprehensive societal perspective, which includes costs incurred by all parties, is often preferred, but requires substantial resources needed to undertake such a study. The healthcare payer or provider perspective capture costs associated with MoH and partners. A healthcare payer perspective study in Costa Rica considered costs incurred by the National Reference Laboratory, the PAHO Costa Rica office, CDC, and a pilot sentinel hospital (106). In a Colombian study, a combined health service and government perspective was applied to estimate costs associated with treatment, surveillance and an outbreak investigation in one hospital and health department (104). Mueller and colleagues provided an example of a study which considered the full opportunity costs covered by the Kenyan and Ugandan public health care systems (102).

Classification of costs

Capital (i.e. one-time investments) and recurrent (i.e. ongoing or operational) costs must both be collected in CDSS cost assessments. Capital costs commonly include vehicles needed for surveillance supervision, laboratory equipment as well as computers and other office equipment. Costs associated with building infrastructure are sometimes omitted due to lack of information on buildings and replacement cost (99, 105). Recurrent costs typically include personnel, supplies and materials and can be very extensive. In one case of costing a dengue control programme, 'materials' included larvacides and insecticides, diagnostic tests, drugs, protective clothing, gloves, office

materials, operational costs, and utilities (99). An activity costing apportions various costs (e.g. transportation and administrative costs) on the basis of intervention-specific activity data. Cost estimates for staff time are generally determined on the basis of staff numbers and full-time equivalent staff work.

Some costs are categorised by different inputs from the start-up and post-surveillance component implementation phase. In some cases, recurrent costs are differentiated between setup costs and running costs. For example, in the above mentioned dengue control programme study, the operational costs included fuel and lubricants, vehicle rent, per diems and food, spare parts and maintenance of equipment, vehicle and buildings (99).

Shared resources

The challenge of attributing costs of a specific surveillance programme with shared resources is particularly common in surveillance since most resources and activities can (and should) be shared across disease programmes. Such costs include utilities, maintenance, administration, personnel, transport, and buildings. While there is no unambiguous rule to apportion shared costs, many economists try to estimate if the cost would change if the programme was taken away or added to the overall activity (this is called a marginal analysis) (107). In practice, cost studies deal with this by asking surveillance and/or clinical staff the proportional time allocated to related disease surveillance activities. Sometimes this method is coupled with observation sessions or existing estimates are retrieved from the literature. Katz *et al.* tackled this issue within a new costing framework for International Health Regulations (2005). In their study they resolved shared cost by eliminating duplication of itemised resources. In effect, they assigned each resource to the most relevant IHR surveillance indicator and not to the others (even if there was some part of that that was used in other activities) (100). However, in most studies, a systematic method for identifying shared costs was not articulated. For instance, in a study of IDSR implementation in three African countries,

the authors note that the data source (i.e. log books of time and expenses) did not provide the level of details needed to divide the cost of IDSR activities with other public health activities (105).

Estimating resource consumption

Costs data can best be collected using bottom up approaches such as the ingredient approach—a detailed micro-costing exercise which collects quantities of resources as well as their respective unit costs (109). This approach seeks to measure costs as accurate as possible, but may be difficult in low-income countries due to absent or incomplete records of service resources (110). Mueller and colleagues assessed costs by means of the ingredient approach and then categorized into recurrent and capital costs to determine the incremental costs needed to set up and run an early detection system (EDS) on top of a functioning health care system (102). They reviewed expenditures for purchases and financial transactions and interviewed staff to estimate time spent on EDS-specific tasks. The authors captured costs at every level of the health system (i.e. health facility, district health office, and national level-MOH). In their study results, they provided a table of annual costs for Kenya and Uganda, disaggregated by different line items.

Costs are sometimes analysed in aggregate without the inclusion of unit prices. For instance, Lukwago *et al.* established baseline costs by applying a top-down approach and collecting aggregate data at the national level due to national operated vertical programmes (i.e. lack of decentralization). Consequently, the analysis produced mean annual costs associated with key resources involved in IDSR implementation (101). A different method was used by Somda and colleagues, who collected aggregate pharmacy, clinical, and medical data using a structured questionnaire based on the SurvCost¹ tool (111), a survey instrument that guides collection of data on all surveillance resources at all health levels (i.e. primary health care, district, region) (105).

¹ SurvCost will be introduced and discussed further in the Methods chapter

The sources of data were surveillance budget and programme records and reported expenditures. Reported expenditures are preferable and always deferred to when there is discrepancy between source data.

Annual depreciation

Depreciation cost, or economic depreciation, is a component of capital costs that measures the decrease in value of an asset over a certain period of time (107). Annual depreciation rates may vary from 3% (105) to 5% (101, 102, 106) to 6% (99). The horizon for depreciation can be described broadly, as “normal length of life” or more specifically, as “over a 10-year useful life time horizon for normal capital costs”(101). Useful-life horizon is used to assess annual depreciation of buildings, laboratory equipment, office equipment, and vehicles (105, 106). Annualised cost is calculated as:

$$\text{Annualized cost} = K \left[\frac{r(1+r)^t}{(1+r)^{t-1}} \right]$$

In this equation, K is the purchase price of the item and r represents the depreciation rate and 't' is the useful life years.

Differences in currency

Cost data is typically collected in local currency and subsequently adjusted to US dollars equivalents in the year corresponding with time horizon for data collection. Occasionally, studies use purchasing power parities (PPP) to adjust exchange rates of national currencies to international currencies that are comparable in different countries (100, 105).

Sensitivity analysis and validation

In all cost analyses, there is a degree of uncertainty regarding the inputs and consequences; a sensitivity analysis is a critical appraisal method that assists in judging the robustness of conclusions. For instance, Mueller and colleagues performed a sensitivity analysis to model potential variation in the costs of the additional components, such as external technical assistance and increases in salaries. They also included variations in the exchange rate and discount rate (i.e. estimated figures with applied discount rate options of 5% to 3% to 7%) (102).

2.4.2 Capturing CDSS cost study results

Cost displayed by population estimates

Analyses of costs vary based on study perspective, resources collected, and use of population estimates. CDSS cost studies often present mean annual costs per resource categories and health structure level as well as disaggregated IDSR activities (e.g. detection, report, and analysis), which included detailed costs by year (105). Generally, estimates per population figure are derived from national data or through a population census undertaken for the study (104). Costs per population are displayed in various ways using different population denominators and time intervals. For example, Baly *et al.*, compared the average total cost per inhabitant per month during the non-epidemic period (January to July) to the outbreak period (August to December) and presented average monthly economic cost by social actor (i.e. community, primary health care, and hospitals) and period (99). In contrast, Mueller *et al.* estimated annual costs of the early detection system per district and translated this to cost per annum per head of population in Uganda and Kenya (102).

Main cost drivers

Study results generally estimate the distribution of costs by programme resource. Overwhelmingly, staff time/personnel cost represent the largest cost driver (99, 102,

104, 106). Transportation of data or lab specimen is also a large cost component. In Uganda, researchers realised that a large proportion of staff time was spent to transport these items and so they completed a separate analysis to differentiate the opportunity costs of staff time. They found that this represented 7% of total surveillance activity costs and could be reduced by half with the introduction of electronic data transfer systems (102).

Missing data

Missing data is often an issue when conducting studies in lower-income countries. One study describes missing cost data needed to approximate the value of half of the building related to laboratory testing and treatment (105). They compensate for building costs by inserting information from similar ministry buildings in the same locality. For laboratory costs they conducted two analyses; one, which excluded missing data, and the other that extrapolated relevant cost data from other countries. Another study stated that a limitation was not including costs such as education and dissemination of information (104). Resources are commonly collected from all relevant health levels, but many times there are difficulties accessing data sources. For example, one study did not consider any costs incurred by MOH and other supra-provincial level actors in regards to surveillance and response costs of dengue. The authors commented that this omission could lead to underestimation during the epidemic period (99).

Laboratory costs

Laboratory costs are often not included in many CDSS cost studies. However, when they are, the detail of costs of materials and equipment is often limited to 'laboratory reagents'. For example, Pinzon-Redondo and colleagues estimated costs for all surveillance-related activities during a meningococcal meningitis outbreak, but did not include specimen transport costs. Additionally, the authors include a category 'tests' in the micro cost analysis of five patients, but do not provide further details. Lukwago *et al.* sum up laboratory aggregate costs contribution in line item *laboratory reagents* (101).

Their narrative focuses more on epidemiologic activities than on laboratory analysis. Somda *et al.* estimate laboratory consumable materials and supplies for various diagnostic tests for IDSR reportable disease as well as laboratory equipment costs (105). The effect of such vague laboratory costs analysis can lead to an underestimation of the burden of resources used for surveillance activities (112). One study reported that laboratory-related costs represented almost a third of total costs and that the national reference laboratory was the largest cost share entity (106). They included costs associated with laboratory costs covered by the national laboratory as well as supplies donated by PAHO, CDC, and the local laboratory. The authors also captured capital and operational inputs of virology, bacteriology, and biochemistry laboratories.

2.4.3 Conclusion: Including cost assessments in CDSS performance evaluations

Though surveillance studies with cost-components are sparse, this section summarised how standard health economic principles have been applied to gain cost information about surveillance and response activities. Difficulties to quantify the costs of disease surveillance include cost sharing, collecting expenditure versus budget information, inaccessible data, and missing information on costs of buildings and laboratories. Still, costing studies for CDSS are necessary and can provide important information in which other studies, such as economic evaluations or cost-of-illness analyses, can build upon (113). However, without a cost-consequence element, cost studies provide limited information to make any inference on surveillance performance quality and association with investment in the surveillance system.

It was noticeable that while all the retrieved costing studies were published in the last 10 years, none made reference (in text or in reference list) to the WHO *Evaluating the Costs and Benefits of National Surveillance and Response Systems* (97). This is possibly because the document provides the steps involved in designing and evaluating surveillance cost studies, yet does not connect this to surveillance performance, but

rather to economic benefits of averting and controlling outbreaks. Finally, existing CDSS evaluation guidelines suggest that costs should be judged relative to surveillance benefits, but does not provide instructions on cost methods, resources, or how to include this component into a CDSS evaluation (31). (The next chapter will expand on the lack of cost assessments in CDSS performance evaluations).

In reality, epidemiologists are not generally health economists, so this missed opportunity may reflect a failure to exchange ideas between academics and operational researchers, as well as a lack of collaboration between the health economics and field epidemiology disciplines. Since cost evaluations benefit from existing baseline data and performance studies aim to persuade donors to invest in system components, there is an opportunity for these fields to unite technical expertise and resources to improve and expand CDSS evaluations.

3 Literature review of communicable disease surveillance system evaluations

This chapter presents a comprehensive review of published literature on CDSS evaluations. The review was undertaken with two objectives: (i) to describe and examine methods used to evaluate CDSS performance and (ii) to analyse findings of CDSS evaluations. In the context of the PhD, the aim of the review was to inform the proposed Work Process Analysis (WPA) framework and the methods of the Chad meningitis surveillance system evaluation study. I have structured this chapter according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2009 checklist¹ and PRISMA 2009 flow diagram².

3.1 Previous systematic reviews

Five published reviews relating to CDSS evaluation were identified during the search. These are summarised in Table 3.1.

Robert German in 2000 (114) and Van Hest *et al.* in 2011 (115) examined the methodologies of studies that calculate specific attributes of disease surveillance systems: sensitivity and positive predictive value (PPV); with Van Hest and colleagues looking specifically at capture-recapture method—a technique which assesses sensitivity of case reporting by using estimations of the total cases in the population under surveillance. In 2009, Sahal *et al.* (116) reviewed 32 studies to gain lessons learned from CDSS evaluations from developed and developing countries. They found that many African countries are “over-centralised” and that lower levels and private

¹ <http://www.prisma-statement.org/2.1.2%20-%20PRISMA%202009%20Checklist.pdf>

² <http://www.prisma-statement.org/2.1.4%20-%20PRISMA%20Flow%202009%20Diagram.pdf>

hospitals were incongruous in their participation of the CDSS, and recommended that a cost or cost-effectiveness element be included in more evaluations.

Two systematic reviews were recently published: One by Drewe *et al.* (98) in 2012 and the other by Phalkey and colleagues (117) in 2015 (published electronically in 2013). Drewe *et al.* reviewed the approaches for 101 human and animal surveillance evaluations and assessed the articles by attributes, performance indicators, methods, framework type, and reportable health conditions. The authors concluded that only 25% of evaluations were performed systematically and recommended the development of a comprehensive evaluation framework. Phalkey *et al.* included 33 studies in their review, which were limited to sub-Saharan Africa and the IDSR strategy. The authors found that several gaps still remain in IDSR implementation, including weak laboratory infrastructures, lack of established networks, and staff shortages. Both of the two recent systematic reviews included published and unpublished evaluations and presented data on system attributes as well as core and support functions performance.

The present literature review has some overlap with these aforementioned reviews and also some distinctions (Table 3.1). While the recent publication date of several of the reviews negates the need for another systematic review of CDSS evaluations, it provides the opportunity to perform a literature review with a more focused objective. The main objective of the present review is to describe and examine the methods of evaluation studies, and more specifically, the data collection processes of studies. The underlying premise of this aim is that the findings of the evaluations are limited to the methods used and the level of information gathered. None of the other reviews held this same objective. While in some ways the present review offers a more narrow scope than other reviews (e.g. animal studies are not included, calculation methodology of surveillance attributes are not assessed, nor are unpublished studies included), it adds to the literature by being more inclusive in other areas (i.e. inclusion of single and multiple surveillance systems, situational analysis reports, and assesses the consideration of costs). Also, since this review contributes to the PhD aims of

informing a new comprehensive evaluation approach—akin to the one that Drewe *et al.* called for—it probes into the data collection method and delineates the who (e.g. study participants), what (e.g. type of questions), and where (e.g. jurisdictions involved). Finally, in addition to this distinctive aim, the present review utilizes some different terms and databases than the other published reviews used to identify published articles.

Table 3.1 Comparison of CDS evaluation review papers

Author	Ref.	No. of studies	Databases / Paper sources	Search Terms	Aim
German RR. 2000	(114)	47	U.S. Public Health Service Combined Health Information Database, Embase, Health Periodicals, Health Planning and Administration (U.S. National Library of Medicine) and Medline	'surveillance system' and 'evaluation'; 'sensitivity' AND 'surveillance' AND 'predictive value positive'	To determine how predictive value positive (PVP) and sensitivity have been reported in epidemiologic literature in order to provide guidance to public health professionals in computing sensitivity and PVP for a surveillance system
Sahal, N et al. 2009	(118)	32	PubMed, WHO, CDC	'surveillance', 'evaluation', 'communicable', 'diseases', 'infectious', 'assessment', and 'system'	To reflect the experience of both developed and developing countries in the evaluation of CDSS in order to learn lessons to improve systems worldwide
van Hest R, et al. 2011	(115)	52	PubMed/Medline	'recapture'	To conduct a systematic review of the performance of capture-recapture analyses in the categories of human attributes, i.e. Hidden populations, injuries and mortality, and non-infectious and infectious diseases, in resource-limited countries, assessing individual quality criteria and a minimum quality criterion per category

Author	Ref.	No. of studies	Databases / Paper sources	Search Terms	Aim
Drewe JA, et al. 2012	(98)	99	Web of Science, Google (grey literature), and conference proceedings of the International Society for Veterinary Epidemiology and Economics and the Society for Veterinary Epidemiology and Preventive Medicine.	'surveillance', 'evaluation', 'analysis', 'performance'	To identify and examine existing frameworks for surveillance evaluation in animal health, public health and allied disciplines to discover which techniques are currently being used across the globe and to assess their strengths and weaknesses to inform the development of a generic evaluation framework for animal health surveillance systems in Great Britain
Phalkey RK, et al. 2015	(117)	33	CDC, Medline, Web of Knowledge, WHOLIS	'programme evaluation', 'project evaluation', 'health care evaluation mechanisms', 'evaluation/assessment studies as topic', 'self-evaluation programmes', 'evaluation studies' [publication type] 'health services research', process assessment (health care)', 'state health plans', costs and cost analysis', 'task performance and analysis', systems analysis', 'benchmarking', 'lessons learned'; and 'communicable diseases', 'communicable diseases, emerging', 'communicable disease control', 'disease outbreaks', AND 'sentinel surveillance', 'population surveillance',	To systematically review and document the experiences, lessons learned and the challenges identified with the implementation of the IDSR systems in low- and lower middle-income countries and identify the main barriers that contribute to sub-optimal functioning of the IDSR.

Author	Ref.	No. of studies	Databases / Paper sources	Search Terms	Aim
				'epidemiology' [subheading]; 'disease eradication' 'infection control'; AND 'integrated disease surveillance and response', integrated advanced information management systems', 'information systems', 'hospital information systems'	
Erondu NA, 2015 (PhD Thesis)		20	Medline, Cochrane Library, Africa-Wide Information and Global Health	'assessment', 'evaluation', 'surveillance', 'communicable disease control', 'data collection, 'disease monitoring, 'disease surveillance' 'evaluation study', 'outbreak investigation', 'surveillance system', and 'vaccine preventable disease'.	To assess and analyse methods used to evaluate CDSS performance in low- and lower middle-income countries to inform new evaluation framework

3.2 Methods

Search strategy

A comprehensive search of the published literature was undertaken using the Medline, Cochrane Library, Africa-Wide Information and Global Health databases. All databases were last accessed 1st December 2014. Appropriate search terms were derived to meet the stated review objectives. These terms were: 'assessment', 'evaluation', 'surveillance', 'communicable disease control', 'data collection', 'disease monitoring', 'disease surveillance', 'evaluation study', 'outbreak investigation', 'surveillance system', and 'vaccine preventable disease'. The search term combinations, use of Medical Subject Heading (MESH) terms and free text phrases are presented in **Error! Reference source not found.** The Cochrane Library produced no relevant or unique results and so was dropped from the review.

The search was limited to papers published from January 1988 to December 2014. The search began in 1988 because that was the year the CDC first published their *Guidelines for Evaluating Surveillance Systems* (119). All languages were included.

Table 3.2 Search terms and search strategy used to identify relevant publications¹

Medline	Africa-Wide Information	Global Health
<ol style="list-style-type: none"> 1. evaluation studies [MESH] 2. data collection/ OR surveillance system [MESH] 3. communicable disease control/OR vaccine preventable disease OR communicable diseases/ [MESH] 4. surveillance OR outbreak investigation OR disease surveillance OR monitoring 5. evaluation OR assessment 	<ol style="list-style-type: none"> 1. communicable disease 2. surveillance system 3. evaluation 	<ol style="list-style-type: none"> 1. evaluation studies [MESH] 2. data/collection/ surveillance system [MESH] 3. communicable disease control/ OR vaccine preventable disease [MESH] 4. surveillance OR outbreak investigation OR disease surveillance OR disease monitoring 5. evaluation OR assessment

Inclusion Criteria

Papers meeting the following criteria were included:

1. Publications relevant to evaluating national communicable disease surveillance systems (i.e. active or passive).
2. Empirical evaluation studies, assessment or lessons learned performed in low- or lower- middle-income countries, as classified by the World Bank.
3. Studies that included an assessment of at least one surveillance system performance attribute or assessed surveillance system by core function or support activity
4. Studies that included an evaluation of a human disease surveillance system

¹ In each database search string results were combined with the operator 'OR' to find most relevant studies, and finally all string results were combined with the operator 'AND' to generate the final list.

5. Published and unpublished reports retrieved from reference lists of included papers that adhered to the inclusion criteria.

These criteria were applied to obtain the most relevant publications and reports on the surveillance aspect of health systems. Particularly, my intention was to retrieve evaluations that focused on health information surveillance systems that monitor epidemic-prone and reportable diseases. A flowchart of the review process illustrates at what point the criteria were applied to the retrieved publications; this is presented in Figure 3.1. The results section further explains how the criteria were applied and the reasons certain publications were excluded.

There is an element of subjectivity in this review, especially with the discretionary unpublished reports that were included. While the search focused mainly on published literature, criteria five was added so that unpublished reports (i.e. grey literature) could be identified from references of selected publications, and included in this review. These reports were included on a discretionary basis. Surveillance system evaluation is primarily an operational research function and many of the evaluation study field reports are never published and only available at the country level or through private institutions. I decided not to include all potentially accessible, yet unpublished evaluation studies that met the criteria of the search due to the structured, but not systematic standard of my review and due to the availability of the recent review by Phalkey and colleagues (117), which includes grey literature.

Dr. Ulla Griffiths, my supervisor, scrutinized all papers to ensure that they met the inclusion criteria. She served as a cross-check to validate this step of the literature review. In case of disagreement we discussed why and if certain papers should be included.

Data extractions and synthesis of findings

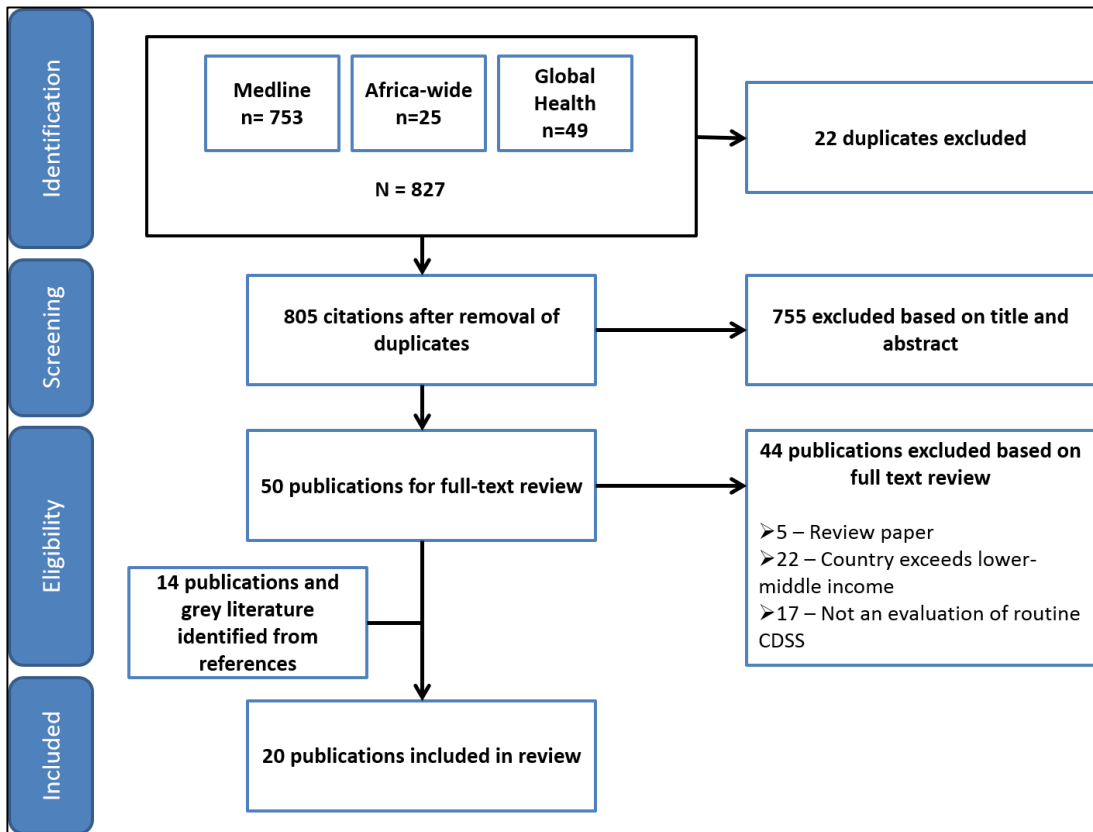
Data abstracted for the review included: country, whether the evaluation looked at an integrated vs. multi-disease surveillance system, date of publication, administrative level(s) included in the study, system components assessed, methods, whether cost was assessed, and key relevant findings. 2013 World Bank country income classifications were used (120). Countries with Gross national income (GNI) per capita of less than US\$ 1,045 were classified as low-income countries and those with GNI per capita between US\$ 1,046 and US\$ 4,125 were classified as lower-middle income countries. Study methods were reviewed, abstracted, and analysed. Information on attributes, core and support functions assessed were documented in a matrix, which included the WHO framework of nine core surveillance functions and six support functions as well as the 13 system attributes identified in the *CDC Updated Guidelines for the Assessment of Surveillance Systems* (31, 34).

3.3 Results

Search results and study selection

The process for selecting publications is shown in Figure 3.1. The search identified a total of 805 publications, after the removal of duplicates. From the title and abstract review, 50 publications were selected for full text review and their citations were imported into an Endnote X6 library. After applying the inclusion criteria to these publications, 44 papers were excluded. Five review articles were excluded, but synthesised and presented above in section 3.1.1 (98, 114-117). The excluded publications included: eleven policy-related framework, guidance documents, and non-evaluation reports (31-34, 44, 47, 121-125), two health system focused studies (126, 127), two non-evaluation reviews of CDSS (30, 128), and two syndromic surveillance system evaluations (129, 130). Other publications were rejected because the evaluation was not performed in a low- or lower-middle income country (131-152).

Figure 3.1 Flowchart for selection of included studies



3.3.1 Overview of selected studies

Twenty published evaluation studies were eligible for review. These publications reported 19 separate evaluation studies; one study (i.e. same sample size) was reported by two publications, but at different time points (153, 154).

Study settings

Characteristics of the selected studies are summarised in Table 3.3. The 20 papers in the review cover a total of 20 countries. SSA dominated the geographic spread with 16 of the 20 studies. Multiple studies were performed in Ethiopia, Ghana, Nigeria, Tanzania, and Uganda (46, 79, 155). Three studies presented multiple country comparisons of CDSS. Two of these studies presented IDSR implementation experiences and lessons learned (46, 79) and the third compared meningitis surveillance systems only (155). Implementation of IDSR was assessed by seven out of the 16 SSA studies (46, 79, 101, 154, 156-158); underscoring the importance and wide use of this regional surveillance strategy.

Types of Surveillance Systems

Eleven studies exclusively evaluated integrated disease surveillance (IDS) systems and discussed shared functions across disease systems. Four studies detailed the transition from a multiple disease surveillance systems (MDS) to an integrated system (157-160). One study assessed a partially implemented integrated system (118). Another two studies assessed MDS only (161, 162). Of these seven studies that included a MDS evaluation, five were conducted before 2004 (157, 159-162). This shows that countries have begun to adopt integrated surveillance during the past ten years. The exceptions were set in Sudan (118) and South Sudan (158). At that time point both of these countries suffered from constant political instability and civil conflict; for instance, the South Sudan assessment was conducted in 2011, the same year it became an independent nation (163). These peculiarities likely reflect the lack of capable governments to support their health systems maturation towards integrated surveillance. The remaining two studies evaluated a community based surveillance system (164) and a meningitis surveillance system (155), and did not indicate the overall CDSS design.

Study designs

All of the studies used WHO and CDC guidelines to guide study design or adapted the WHO protocol for assessment teams to inform the data collection methodology(26).

Table 3.3 show which studies used either or both of these guidelines. Sub-national level units (i.e. either peripheral or intermediate level) were part of the study design in 18 out of the 20 studies. Data collection from peripheral level health facilities or clinics occurred in 14 of these studies (101, 118, 153, 154, 156-160, 162, 164-167). Only one study evaluated a national health system only from the central office, i.e. national health authority, and did not engage sub-national levels. This study was conducted in West bank and Gaza in 2001 (161) and describes a dubious socio-political environment of insecurity and instability of populations, which may have affected access to peripheral sites. The smallest structural unit included in site selection for data collection was the health facility. This ranged from zero (161, 162) to 217 health facilities included in the study evaluations (101) (Table 3.3). Districts were selected either by convenience, to give a snap shot of the CDSS, or through a specific sampling method to ensure generalisability. None of the studies included primary data collection from all health facilities of any country, as this would have demanded considerable financial and personnel resources. Eight studies mentioned inclusion of non-governmental health facilities in their sample size or study population (101, 153, 154, 157, 160, 161, 165, 167).

Table 3.3 Overview of included evaluation studies of CDSS

Ref	First author	Guide-line used ¹	Country, year	Study design	Type of surveillance system studied	Number of sites	Levels included (P, I, C)	Study objective(s)
(159)	CDC	WHO	Uganda, 2000	Cross-sectional survey	MDS	8 districts, 52 HF's	P,I	<ul style="list-style-type: none"> To describe results of CDSS baseline assessment To indicate additional efforts needed for effective surveillance progress towards IDS
(161)	Awad R	CDC	Palestine, 2001	Descriptive study	MDS	3 health system providers (West Bank, Gaza Strip, UNRWA ²)	C	<ul style="list-style-type: none"> Describe the evaluation and make recommendations for strengthening CDSS
(160)	WHO	WHO	Ethiopia, 2001	Cross-sectional survey and qualitative assessment	MDS, IDS	MoH, 11 regional bureaus, 12 zonal depts., 33 Health facilities	P,I,C	<ul style="list-style-type: none"> To illustrate first steps in transitioning from a multi-disease to integrated surveillance approach

¹ Refers to if the assessment used either the CDC's Updated guidelines for evaluating public health surveillance systems or WHO's Communicable disease surveillance and response systems: Guide to monitoring and evaluating.

² United Nations Relief and Works Agency for Palestine Refugees in the Near East

Ref	First author	Guide-line used ¹	Country, year	Study design	Type of surveillance system studied	Number of sites	Levels included (P, I, C)	Study objective(s)
(162)	Wuhib T	CDC	Armenia, 2002	Qualitative assessment	MDS	1 National surveillance system	P,I,C	<ul style="list-style-type: none"> To present observations and recommendations for reforming the Armenian infectious diseases surveillance system
(157)	Mghamba JM	WHO	Tanzania, 2004	Qualitative assessment	MDS, IDS	4 districts, 26 HFs	P,I	<ul style="list-style-type: none"> To discuss and detail the challenges within the surveillance functions and to present recommendation for adopting IDSR
(166)	Alfred D	WHO	Uganda, 2005	Retrospective cross-sectional	IDS	1 district, 62 HFs	P,I	<ul style="list-style-type: none"> To assess the reporting component of the CDSS in one district
(167)	Quality Health Partners	WHO	Ghana, 2005	Cross-sectional survey	IDS	28 Districts, 171 HFs	P,I	<ul style="list-style-type: none"> To gather data related to the readiness of facilities to provide quality reproductive and child health services To collect baseline data for performance management and evaluation plan
(153)	Gueye D	WHO	Tanzania, 2006	Pre-post test	IDS	8 regions 12 districts 109 HFs	P,I	<ul style="list-style-type: none"> To gather specific information on the performance of IDSR systems in each of the selected districts
(154)	Rumisha, SF	CDC	Tanzania, 2007	Baseline assessment	IDS	8 regions 12 districts 109 Health facilities	P,I	<ul style="list-style-type: none"> To assess surveillance system performance before and after IDSR intervention

Ref	First author	Guide-line used ¹	Country, year	Study design	Type of surveillance system studied	Number of sites	Levels included (P, I, C)	Study objective(s)
(164)	Chau, PD	CDC	Cambodia, 2007	Descriptive	CBSS, EWORS	3 provinces, 11 HFs/sentinel sites	P	<ul style="list-style-type: none"> To identify strengths and weaknesses of the Community-based surveillance system (CBSS) and Early Warning Outbreak Recognition System (EWORS) in detecting disease outbreaks in Cambodia by using a modified CDC evaluation method.
(46)	Nsubuga, P	WHO	Ghana Tanzania Uganda Zimbabwe, 2010	Qualitative assessment, Descriptive	IDS	4 countries, 56 Key informants	I,C	<ul style="list-style-type: none"> To identify accomplishments and IDSR implementation lessons learned in four Global Surveillance Project countries
(118)	Sahal, N	WHO	Sudan, 2010	Descriptive, retrospective, cross-sectional	MDS, IDS	1 state, 177 epidemiology units	P,I	<ul style="list-style-type: none"> To assess the core activities and supportive functions of the CDSS in Khartoum state from 2005 -2007
(79)	Sow, I	WHO	Cabo Verde, Eritrea, Gambia, Guinea Bisau, Uganda, 2010	Retrospective descriptive	IDS	8 countries, 116 districts	I	<ul style="list-style-type: none"> To review and analyse the findings of separate country assessments in regards to training health personnel on IDSR approaches, and how training can contribute to strengthening of national CDSS

Ref	First author	Guide-line used ¹	Country, year	Study design	Type of surveillance system studied	Number of sites	Levels included (P, I, C)	Study objective(s)
(165)	Abubakar, AA	CDC	Nigeria, 2010	Cross-sectional descriptive	IDS	1 local government area (LGA), 49 HFs	P,I	<ul style="list-style-type: none"> To assess the preparedness to respond to outbreaks and the capability to identify outbreaks in Sabon Gari LGA of Kaduna State
(168)	Dairo, MD	WHO	Nigeria, 2010	Cross-sectional descriptive study	IDS	2 States, 42 surveillance officers	I	<ul style="list-style-type: none"> To assess the adequacy of the logistic support available for timely collection of data and its association with poor reporting of epidemics in the respective states of the federation
(158)	Pond, B	WHO	South Sudan, 2011	Qualitative assessment, descriptive	MDS, IDS	6 states, 9 counties 38 HFs	P,I	<ul style="list-style-type: none"> To determine how effective the WHO has been in implementing the IDSR project To recommend programmatic shifts to more effectively achieve the project's aim To provide recommendation for improving impact during the life of the USAID project identify issues to consider beyond the life of the project
(155)	Djingarey, M	CDC	Mali Burkina Faso, 2012	Descriptive	Meningitis surveillance system	2 countries, 114 districts	I,C	<ul style="list-style-type: none"> To describe the results of evaluations of existing meningitis surveillance systems in Burkina Faso and Mali before the introduction of serogroup A meningococcal conjugate vaccine

Ref	First author	Guide-line used ¹	Country, year	Study design	Type of surveillance system studied	Number of sites	Levels included (P, I, C)	Study objective(s)
(156)	Abubakar, AA	WHO	Nigeria, 2013	Cross-sectional descriptive	IDS	1 state, 3 LGAs, 21 HFs	P,I	<ul style="list-style-type: none"> To assess IDSR implementation in selected LGAs of Kaduna State
(101)	Lukwago, L	WHO	Uganda, 2013	Pre-post test	IDS	56 districts (2001-2005) 80 districts (2006-2007)	P,I,C	<ul style="list-style-type: none"> To provide information on the progress, successes, and challenges of IDSR after several years of implementation To highlight the costs involved
(169)	Phalkey, RK	WHO	India, 2013	Multi-centre retrospective cross sectional	IDS	1 state, 34 districts, 46 HFs, 25 laboratories	I,C	<ul style="list-style-type: none"> To assess the structure and performance of the IDSS in Maharashtra state of India To understand the challenges for successful integration of surveillance functions in the district health care machinery To make recommendations for a smooth transition to the district health surveillance system

MDS: Multiple disease surveillance system; IDS = Integrated disease surveillance system

P: Peripheral (local level health facilities that usually provide primary health services for community),

I: Intermediate (usually called district, regional, or in some cases local government agent –Responsible for oversight and support of peripheral level and reports to Central level)

C: Central level (indicates the country's national or federal entity)

HF: Health facility

Assessed attributes and functions of CDSS

To be included in the literature review, publications had to include an assessment of at least one surveillance system performance attribute or assess the surveillance system by core function or support activity, as respectively outlined by CDC (31) and WHO (26) guidance documents. As summarised in Table 3.4¹, most studies conjointly assessed at least one attribute and some core and support functions. Wuhib *et al.*(162) was the only study to assess all attributes and core and support functions in their assessment of the Armenian surveillance system. This assessment used only qualitative methods and while it even included a cost review, no quantitative data was reviewed. Sixteen studies (46, 79, 101, 118, 153, 154, 156-159, 162, 165-169) included an assessment of core and support functions. These assessments appraised core functions (i.e. detection, registration, confirmation, reporting, analysis, and feedback) and support functions (i.e. communication, training, supervision, and resources) in some combination or collapsed form. These studies usually occurred within the context of IDSR, though this was not the case in two studies; one conducted in Armenia (162) and one in India (169)—though this one did review the Indian Integrated Disease Surveillance Project strategy in one Indian state.

‘Timeliness’ and ‘data quality’ were the most assessed attributes. Overall, studies measured timeliness as the percentage of expected reports (i.e. weekly and monthly) received at the relevant health level by the pre-set due date. This attribute was normally measured against the IDSR 80% indicator (45). Assessing completeness and consistency of case-level and aggregate data forms were usually the criteria to evaluate ‘data quality’. Accordingly, studies that exclusively assessed these two attributes, usually did so while conjointly reviewing case detection and reporting core functions (46, 79, 101, 154, 155, 162, 167).

¹ All definitions of surveillance attributes are listed in Table Table 2.4.

Three studies selected one attribute to proxy the ability of a specific programme activity. Dairo *et al.* assessed case reporting in two south western Nigerian states in order to determine the association between logistic support availability and reporting of epidemics (168). They measured the percentage of health staff trained on reporting and notification to control for a potential confounder. Abubakar *et al.* (2010) (165) assessed training, 'timeliness', and 'completeness' to identify needs to better position the intermediate CDSS for outbreak preparedness. Alfred (166) also examined outbreak preparedness by concentrating on sub-national data reporting but assessed 'timeliness', 'completeness', 'accuracy' to reveal other explanations for poor surveillance performance.

Table 3.4 Surveillance components assessed by included evaluation studies

		No. of studies	References
<i>Surveillance attributes</i>	Acceptability	2	(161) (162)
	Flexibility	2	(162) (164)
	PPV	2	(162) (164)
	Representativeness	4	(161) (162) (164) (155)
	Simplicity	4	(160) (161) (162) (164)
	Sensitivity	2	(162) (164)
	Stability	1	(162)
	Quality	12	(153) (154) (158) (155) (46) (79) (162) (159) (166) (167) (165) (101)
	Timeliness	15	(118) (153) (154) (158) (160) (162) (164) (155) (46) (79) (166) (167) (165) (168) (101)
	Usefulness	3	(164) (161) (162)
Core and/or support functions	16	(118) (153) (154) (158) (46) (79) (162) (159) (157) (166) (167) (165) (168) (156) (101) (169)	
Cost	3	(162) (166) (101)	

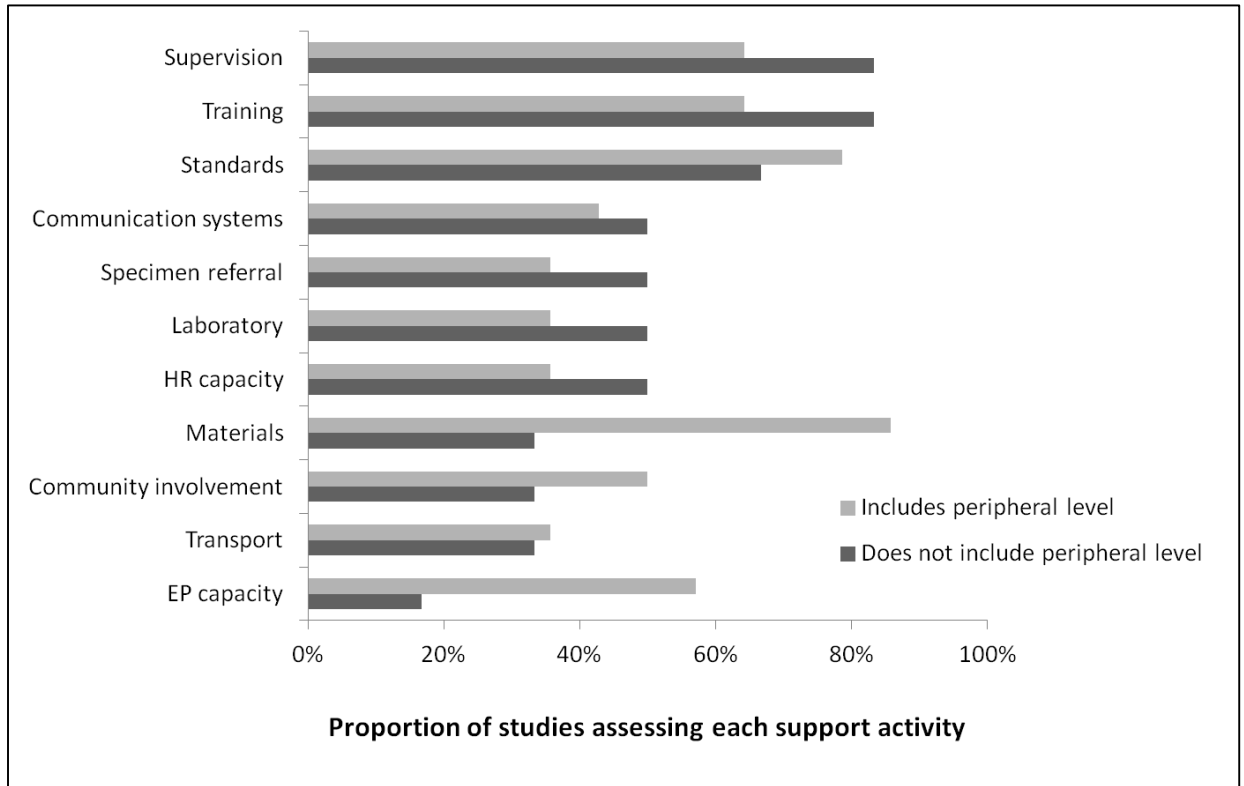
PPV = Positive predictive value

Core functions (i.e. detection, registration, confirmation, reporting, analysis, and feedback) and support functions (i.e. communication, training, supervision, and resources)

Support entities and functions, such as laboratory confirmation, are essential to the continuance of CDSS and to facilitate the core surveillance functions. Eleven included support functions are listed in Figure 3.2. When examining the studies by support functions assessed, they range from inclusion of one of eleven functions (164) to the inclusion of ten (169). 'Standards' (i.e. knowledge of standard case definition) was the most assessed function, with only five of the 20 studies failing to include it in their evaluation (79, 155, 164, 168, 169). Transportation (i.e. means of transport for staff to perform surveillance duties) was the least assessed support function, included in only seven studies (156, 158, 165, 167-169).

Figure 3.2 also shows the results of the studies stratified by whether or not data collection was completed at the peripheral level. While most of the functions were comparable between the two groups, 'emergency preparedness capacity' and 'materials' (e.g. surveillance registers, specimen collection receptacles, and cold boxes) were assessed disproportionately more in evaluations, which included the peripheral level. Specifically, 'materials', a basic need to facilitate case detection and reporting, was assessed two and half times more in studies that engaged peripheral staff. Similarly, 'emergency preparedness', which is paramount to effective outbreak response, was assessed three times more in the peripheral group. In both groups 'supervision', 'training', and 'standards' were assessed most frequently.

Figure 3.2 Proportion of studies assessing selected support functions according to inclusion of peripheral health level



EP: Emergency preparedness; HR: Human resources

3.3.2 Evaluation study methods

A summary of the methods used for evaluating surveillance systems is seen in Table 3.5. In accordance with CDC guidelines (31), eight out of 20 studies included a description of the CDSS flow of information (156, 159-162, 166, 168, 169). A mixed method approach was applied far more commonly than quantitative only or qualitative only approaches—just one study (164) used qualitative methods only and five studies exclusively used quantitative methods (79, 101, 161, 165, 168, 169). The evaluation studies often started by reviewing policies and guidelines, followed by key informant interviews and field visits to gather information. The most common quantitative method, employed by eleven studies, was for researchers to conduct a facility audit and review surveillance-related tools (e.g. registers, archived line lists, etc.), reports, and

other materials to capture the proportion of suspected cases reported and the quality of records (46, 118, 153-155, 157, 158, 165-167, 169). The other quantitative methods that were applied included budget or expense records review, record tracking (i.e. following one suspected disease record through all levels of the CDSS to demonstrate accuracy and timeliness of data), secondary data analysis, interviewer administered and self-administered questionnaire.

The most widely used qualitative method was 'field visit'. Five studies explained this method as a process that involved the evaluation researchers speaking to health staff at the intermediate (district, regional) and local/peripheral level and having an un-structured discussion to capture flow of surveillance and to assess more subjective attributes, such as 'simplicity' and also measure support functions, such as training and logistics (157, 159, 162, 166, 167). Mghamba *et al.* (157) did this by speaking to health staff in Tanzania about how and why disease surveillance related activities occur and about perceptions of the CDSS from those who implement it. Other qualitative methods used by studies included: qualitative system description, focus group, key informant interview, pre- and post-assessment workshop, and SWOT (strengths, weaknesses, opportunities, threats) analysis.

Both qualitative and quantitative methods were used to assess the impact of surveillance system improvement after IDSR implementation. Lukwago and colleagues (101) and Nsubuga *et al.* (46) customized versions of the WHO and CDC monitoring framework to perform multiple year assessments of IDSR indicators in a total of five SSA countries. Gueye *et al.* (153) and Rumisha *et al.* (154) undertook baseline and follow up assessments, respectively, of IDSR implementation in selected districts in Tanzania.

Effect of evaluation method on study results

Studies that focused on core and support functions as recommended in the WHO guidelines generally found more precise system issues and were able to make more

applied and detailed recommendations for improvement than studies that only assessed system attributes. For instance, the Uganda CDSS evaluation was able to recommend that a specific position, 'Records Assistant', be designated and trained for all health units in order to fill the gap of incomplete and unreliable data (166). In contrast, studies that solely used the CDC evaluation guidelines, which focuses solely on surveillance attributes, were less likely to provide recommendations for specific operational improvement. Sahal and colleagues (118) found a similar result in their study.

Five studies specifically stated as an objective to provide recommendations for policy or programme improvement (157, 158, 161, 162, 169). These studies varied in which health system levels were included and in study design, though just one study used quantitative methods only (169). Compared to the Awad *et al.* study, which only included the central level (161), studies that included at least one sub-national level (157, 158, 162, 169) differed in the type and amount of information assessed for the evaluation. Additionally, studies that included sub-national data collection generally included information on vehicle use, logistics, training, staff burden, and sustainability of resources in detail and gave precise recommendations to optimise peripheral and intermediate surveillance performance.

As a result, the studies that included sub-national data collection, and more specifically the peripheral level, were able to spot specific surveillance system gaps and craft recommendations to the appropriate entity. For example, Awad and colleagues (who only included national data collection) developed recommendations for national unification of health systems, general instructions for more multilateral participation in surveillance, and increased support and feedback. In contrast, Pond *et al.* (158) reported the uses of equipment used by county surveillance officers (intermediate level) and provided unique recommendations about technical programme improvements to USAID, Ministry of Health, and the WHO. Pond *et al.* and similar sub-national inclusive studies reported that recommendations had already been incorporated in policy and

structural reformation initiatives (46, 154, 155, 158, 160, 162, 167). In contrast, studies that focused data collection and study engagement only at the intermediate and central levels missed an important opportunity to obtain verifiable data and information about barriers to optimal exercise of surveillance functions (46, 79, 155, 161, 168, 169).

Lessons learned or critical comparisons of the study results compared to previous studies were presented in six studies (46, 154, 156, 157, 160, 168). Nsubuga *et al.* (46) distilled lessons from data collected at the intermediate and central levels of experience implementing IDSR in four countries and provided guidance to the AFRO region on establishing central coordinating bodies and strengthening laboratory networks, among other points. Similarly, Rumisha and colleagues (154) juxtaposed their findings to the literature to illustrate a pattern of challenges that low-income countries have in IDSR management and implementation. Through speaking with health staff at the peripheral and intermediate levels the authors discovered issues, such as weak data management and organisation at health facilities and in the district surveillance offices.

Table 3.5 Qualitative and quantitative methods used in each evaluation study

First author	(REF)	Qualitative Methods						Quantitative Methods					
		System description	Field visit	Focus group	Key Informant interview	Pre-/post-assessment workshop	SWOT Analysis	Budget/expense record review ¹	Document review ² /facility audit	Record tracking	Secondary data analysis	Interviewer administered questionnaire	Self-administered questionnaire
CDC	(159)		X					X					
Awad R	(161)										X		
WHO	(160)					X	X					X	
Wuhib T	(162)		X	X								X	
Mghamba JM	(157)		X						X				
Alfred D	(166)		X						X	X			
QHP	(167)		X						X				
Gueye D	(153)			X					X				X
Rumisha SF	(154)			X					X				
Chau PD	(164)	X											
Nsubuga P	(46)				X				X			X	
Sahal N	(118)								X				
Sow I	(79)										X		
Abubakar AA (2010)	(165)				X							X	
Dairo MD	(168)												X

¹ Record review = surveillance tools, i.e. registers, disease surveillance forms, outbreak investigation and response, annual audit reports

² Document review = reports, databases, budgets, training schedules, bulletins, etc

		Qualitative Methods						Quantitative Methods					
First author	(REF)	System description	Field visit	Focus group	Key Informant interview	Pre-/post-assessment workshop	SWOT Analysis	Budget/expense record review ¹	Document review ² /facility audit	Record tracking	Secondary data analysis	Interviewer administered questionnaire	Self-administered questionnaire
Pond B	(158)				X				X				
Djingarey M	(155)				X				X				
Abubakar AA (2013)	(156)								X			X	
Lukwago L	(101)							X			X		
Phalkey RK	(169)								X				

3.3.3 Factors influencing surveillance performance

Several factors were identified as having a direct impact on CDSS performance or indirectly on activities that affect CDSS performance. Several studies cited lack of standardisation of procedures, such as case definitions, as a barrier to accurate case detection (118, 159, 162, 167). Lack of regular feedback and/or supervision was frequently mentioned as a cause of low motivation among health staff to optimally participate in surveillance activities (79, 118, 153, 154, 156, 159, 161, 162, 167, 169). This factor was often stated as essential, with one study concluding that supervisory feedback is one of the most important tools to develop skills in health workers and improve their work performance (154). Similarly, Abubakar (2013) *et al.* remarked that the absence of feedback on suspected cases from higher levels may lead to poor performance due to staff not receiving the results of reporting.

While the existence of adequate resources is an underlying requirement for surveillance performance, only six studies explained in varying levels of detail how budgets and funding impact surveillance performance (101, 158, 162, 166, 168, 169). Importantly, Dairo and colleagues showed a significant association between inadequacy of support and reporting of epidemics in 42 local government area in Nigeria (168) and findings from Lukuwago *et al.* suggested a link between political and financial commitment and progress of IDSR performance (101). While cost of surveillance was often suggested as an essential consideration for CDSS performance, only one study performed a cost calculation (101). More commonly studies noted the concern for the sustainability of, and investment in, surveillance systems (79, 160). A study from Uganda found that a surge of government funding for surveillance greatly benefited the performance of the newly adopted integrated system (166). Other studies underscored the importance of surveillance funding by crafting recommendations that urged MoHs and partner agencies to increase surveillance funding and provide adequate resources to support staff and routine and outbreak response activities. Sustainability was also captured by Nsubuga *et al.* (46) who recommended educational and career structures to support

local capacity building and assurance of surveillance expertise and knowledge transfer through the promotion of university linkages and establishment of a field epidemiology training programme.

Studies which documented the modernisation (e.g. more complex strategy or advanced streamlined processes) of out-dated surveillance systems cited efforts such as, harmonising reporting forms (155, 157, 161), transitioning to computerised reporting (155, 156, 166, 169), and ensuring complete transition between old and new systems (79, 118, 165, 169) as important developments for optimal surveillance performance .

Country studies that described IDS adoption supplied some unique reasons for weak surveillance system performance. One of these was persisting vertical surveillance systems, which were often described as the unwanted relics of vertical funding structures (e.g. guinea worm, polio, and measles programmes)—this factor was identified as a hindrance to actual integrated surveillance (101, 117, 158, 167).

Additionally, data analysis at sub national levels (117, 118, 154, 156, 167) and IDS training and mentorship (46, 79, 153, 155, 159, 166, 168) were recognised as needed institutionalised components of healthcare systems to guarantee synthesis of work processes and full commitment of staff. Table 3.6 presents the comprehensive list of CDSS performance factors identified in the included studies.

Table 3.6 Factors that influence CDSS performance

1.	Access and availability to transport to perform surveillance activities	21.	Partial vs. full implementation of surveillance strategy
2.	Amount of work for health staff (i.e. existing non-surveillance duties)	22.	Perceived severity of the disease by health staff
3.	Anonymised data (if it hinders linking of clinical and lab data)	23.	Perceived value of disease surveillance (i.e. staff motivation)
4.	Clearly written objectives for CDSS	24.	Strength of data analysis capability at intermediate level
5.	Community involvement in case detection	25.	Political commitment and motivation
6.	Established and effective specimen transport system	26.	Managerial skills
7.	External funding and support	27.	Punitive measures for low case reporting
8.	Frequency of feedback (i.e. confirmed status of suspected case)	28.	Rapid outbreak response capacity and/or established rapid response teams
9.	Frequency of supervision	29.	Regular evaluation of the CDSS
10.	High staff turnover	30.	Technical support from highly skilled health staff
11.	Human resource capacity to perform surveillance activities	31.	Training of staff in surveillance methods
12.	Adequate government funding	32.	Separation of surveillance and clinical activities
13.	Adequate resources for CDSS	33.	Simplicity of case definition
14.	Incentives for case reporting	34.	Simplicity of data form
15.	Integration of health systems and surveillance functions	35.	Standardised procedures and definitions
16.	Laboratory capacity to confirm all priority diseases	36.	Standardised surveillance forms
17.	Level of involvement of NGO's, public and private health facilities	37.	Strength of core and support functions
18.	Linkage between clinical, laboratory and surveillance data	38.	Strength of support functions at sub-national levels
19.	Logistic support	39.	Sustainable funding for CDSS
20.	Multiple communication channels	40.	Use of proven surveillance tools

3.4 Discussion

The review identified studies that have evaluated CDSS in low and lower-middle income countries. The primary aim of the review was to explore which methods were used to evaluate CDSS performance and synthesise evaluation findings. In total, 20 publications met eligibility criteria and these contained 19 distinct evaluations of CDSS.

The review revealed that there is a greater benefit of including an assessment of core and support functions in evaluation methods for low-income countries than assessing surveillance system attributes only. This suggests that there may be a system maturation gradient to consider when deciding which evaluation method is most applicable. This is an important finding for future CDSS evaluation design, given that the specificity and accurateness of recommendations affects the overall evaluation usefulness—evident by the uptake of findings and influence on relevant policies.

The review findings suggest that studies conducted in countries with resource constraints prefer primary data collection to analysis of secondary data—all studies, with the exception of two (79, 161), collected data from primary sources. This strategy appears counterintuitive since it requires more resources to collect primary data (e.g. researchers usually need to travel to reach primary health centres and to interview informants compared to stationary analysis of a data set); however, researchers who undertook this effort were able to validate data quality and contextualise system impediments. Both qualitative and quantitative methods were useful in obtaining information for surveillance systems improvement. Particularly, methods that engaged health staff and officials (e.g. structured interviews, key informant interviews and focus groups) produced the most robust evaluation findings and provided a vital perspective of reported performance measures. Additionally, the review findings show that health level included in study design influences study methods and may play an important role in identifying useful and targeted information for CDSS improvement. Participation and data collection at the sub-national levels appeared to provide

information to craft recommendations, which were more likely to be taken up by policy.

3.5 Conclusion

This review illuminates CDSS evaluation methods and factors affecting surveillance performance. The way these methods are incorporated into evaluation plans is highly dependent on understanding how the PHSS operates in a specific country. The studies highlighted the major factors in surveillance performance, including: timely feedback, regular supervision, perceived complexity of case definition, and attitudes about reporting. Still, none of the studies cited operational or environmental factors (e.g. 'condition of roads' or 'data transmission method') as direct or indirect factors affecting CDSS performance. These factors are directly linked to programme planning and a high-level commitment to the surveillance system effectiveness.

While many of the studies mentioned the need for support or reinforcement of skills, capabilities, or human resources, none undertook a detailed assessment or review of CDSS costs. These omissions are important to underscore as they influence public health budget development and programme planning. For example, when funding is allocated for disease-specific surveillance, hidden gaps between these vertical (i.e. non-integrated) systems can impede overall performance.

The studies benefited from existing frameworks that provide general descriptions, standard surveillance definitions, and other important guidance about what functioning communicable disease surveillance systems should achieve (8, 31, 33).

While overall system performance is important, other information, such as programme integration and collaboration, programme planning priorities, costs, and specific training needs have proven difficult to ascertain using traditional methods; especially in challenging or resource-constrained settings. Neglecting these considerations reveals a lack of understanding of the full range of system complexities between human, structural, and financial influences. Finally, the current literature reveals a distinct lack

of standardisation regarding the best approach for using CDSS evaluation findings facilitate decision making (98). Based on these findings, the intention of this PhD is to undertake a detailed evaluation of a CDSS in a low-resource setting, by integrating rigorous research methods and health economic costing principles into traditional programme evaluation. The identified shortfalls of the existing CDSS frameworks and methods are addressed in this thesis.

4 Thesis aims, objectives, and conceptual framework

In this thesis I examine the intersection of policies, funding, and programme implementation for sustaining CDSS in sub-Saharan Africa and try to understand the causes and impacts of the current dynamics. Guidelines and practical frameworks for CDSS evaluations exist, but have seldom been reviewed for effectiveness. With this PhD, I seek to understand how these standards have practically guided public health surveillance and epidemiological investigations, and critically consider whether they are sufficient for progressive programme improvement, particularly in low-income countries.

The potential benefit of an improved evaluation approach, which combines cost and performance information, may be greater for low-income countries as they have a greater need to advocate for financial and non-pecuniary resources to sustain CDSS, especially at sub-national health levels. The conceptual and empirically tested approach presented in this thesis will provide evidence-based recommendations that can fuel policy and health system improvements. Further, the work sets out to underline the advantages of incorporating health economic costing principles in field epidemiology and operational surveillance research activities.

The aim of this PhD is to ascertain a methodology to practically and proactively improve CDSS operations and performance in resource constrained settings. This thesis seeks to reach this goal by 1) examining existing CDSS monitoring and evaluation (M&E) frameworks and methods 2) presenting and critically assessing a new M&E framework and 3) empirically validating this framework through evaluation of the Chad meningitis surveillance system.

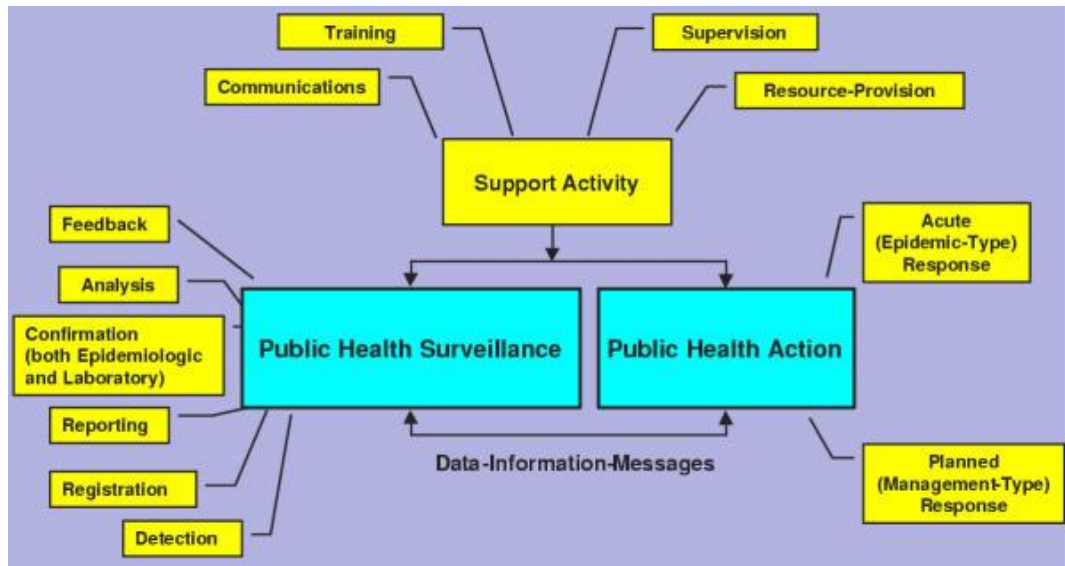
The specific research objectives are as follows:

1. To understand the methods and findings of previous work and existing literature of CDSS evaluations
2. To describe a new methodological approach for surveillance evaluation
3. To apply said approach to develop an evaluation plan and data collection and analysis for the Chad meningitis surveillance evaluation
4. To conduct a performance and cost evaluation of the Chad meningitis surveillance system
5. To examine how unconventionally assessed contextual factors influence surveillance performance
6. To explore the policy and general programme implications of the research findings

Thesis conceptual framework

McNabb *et al.*'s conceptual framework of public health surveillance and action and its application to health sector reform is the foundation from which the current work builds (33). This framework was also the fulcrum for the IDSR strategy and WHO's guide to monitoring and evaluating CDSS (8, 49). The objective of the framework is to facilitate and standardise national-level assessments in order to produce an easy to follow plan of action for national surveillance reform. This objective is achieved by developing and aligning relevant inputs (i.e. activities) to the public health functions of surveillance and action, as seen in Figure 4.1.

Figure 4.1 Conceptual framework of public health surveillance and action



Source: McNabb et al. (33)

The conceptual thinking and causal relationship of my PhD and study activities are captured in the log frame presented in Figure 4.2. The sources used to construct this framework include previous research, my aforementioned experiential knowledge, personal thought experiments, and some exploratory research. The new M&E approach presented in this thesis (i.e. the work-process analysis [WPA]) is used to maximise the usefulness of surveillance outputs for action by deconstructing the McNabb *et al.*'s six core and four support activities and isolating discrete and measurable tasks. This thesis proposes a new approach that does not replace existing CDSS evaluation methods, but supplements traditional methods with tools that produce activity-specific information and exposes gaps and impediments in the system. The hope is to present a new standard, systematic, and quantifiable approach to comprehensively evaluate surveillance system performance.

Figure 4.2 Study framework for the process-centred evaluation of Chad meningitis surveillance system

Inputs	PhD/study activities	PhD/study outputs	Programme Outcomes
Technical skill & ability	1. Review of current evaluation guidelines	Gaps in current evaluation guidelines are identified	Elimination of type A meningococcal meningitis in Chad Robust and sensitive meningitis surveillance in Chad Improved detection capacity for integrated surveillance in Chad
	2. Apply WPA and ingredients costing approach to development of evaluation plan	Task specific and process-centred evaluation questionnaire Customised performance indicators	Improved meningitis detection and epidemic prevention
Political will	3. Interview surveillance staff and collect cost of meningitis surveillance activities	System gaps and impediments are identified	Improved early detection and response of meningitis suspected cases
Human & financial resources	4. Capture contextual factors		
	5. Design surveillance optimisation model	Evaluation results align specific surveillance performance outputs to accountable programme actions Model includes required inputs and cost estimates for optimal surveillance	Training on IDSR requirements and laboratory standards
	6. Develop policy recommendations	WPA framework is empirically validated for evaluation of CDSS	Adequate financing of surveillance system

WPA: work process analysis; CDSS: communicable disease surveillance system; IDSR: integrated disease surveillance and response

Figure 4.2 illustrates how the evaluation findings and recommendations can lead to critical programme outcomes to ultimately achieve the goal of elimination of type A meningococcal meningitis in Chad (green box). Moreover, this framework highlights the progressive relationship between the PhD activities and emphasises those completed as part of the meningitis evaluation study (orange box). All components of this model are impacted by the inputs, which represent potential drivers (or inhibitors) of the project activities and outcomes at different points. In this conceptual framework I have identified three concepts (i.e. inputs), which are defined below.

Technical skill and ability

Training and written guidance should be available to health facility personnel participating in surveillance activities and should include such topics as reporting requirements, epidemiologic methods, case finding, and investigation. Likewise, surveillance officers at each jurisdictional should have the knowledge and means to transmit this information and make it readily available to national authorities and others who are required to participate in disease reporting and surveillance (170). This concept also encompasses the skill and expertise needed to conduct evaluations and translate recommendations into useful, effective programmes and political strategies.

Political Will

Political will is defined as the highest political commitment and significant financial support to invest in the development of health systems, including overall strengthening and sophistication of routine surveillance systems. This commitment translates to a long-term investment in national capacity-building, such as laboratory strengthening and establishment of a field epidemiology training programme (124). In many African countries, political will is highly contingent on national priorities and political agendas as well as local and international stakeholders.

Human and financial resources

Resources to sustain surveillance can be used to facilitate support functions, including financial, technical, and human inputs, the availability of funds, trained personnel, materials and communications infrastructure (i.e. Telephone or computer). Resources should promote or improve all eight core surveillance activities (33).

5 Methods overview

This chapter presents a summary of methods employed for each component of the research study. Section 5.1 introduces the Work Process Analysis (WPA) approach and details how this primarily business and industrial concept can benefit the public health practice of surveillance. The methods to apply this approach to the development of a new CDSS evaluation framework are also described. Section 5.2 introduces the Chad meningitis surveillance costing and evaluation study and provides a summary of the methods used. The summary includes the study setting, research activities, development of the study instruments using the WPA framework, description of the sample, and data collection and analyses techniques. The chapter concludes with section 5.3, which describes the ethical and administrative approval procedures for the Chad study. Detailed methods of the main study components (i.e. performance assessment, cost analysis, and upgrading exercise) are presented in the succeeding Results chapters (Chapters 6-9).

5.1 Introducing the work process analysis approach

Understanding workflow processes can increase the productivity of a system (125). The workflow process analysis (WPA) evolved from the notion of process analysis in manufacturing where it was used to increase productivity by concentrating on the routine aspects of work activities (171). Used frequently in business management, 'processes' are defined as market-centred descriptions of organisations' activities and 'workflow' is a schematic that provides a conceptual explanation for understanding, evaluating, and redesigning business processes. Since industrialisation, the manufacturing and business fields have been at the forefront of developing techniques to increase efficiency and reduce costs and waste. These fields have used work flow models in many diverse ways, such as: to guide selection of the appropriate project management processes for the EU Energy Sector (172), to analyse the loan evaluation processes (173), and develop complex operations metrics (174). Wide-spread use and increased understanding of work flow processes has led to the development of analytic

frameworks (173, 175), evaluative tools (172) and innovative workflow designs and process models (174).

The health field is slowly beginning to adapt WPA to improve efficiency and to capture performance within health care settings. While there are few documented examples, one study found that proposing alternative work-flow models in hospital operating rooms demonstrated better cost- and work-efficiency than the traditional work pattern (176). WPA has also been used to harmonise and connect informatics support teams to traditional research teams and streamline collaborative production (177). The appeal from international health leaders for more measurement and accountability in health (178) (179), speaks to the need for application of such a technique. WPA is a pertinent exercise for public health practice and is nimble enough to be employed in most scenarios.

Development of the WPA as a public health evaluation approach

The work process analysis approach for public health practice is a product of several years of experience of working within different health systems. Dr. Scott McNabb, a prominent epidemiologist and former director of the CDC's Division of Integrated Surveillance Systems and Services, first customised WPA for PHS in 2002. Then, he and colleagues separated surveillance work into a conceptual framework of core function and support activities—the framework was eventually adopted by the WHO-AFRO regional office as the IDSR surveillance strategy (33). In their framework they presented an approach for standardising evaluation assessments by defining measurable activities across public health surveillance systems. The other objective was to create actionable evaluation results for system improvement. In that same year, McNabb and colleagues incorporated the WPA into a framework to evaluate a tuberculosis surveillance and response system. They focused on specific activities and programme processes and associated costs in a county health unit in the U.S. state of Florida (180). The researchers were able to measure the performance and cost and found that there were several activities that were amenable to intervention modifications and cost savings.

I started working with Dr. McNabb at CDC in 2009 as a junior science fellow in his unit, and then again from 2012 as an epidemiologist with a team of public health consultants. In this capacity I have worked with them to refine this approach through both conceptual and practical exercises. I have personally been involved in the application of this framework to monitoring and evaluating laboratory biosafety programmes (181) and assessing implementation of International Health Regulations (2005) (182, 183). The team worked to cultivate the approach into a conceptual and then applied analytic framework. It is agnostic to a health system but is particularly useful for disease surveillance, since it can provide information that highlights system gaps and areas of integration. Additionally, this framework advocates for the identification of cost estimates for surveillance activities, and provides a platform to examine contextual factors that affect each setting differently (e.g. road access, availability of courier). The next sections discuss the research rationale and the constructs of the WPA as a CDSS evaluation framework.

5.1.1 Rationale for using WPA in CDSS evaluations¹

The WHO Health Systems Framework cites improved efficiency and financial risk protection as two of the four desirable outcomes of a comprehensive health system (5). National surveillance systems should also produce these outcomes. Yet, as demonstrated by the literature review, the current PHSS evaluation frameworks do not provide a systematic way to assess financing and efficiency.

For effective public health surveillance, processes, inputs, and even hindrances to the system must be identified, understood, and sufficiently supported. Certain work processes are repeated for every disease programme, and surveillance systems can benefit greatly from consolidating repeated tasks into discrete programme components that are easier to manage; this is the premise of IDSR. A practical example of the multi-

¹ This section is broadly based on the Elsevier textbook chapter *Erondu N. New public health surveillance evaluation model*, in: McNabb SJN, J.C. M, Ferland LD, Okutani SML, Park MM, Shaikh AT, *et al.*, editors. *Transforming Public Health Surveillance In The 21st Century: Promises Yet Unfulfilled*, Elsevier; Forthcoming 2015

componential nature of communicable disease detection can be seen when examining the processes at the patient's first point of contact (i.e. the local health facilities).

To successfully monitor priority diseases, each person who exhibits clinical symptoms meeting the case definition for a priority or reportable disease must first be diagnosed by a clinician and then reported to the appropriate public health authority.

Furthermore, at this first point of contact, the provider must collect and send the necessary specimen (e.g. blood samples for suspected measles or stool samples for suspected poliomyelitis), according to standard operating procedures (SOPs), to the laboratory for analysis and confirmation of the disease agent (e.g. bacteria strain or virus type). Several presuppositions underlie this process:

- 1) There are policies in place that establish national priority and reportable diseases;
- 2) There are enough health workers at the local health facilities to adequately serve the population;
- 3) These health workers are aware of national reportable and priority diseases and are able to identify each disease based on standard case definitions;
- 4) There are appropriate tools and mechanisms to register and report suspected cases of notifiable diseases;
- 5) Health workers have been trained to collect appropriate specimens for laboratory analysis;
- 6) There are materials and mechanisms (e.g. accessible roads, services, vehicles) in place to store and send the specimens to a diagnostic laboratory;
- 7) There is an accessible diagnostic laboratory equipped to analyse the specimens and confirm the presence of disease; and
- 8) There is a mechanism for the laboratory to report back the results

Activities in the above list delineate various public health surveillance work processes needed to operate a disease surveillance system—they also highlight possible contextual factors that might impede or interrupt this process (e.g. step 6). Additionally, there are several inputs that must be identified in order for these tasks to occur, including human and financial resources (e.g. laboratory technicians, funds to purchase

materials for the specimen). These inputs will change depending on work tasks and must be thoughtfully identified and considered to ensure that the system is able to meet the needs of the population. Further, context-specific factors may augment or lessen the costs and effectiveness of these inputs. The process-activity-input relationship is the central construct of the WPA approach and the substructure of every health system. The WPA allows for a granular examination of this relationship at all administrative levels. This differs from traditional evaluation approaches which are all-encompassing, but generally less precise assessment.

In summary, the WPA methodological framework presented here is intended to supplement traditional surveillance frameworks by identifying gaps in public health practice and processes by providing more robust data and tailored information to fill those gaps. The framework incorporates research and programme evaluation principles to provide evidenced-based recommendations to decision makers and programme managers. The ultimate aim is to ensure that surveillance systems are efficient, satisfactorily resourced, and able to operate at an acceptable standard. The following section describes this approach as a public health M&E framework, and details its constructs and tools.

5.1.2 WPA as a CDSS evaluation framework

Adapting the WPA approach into a public health evaluation framework provides a more precise methodological approach for assessing the performance of communicable disease surveillance processes than what is currently available. Three steps were undertaken to develop the WPA framework. The first was to describe the workflow in sequential order (i.e. Logic model). This served as the foundation of the framework and from which the next two components were built. The second step was to create a task-by-task description of work activities (i.e. Work process tree). The third step was to identify or develop indicators that provide objective measurements of performance (i.e. Indicator database). This section provides the operational definitions of the constructs and components of the framework.

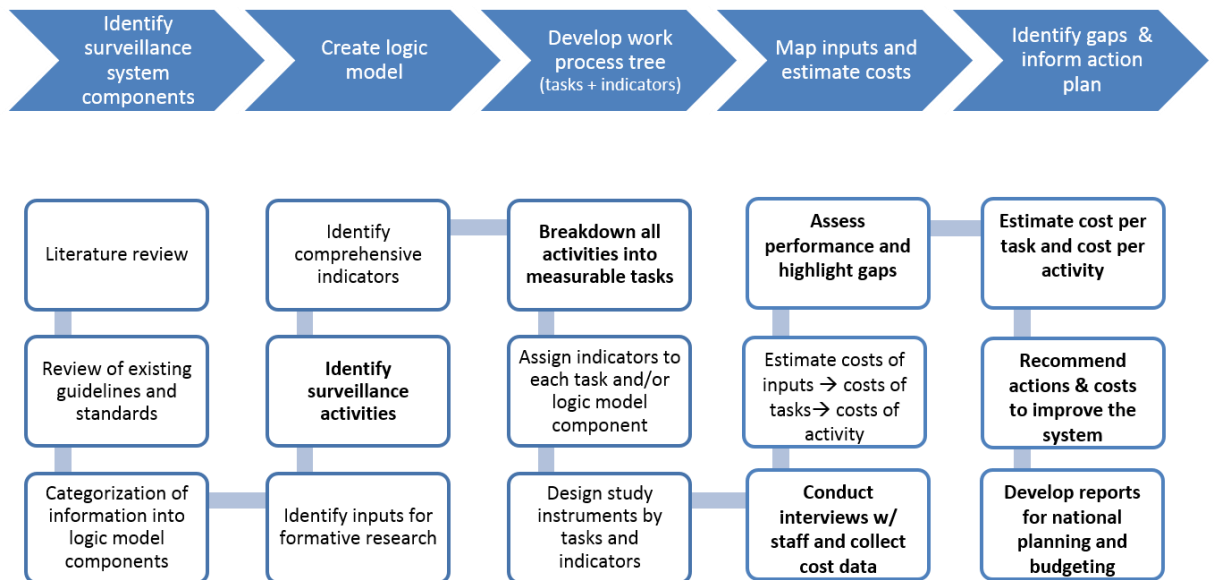
The process-activity-input Relationship

The following definitions are applied: A process is a high level activity that must be achieved. It is then disaggregated into discrete work-tasks. Activities (sometimes referred to as tasks) are chronological steps needed to fulfil the attribute listed. Finally, the inputs needed to complete each task are identified. Inputs are composed of associated costs for human labour, materials, and other items needed to fulfil a task.

Framework tools

The objective of the WPA framework is to define and assess discrete public health processes by linking work tasks to programme indicators and outcomes. Assessing discrete tasks allows for a more granular understanding of work processes throughout the administrative levels of the public health system. Figure 5.1 depicts the steps described in developing each tool as well as how the set of tools produce useful evaluation results and outputs.

Figure 5.1 Work Process Analysis conceptual framework



The WPA uses of the following tools to organise evaluation components:

1. Logic model:

A logic model is a graphic representation of a system and identifies important elements and their relationships (181). When properly constructed, the logic model illustrates the underlying hypotheses that a selected intervention(s) will result in an observable and measurable outcome. A logic model frame is used to separate surveillance components into individual programme and evaluation elements, including inputs, outputs, intermediate outcomes, and long-term outcomes (Table 5.1). Logic models should be 'read' as though following a chain of reasoning or 'if-then' statements that connect the programmes' components.

In the WPA framework, the logic model is also a portrayal of the 'operational standard' for ideal implementation of the surveillance system and depicts the standard system components identified by international and local authoritative sources (e.g. World Health Organisation, CDC, MoH). This can only be assembled by understanding the different players and their roles—this means perspectives from high-level policy makers to local health practitioners.

This tool provides a systematic blueprint of expected public health practice, allowing programme managers to articulate gaps, areas of overlap, and impediments. In the CDC CDSS evaluation framework, steps 1 and 2 are describing the programme and engaging stakeholders (31); the logic model provides a platform to do both. Furthermore, the logic model provides a starting point to identify performance measures and indicators.

Table 5.1 Logic model component definitions

Data categories	Definitions
Inputs	Resources, policies, and other needs to set up or start the programme
Activities	Steps to implement (i.e. detection, confirmation, reporting, analysis, and feedback activities)
Outputs	Evidence that the activity was executed
Short-term outcomes	Measure of implementation of activities or application of tools (i.e. measuring if and how the activity is occurring)
Intermediate outcomes	Measure of application of activities (i.e. if the activity is implemented, how is it going?)
Long-term outcomes	Measure of overall programme progress/ impact (i.e. overall quality of the programme)

2. Comprehensive performance indicators:

Performance indicators are items of information collected at regular intervals to track the performance of a system. Indicators that assess surveillance performance should include international, national, and disease-specific measures. The indicators can also comprise both impact and process measures. Once selected or developed, indicators can be used to develop complementary evaluation tools, such as interview questions and study questionnaires, data abstraction forms, and checklists.

3. Work process tree:

This tool is a diagram that incorporates work processes identified through the established guidance and evaluation data collected from system stakeholders. Work process trees are composed of sequential tasks needed to complete a given surveillance activity and inform graphical representations that illustrate gaps in the surveillance system. The tool also provides a platform for collecting data on the cost of surveillance activities, which can be harmonised with micro-costing methods. Along with the selected indicators, the tasks from the work process can be transposed to study evaluation instruments.

Beyond measuring surveillance systems' performance, the WPA approach can provide decision makers and programme implementers with data to inform a comprehensive plan of action. The plan should define an operational standard of surveillance in the country of implementation and identify interventions to fill gaps and impediments in the current system; from here the costs of proposed interventions can be estimated. Countries can use the results of the evaluation to solicit donor funding for strengthening surveillance activities. The disaggregation of functions into tasks can also be useful in identifying system components needed to achieve requirements under IHR (2005).

In summary, this new M&E framework: (1) describes the work tasks to achieve effective and efficient public health surveillance, (2) identifies impediments and gaps in performance, and (3) assists programme managers in decision making. Further, the resulting rich evaluation outputs could enable decision makers to prioritize needs and allocate resources and (potentially) assess budget impact. In the Chad meningitis surveillance evaluation study, the framework was used to develop study instruments, shape the analysis, and guide policy recommendations.

5.1.3 Added benefit of the WPA approach to traditional evaluation frameworks

The traditional evaluation frameworks provide structure with a basis to assess and inform operational CDSS. Likewise, the present evaluation built upon this guidance, but found it insufficient to address the challenges of evaluating health systems in low-resource settings. The WPA approach adds several evaluation optimisation considerations to the WHO and CDC frameworks (collectively referred to as 'traditional evaluation frameworks'). The matrix shown in Table 5.2 summarises these by presenting each methodology by evaluation domain and with particular attention to the practical application in resource-constrained settings. The matrix illustrates that the CDC framework reinforces broad mechanical attributes of the system that should be tailored, while the WHO generally emphasises the value of ensuring surveillance functionality and optimising Member State cross-collaboration and coordination. Column 4 of the matrix shows how the WPA approach fills areas that the other

frameworks miss. The main advantage of the WPA is the systematic and narrow focus on identifying and reinforcing specific programme needs. Its explicit links to budget development and policy influence is more beneficial to countries like Chad compare to comprehensive and impactful evaluations; especially since regular assessments are not possible due to financial constraints and a paucity of evaluation expertise.

The thesis contends that conventional evaluation methods are more suitable for well-functioning CDSS. Defining a 'well-functioning CDSS' can present its own challenges when considering contextual relativity; however, most standards are developed to be generalizable and thus should be applicable at or around the average situation. The WPA approach provides structure for the CDSS outliers that fall much lower than the average. Chad is a fitting example of these types of settings. As one of the 48 least developed countries, Chad meets the UN criteria of depressed per capita income, low performing human asset indicators, and detrimental economic vulnerabilities (184). Least developed countries have health systems that differ substantially from the rest of the world. The WPA is a methodological evaluation approach that anticipates and embraces these challenges.

Table 5.2 Comparison of WPA contributions to traditional CDSS evaluation guidelines in low-resource settings

Key Evaluation Domains	CDC’s updated guidelines for evaluating public health surveillance systems	WHO’s communicable disease surveillance and response systems: Guide to monitoring and evaluating	Work-process analysis approach for CDSS evaluations in low-resource settings
Intended Audience	<ul style="list-style-type: none"> ▪ U.S. State and local health department and general PHSS 	<ul style="list-style-type: none"> ▪ MoH surveillance and epidemiology staff ▪ CDSS programme managers and surveillance officers at all levels ▪ Public health laboratory personnel at all levels; ▪ Other persons with the mandate or interest in monitoring and evaluation of CDSS 	<ul style="list-style-type: none"> ▪ CDSS programme managers in low resource-settings ▪ Researchers evaluating rudimentary CDSS ▪ Financial managers in charge of CDSS budget development ▪ CDSS stakeholders and key development partners
Stakeholder engagement	<ul style="list-style-type: none"> ▪ Provides comprehensive list of stakeholders (defined as people who use PHSS data) 	<ul style="list-style-type: none"> ▪ Encourages networking and partnerships between stakeholders, partners and countries ▪ Refers to inter-sectoral collaboration and coordination 	<ul style="list-style-type: none"> ▪ Promotes meaningful engagement of local stakeholders (defined as any entity that participates in operation of national CDSS) ▪ Purposeful collaboration of stakeholders during the formative research stage to secure “buy-in”
Describing the surveillance system	<ul style="list-style-type: none"> ▪ Provides guidance on how to describe the purpose and operations of PHSS ▪ Suggests parameters for measuring diseases in relation to population health (E.g. total number of cases/deaths, case fatality rates) 	<ul style="list-style-type: none"> ▪ Emphasizes need to articulate the role and responsibilities of implementers and stakeholders ▪ Promotes clear understanding of flow of surveillance data across different levels ▪ Provides guidance on defining standards and guidelines 	<ul style="list-style-type: none"> ▪ Triangulates data sources to validate data and increase confidence in findings; particularly for CDSS with low quality data or high amounts of missing data. ▪ In addition to CDSS description, explains how materials and forms are managed ▪ Includes non-surveillance contextual factors to explain differences across performance

Key Evaluation Domains	CDC’s updated guidelines for evaluating public health surveillance systems	WHO’s communicable disease surveillance and response systems: Guide to monitoring and evaluating	Work-process analysis approach for CDSS evaluations in low-resource settings
Methods	<ul style="list-style-type: none"> ▪ Promotes assessing system quality by attributes. ▪ Makes certain assumptions that favour established systems, such as connectivity between surveillance entities, availability of data, and minimum standards of data availability ▪ 4 out of 9 attributes require reliable data 	<ul style="list-style-type: none"> ▪ Evaluates CDSS attributes and core and support functions ▪ Assess surveillance system structure in regards to local, regional and global policies ▪ Periodic review of national priority diseases ▪ Provides examples, formulas and case studies of practical calculation and description of certain CDSS surveillance attributes 	<ul style="list-style-type: none"> ▪ Structured by core and support functions ▪ Focuses on features work processes and ability to perform expected tasks. ▪ Seeks to understand weaknesses and hindrances for collecting and reporting quality data, particularly at the sub-national levels ▪ Promotes inclusion of indicators from multiple sources, as well as development of sound indicators when necessary
Resource assessment	<ul style="list-style-type: none"> ▪ Suggest evaluations consider direct costs of personnel and “other” resources ▪ Does not provide any methods for systematic assessment ▪ 	<ul style="list-style-type: none"> ▪ No mention of CDSS resource assessment 	<ul style="list-style-type: none"> ▪ Employs rigorous health economic cost-analysis methods ▪ Collaborates with health economist for study design ▪ Provides example for how to integrate cost with performance assessment ▪ Includes direct and indirect costs
Evaluation recommendations	<ul style="list-style-type: none"> ▪ More broad and general descriptions according to system attribute (forest approach) ▪ Justifies whether or not the PHSS reaches its objectives and address public health problems ▪ Does not explicitly link to specific programmatic improvements 	<ul style="list-style-type: none"> ▪ Suggests that recommendations should inform planning ▪ Does not provide any examples on types of recommendations ▪ 	<ul style="list-style-type: none"> ▪ Focuses on specific CDSS improvements in relation to its objective, with an emphasis on context and feasibility (trees approach) ▪ Provides “Step-by-step” recommendations towards realizing progressive system strengthening ▪ Aligns missing resources with system priorities and needs

Key Evaluation Domains	CDC's updated guidelines for evaluating public health surveillance systems	WHO's communicable disease surveillance and response systems: Guide to monitoring and evaluating	Work-process analysis approach for CDSS evaluations in low-resource settings
			<ul style="list-style-type: none"> ▪ Aims to rapidly resolve low-hanging fundamental gaps and impediments
Dissemination and use of findings	<ul style="list-style-type: none"> ▪ Encourages dissemination of findings and lessons learned ▪ Promotes formal written reports and journal publications 	<ul style="list-style-type: none"> ▪ Suggests evaluation results should be disseminated, through summary reports, to all implementers and users of the CDSS. ▪ Focus on sharing lessons learned at the central level and between Member States 	<ul style="list-style-type: none"> ▪ Encourages collaborative dissemination meetings with stakeholders and participants to increase probability of real programme improvement and system sustainability ▪ Encourages transfer of knowledge from peripheral to central levels ▪ Focuses on informing PHSS budget and optimising surveillance and response plan of action

CDC: U.S. Centers for Disease Control; CDSS: Communicable disease surveillance system; MoH: Ministry of health; PHSS: Public health surveillance system;

WHO: World Health Organisation

5.1.4 Key limitation of the WPA approach

The Chad meningitis surveillance evaluation study required two months cumulative data collection (includes formative research). In contrast, WHO's *Protocol for The Assessment of National Communicable Disease Surveillance and Response Systems* estimates 17 days, inclusive of analysis and report, to conduct the activities of the WHO guidelines (185). Table 5.3 compares the duration of the evaluation activities in Chad to the WHO's recommended schedule. A major factor of the 16-fold difference in activity duration is the composition of the assessment team. The WHO protocol recommends having an external leadership team that facilitates multiple national assessment contingents. For the Chad study, the field team was composed of one research assistant and myself.

Table 5.3 Comparison of Chad study and WHO protocol evaluation steps

Evaluation Step	Chad study (WPA)	WHO guidelines protocol
Pilot test or pre-assessment workshop	2 days	3 days
Training	3 days	3 days
Field assessment and travel	7 weeks	6 days
Analysis and report	24 weeks	4 days
Post-assessment workshop	1 day	1 day
Total	~32 weeks	17 working days (3 weeks)

5.2 Evaluation of performance and cost of meningitis surveillance in Chad

5.2.1 Study aim and objectives¹

The WHO in collaboration with The London School of Hygiene and Tropical Medicine (LSHTM) and Agence de Médecine Préventive (AMP) initiated a project to establish strong surveillance in the African meningitis belt. The study, entitled *Estimation of the Costs of Meningitis Surveillance in Chad and Niger*, assessed the costs of various levels of meningitis surveillance in Chad and Niger and was funded by the Bill and Melinda Gates Foundation. This was the first study to estimate the cost of meningitis surveillance in the African meningitis belt. The two countries were selected partly because of already established institutional links in both countries and also because between them several of the WHO recommended surveillance strategies were represented in their national surveillance plans of action.

The LSHTM was responsible for the study in Chad and AMP conducted the fieldwork in Niger. While the two country studies used a similar data collection protocol, collaboration was limited. Thus, the remainder of this thesis will refer to the Chad study only.

The need to conduct this study arose from several evident issues in the African meningitis belt, specifically:

- The need for countries to adapt their surveillance systems to capture epidemiological shifts in bacterial meningitis after introduction of MenAfriVac[®] as well as Hib and pneumococcal conjugate vaccines.
- The need to know the costs of strengthening surveillance to be able to assess the impact of MenAfriVac[®], Hib and pneumococcal conjugate vaccines.

¹ Many parts of this section are modified from “*Estimation of the Costs of Meningitis Surveillance in Chad and Niger: Study Protocol, LSHTM 2014*”

- The need for countries and partners to know the costs of implementing different levels of surveillance to aid in determination of the most feasible and sustainable surveillance strategies.

The aim of the study was to estimate the total and incremental costs of various meningitis surveillance strategies to inform the choice of the most appropriate and sustainable system within a specific country, and supplement the WHO guidelines, *Epidemic meningitis surveillance in the African meningitis belt: Deciding on the most appropriate approach* (80). The aim of these guidelines are to properly equip countries to select the best-fit and appropriate strategy in light of their disease programme aims, capacity, and available resources. At the time of its publication the guide only qualitatively presented the types of incremental resources needed and provided no figures on costs. For this reason, an aim of the study was to provide reliable estimates of total and incremental costs to complement the WHO guidelines.

The study objectives were:

1. To estimate the current costs of enhanced epidemic meningitis surveillance in Chad.
2. To estimate the current costs of case-based district sentinel meningitis surveillance in Chad.
3. To estimate the potential, incremental costs of upgrading from enhanced epidemic surveillance to case-based district surveillance in Chad.
4. To estimate the potential, incremental costs of upgrading from case-based district meningitis surveillance to nationwide case-based surveillance in Chad.
5. To use the study results to develop a cost extrapolation model that can generate cost predictions for other countries in the meningitis belt.
6. To evaluate the performance of the meningitis surveillance system in Chad.
7. To examine the contextual factors that influence meningitis surveillance performance in Chad.

Study objectives 6 and 7 were added partly because of the aims of this PhD, but also because intuitively it became clear that to properly assess the utility of distinct surveillance strategies, it would be necessary to not only estimate costs, but to also measure system performance.

5.2.2 Application of qualitative methods

The gold standard to increase validity for qualitative research methods is to use cross validate data analysis and findings with a trained researcher. Due to the solitary nature of this project and the unavailability for an additional experienced researcher to work with me in the field collection and data analysis, other measures were used to cross-validate the study findings. These methods include having a dissemination meeting to review all findings and interpretation, review of findings by my PhD supervisor and advisory group members, and validation of findings with the AMP study team. Table 5.4 describes the methods in which the analysis and findings were cross-checked (i.e. validated). Further, as explained later in this thesis, measures such as interview recording and double data-entry were undertaken to ensure that the data quality was to the highest standard possible.

Table 5.4 Description of validation measures for analysis and findings

Research analysis or findings	Validation measure
Description of Chad surveillance system	<ul style="list-style-type: none"> - Input provided and reviewed by Chad MoH officials - Input provided and reviewed by counterparts at CSSI - Presented at the study dissemination meeting (participants included: Chad MoH, WHO-CHAD, CSSI, LSHTM, and CDC)
Chad meningitis surveillance performance analysis	<ul style="list-style-type: none"> - Presented at study dissemination meeting - Reviewed by all study partners for inclusion in study report
Chad meningitis surveillance cost-analysis	<ul style="list-style-type: none"> - Performed conjointly with Dr. Ulla Griffiths - Reviewed and comments/input provided by AMP and WHO-Geneva counterparts - Upgrading method and data were guided by input from laboratory and meningitis experts from Chad, LSHTM, MSF, and WHO

	<ul style="list-style-type: none"> - Reviewed by AMP and reviewers for journal <i>Vaccine</i>, where it was subsequently included in a co-authored publication with AMP
Application of WPA framework for upgrading	<ul style="list-style-type: none"> - Method published in book chapter and reviewed by editors and colleagues - Framework was also used by AMP colleagues - Reviewed by all study partners for inclusion in study report
Discussion and interpretation of findings	<ul style="list-style-type: none"> - Reviewed by Dr. Ulla Griffiths - Reviewed by Dr. James Stuart and Dr. Heather Meeks, advisory committee members - Reviewed by Dr. Bernadette Henson, colleague

The methods described in this section include qualitative data collection methods for process and outcome evaluation. My background includes training in these methods, which was part of my Masters in Epidemiology coursework and fellowship training at the Centres for Disease Control and Prevention from 2008-2011. I have experience in structured and semi-structured interviews, focus group discussions, and key informant interviews.

5.2.3 Study setting

From March 1st to June 30th 2012, surveillance in Chad was scaled up in three regions (12 districts), which were vaccinated in December 2011. This was possible through the support provided by the MenAfriCar consortium carriage study (187), coordinated by LSHTM. The study supplied health facilities in these districts with training, standard operating procedures for meningitis surveillance, a secure transport system for CSF samples, and they identified points of contact at each laboratory and health facility (73). This study successfully demonstrated that MenAfriVac® is highly effective at preventing meningococcal meningitis carriage, and moreover, it showed that with sufficient funding, Chad could implement case-based surveillance, as pertinent to the present study of meningitis (73). Following these findings, the Chadian Ministry of Health (hereafter referred to by the French designation *Ministère de la santé publique*

[MSP]) in 2012 developed a plan of action to implement case-based surveillance in 18 districts (87). To date, this plan has not yet been implemented.

The costing and evaluation study was authorized on 14 March 2013¹, which followed the MenAfriCar study by one year. At this time, the MenAfriCar case-based surveillance support activities were dwindling in selected districts. The two LSHTM professors, Sir Brian Greenwood and Dr. James Stuart, who coordinated and managed the MenAfriCar study to local health stakeholders, were instrumental in the introduction of our evaluation study and provided an important link to in-country networks and contacts. Furthermore, the positive perception of the LSHTM brand was useful in engaging with local Chadian partners for our project. Professor Stuart accompanied Dr. Griffiths and myself on the initial visit in April 2013.

5.2.4 Study design

This study utilised a retrospective and cross-sectional design. The study objectives fell into five main study activities: First, conduct a systematic evaluation of the Chad meningitis surveillance system; second, estimate the actual costs of the existing meningitis surveillance systems in Chad; third, estimate the costs of upgrading to operational standards and scaling up the surveillance systems according to relevant options outlined in the WHO concept paper; fourth, use the results to develop a surveillance cost model that can be used for predicting the costs of surveillance strategies in other countries in the meningitis belt; and fifth, to examine how certain factors affected performance of surveillance activities (this was added for the purpose of this thesis). Table 5.5 presents an overview of these components with associated study methods (i.e. activity used to achieve study component, study instrument, and population included in the activity).

¹ See study authorisation can be found in the Appendix 1.

Costs and process data were collected for the July 2012 – July 2013 period. The main data collection activities occurred during September and October 2013. Interviews were conducted with surveillance-related personnel at each level of the health system, which included health facility, district, regional, national, and international staff. Paper based questionnaires were developed for each entity and used to administer the interviews. I was the principal researcher for the in-country portion of this project. One research assistant, Ms. Haoua Oumar, and I (hereinafter referred to as “the study team”) conducted all data collection activities and data entry. The full research timeline and a summary of the research activities indicating my role and the roles of others are provided in Table 5.6.

Table 5.5 Overview of study methods for each study component

Study component	Activity	Study instrument	Population
1. Conduct a systematic evaluation of the Chad meningitis surveillance system	Construct Chad meningitis surveillance system description through formative research (i.e. literature reviews, key informant discussions, government document reviews)	WPA: logic model and work process tree	Subject matter experts with experience in Chad surveillance
	Review of health facility registers for missed cases of a 28 day period during 2012 and 2013 meningitis season	Retrospective record search	Health facilities
2. Estimate actual costs of existing meningitis surveillance system in Chad	Conduct inventory of materials and supplies used for surveillance and record unit costs; capture resource utilisation	Excel spreadsheet Structured questionnaires	National finance records, laboratories Surveillance staff at study sites
3. Develop upgraded model for Chad meningitis surveillance system (i.e. Design operational standard)	Identify gaps in existing systems and estimate cost to bring system to a feasible and operational standard	WPA: work process tree Cost analysis	Chad
4. Develop surveillance predictive cost model		Cost analysis	African meningitis belt
5. Examine the factors that influence surveillance performance	Direct observation of work processes, health facility characteristics, and other relevant factors,	Structured questionnaires Field notes	Health facilities
	Interviews to capture indicator measures and contextual factors	Semi-structured interviews	Key informants

Table 5.6 Timeline of PhD research activities for Chad study

Study Component	Timeline	Activity	Lead*	Additional support*
Preparatory work	Feb 2013 – July 2013	Ethics approval and amendment AMP, WHO communication and coordination	UKG	NE
Study design		Design and development of protocol and study instruments	UKG, NE	AMP, JS, WHO
Data collection	Field visit 1: 29 April – 14 June 2013	Coordinate local travel to the seven districts for LSHTM and local researchers, including obtaining all necessary clearances from the Ministry of Health	JT, HO	NE
Data collection		Introduction trip to introduce study	CSSI, NE	MSP
Data collection		Determine surveillance system structure, format, and data/specimen flow	NE	HO, KG
Data collection		Field test study tools	NE	HO
Data collection		Field visit 2: 18 August – 29 October 2013	Collect data on selected indicators of health- and immunisation system functions in relation to meningococcal surveillance	NE
Data collection		Identify key experts on surveillance systems at national level	NE	JS, JT
Data collection		Meet with each key informant for individual interview or focus group discussion	NE	HO
Data collection		Conduct interviews in the seven districts	NE, HO	
Data collection		Laboratory data collection	NE	KG, HO
Data entry		Record and translate all interviews and focus group discussions	NE, HO	
Data entry		Data entry	NE, HO	

Study Component	Timeline	Activity	Lead*	Additional support*
Data analysis	<i>November 2013 – April 2014</i>	Data cleaning and preliminary analysis	NE	
Data analysis		Cost analysis and extrapolation	UKG	NE
Data analysis		Reanalysis of cost for thesis	NE	UKG
Data analysis		Participate in the synthesis meeting towards the end of the project to review and compare data and draw lessons from Niger and Chad	NE, UKG, AMP	
Dissemination	<i>January 2014 – April 2014</i>	Draft a country report	NE, UKG	KG, JS
Dissemination	<i>March 2014</i>	Conduct Chad dissemination workshop	CSSI, NE	UK, JS, MSP
Dissemination	<i>April 2015</i>	Development of policy recommendations	NE, UKG	
Dissemination		Submission of paper 'The actual and potential costs of meningitis surveillance in the African meningitis belt: results from Chad and Niger' ¹	AMP	NE, UKG, WHO,
Dissemination		MenAfriNet visit	CDC	NE, JS
Dissemination	<i>May 2015</i>	Finalisation of report and submission to country	NE, UKG	KG
Supervision	<i>July 2013 – July 2015</i>	Overall project	UKG	NE (Chad)
		Overall PhD/thesis	UKG	

* Individuals or groups responsible for each activity denoted by initials or acronym.

NE: Ngozi Erondy, UKG: Ulla Kou Griffiths, JS: James Stuart, JT: Jacque Toralta, HO: Haoua Oumar, KG: Kadidja Gamougam

AMP: Agence de Médecine Préventive, CSSI: Centre du Support en Santé International, WHO: World Health Organisation, MSP: Chad

Ministère de la Santé Publique; CDC: Centers for Disease Control and Prevention

¹ Submitted to journal *Vaccines*, candidate is second author

Site selection

Selection of districts and regions

Centre du Support en Santé International (CSSI) and Ministry of health officials guided a purposive sampling strategy to ensure inclusion of sites from different geographic areas with recent meningitis cases. Chad has 23 health regions, 102 health districts (of which only 75 are functioning) and 1,305 health zones (of which 1,061 are functioning). Non-functioning health zones do not have either staff or a structure, so the functioning health zones cover for the non-functioning ones. Due to insecurity in many parts of Chad, we were only permitted to travel to the southern part of the country. It was decided that seven districts would be most feasible due to road access, feasibility and time constraints. Two criteria guided district selection a) the district reported a suspected meningitis case in the previous four years and b) the district had meningitis surveillance activities in place.

In order to compare different surveillance strategies, the original selection approach was to select three districts operating case-based surveillance and four that were operating enhanced surveillance. To ensure variation, districts were considered across four regions and a mix of primarily urban and rural districts were selected. Urban and rural were defined by population (i.e. > 5,000 persons or < 5,000 persons) of district and geographic proximity to major trade routes¹. Though the capital, N'djamena, was not included as one of the study districts, the national reference laboratory was included due to its essential role in meningitis surveillance in Chad. The final included regions and districts are listed in Table 5.7 and can be seen on the map in Figure 5.2.

Among the enhanced meningitis surveillance districts, Moundou is an urban district with a regional laboratory. Goundi district is rural and was reporting the most meningitis cases during 2012/2013. Koumra is also a rural district, in the same region as

¹ The definition of 'urban' and 'rural' changed during the course of the study to reflect characteristics of the surrounding area (i.e. a concerted built environment such as a city or town) rather than just the catchment population.

Goundi. Among the CBS districts was N'Djamena Nord, which is part of the capital and thus an urban district. Two rural districts, Gounou-Gaya and Guelengdeng, were also selected as CBS districts and along with N'djamena Nord were part of the MenAfriCar carriage study that were still being supported by LSHTM (73). The fourth CBS district was Moissala, another rural area, where CBS was implemented and supported by Médecins Sans Frontières (MSF) (92).

Figure 5.2 Map of Chad with study regions and districts



Reclassification of case-based surveillance study districts

It was discovered that the districts that were part of the MenAfriCar study (N’ djamena Nord, Gounou-Gaya, and Guelengdeng) were not actually performing complete CBS. MenAfriCar was concluding and the overlap of financial and technical support to those districts with our study activities was for approximately four months. For the remainder of the year, ENS was in place. Hence, the study team retroactively classified these three districts as “partial” CBS systems compared to Moissala, which operated “exclusive” CBS.

Table 5.7 Study districts and regions

District	Region	2012 population
<i>Enhanced surveillance</i>		
Koumra	Mandoul	189,029
Goundi	Mandoul	158,379
Moundou	Logone Occidental	393,876
<i>Partial case-based surveillance</i>		
Gounou-Gaya	Mayo-Kebi Est	293,538
Guelengdeng	Mayo-Kebi Est	214,254
N’Djamena Nord	N’Djamena	166,100
<i>Exclusive case-based surveillance</i>		
Moissala	Mandoul	260,145

Selection of study health facilities and laboratories

The project research proposal stated that approximately 15 percent of health facilities in each study district were to be included. This proportion of health facilities was determined by the study team based on the total number of sites in Niger and Chad that could practically be reached during the study period. This resulted in three health facilities per district in Chad. The study area was further restricted to the Southern region of Chad because of safety concerns in the north and east of the country and near the region of Lake Chad.

The actual health facilities were selected during the first introduction visit. The Chief Medical Officer (*Médecine Chef du District*) coordinated our visit with the district surveillance focal point(s), who normally held the position/title of *Chef du Zone* (CdZ). The CdZ was designated to guide the researchers with selection of health facilities. The two selection criteria were:

- (i) The health facility had reported higher numbers of suspected meningitis cases in comparison to other health facilities in the same district during 2012 or 2013
- (ii) The health facility would be accessible for the study team during the rainy season

A variety of facility types were included, such as government, private, and NGO. Each associated district laboratory was automatically included in the study as well as the regional reference laboratory in Moundou¹ and the national reference laboratory in N'djamena. The MSP, the regional delegate, and laboratory directors approved laboratory participation. Table 5.8 list all sites included in the study, including the final surveillance strategy classification of districts.

Table 5.8 Total number of data collection sites (n = 44)

Surveillance office	Health facility	District lab	Regional lab	District surv. office	Regional surv. office	National surv. office	National lab
N'Djamena – HGRN	-	-	-	-	-	-	1
MSP	-	-	-	-	7	1	-
<i>Enhanced Surveillance</i>							
Koumra	3	1	-	1	-	-	-
Goundi	3	1	-	1	-	-	-
Moundou	3	-	1	1	-	-	-

¹ The Moundou laboratory serves as the laboratory for the large Moundou hospital, the Moundou district, and for the surrounding regions (i.e. in the Southeast part of the country).

Surveillance office	Health facility	District lab	Regional lab	District surv. office	Regional surv. office	National surv. office	National lab
<i>Partial case-based surveillance</i>							
Gounou-Gaya	3	1	-	1	-	-	-
Guelengdeng	3	1	-	1	-	-	-
N'Djamena Nord	3	1	-	1	-	-	-
<i>Exclusive case-based surveillance</i>							
Moissala	3	1	-	1	-	-	-
TOTAL	21	6	1	7	7	1	1

HGRN: L'Hôpital Général de Référence Nationale (Chad national reference laboratory)

MSP: Ministère de la santé publique (Ministry of health)

ES: Enhanced surveillance

CBS: Case based surveillance

Surv. = surveillance

Design and validation of study instruments through the operationalisation of the WPA framework

This section provides steps of how the WPA framework was applied to the design of the evaluation questionnaires for the present study. Moreover, this section details the construction of WPA tools, which resulted in questionnaire items and selected variables.

Step 1. Construction of Chad meningitis surveillance programme logic model

As explained in the WPA framework description, understanding how the country-specific nuances of how the surveillance system is implemented is the starting point for creating an evaluation plan. An extensive literature review was conducted to identify the needed resources, standard activities, and programme objectives needed for enhanced and case-based meningitis surveillance in the African Meningitis Belt. To serve the Chadian context, existing national guidelines, policies, and regional standard operating procedures were also reviewed (45, 71, 77, 188, 189).

While the overall evaluation study was to assess process performance and certain outcomes, the application of the WPA framework was for formative evaluation purposes. Formative evaluations aim to optimise and improve a programme's design of purpose (in this case the programme is CDSS evaluation) (190). Formative questions isolate specific tasks so that gaps in processes are easier to identify for improvement and summative evaluation questions correspond to programme outcomes and are helpful in measuring the quality and effectiveness of the current surveillance system. Table 5.9 outlines the evaluation components and questions developed for this thesis.

Table 5.9 Operationalisation of the WPA framework into evaluation study components

Objective	Research activity	Evaluation questions
<p>Apply Work Process Analysis framework to assess operational and financial gaps in the meningitis surveillance system</p>	<p>a. Map meningitis surveillance components into logic model and work process tree framework b. Collect information on what is needed to achieve an optimal and feasible MSS in Chad c. Measure gap between current system and desired optimal and feasible MSS d. Assess areas for programme integration opportunities</p>	<ul style="list-style-type: none"> ▪ What are the activities and costs to achieve an optimal and feasible MSS in Chad? (F) ▪ Where are the opportunities to strengthen meningitis work processes with other communicable diseases surveillance activities? (F) ▪ What are the incremental costs of improving the current system to a desired optimal and feasible MSS? (F)
<p>Conduct a systematic evaluation and costing of the meningitis surveillance system</p>	<p>a. Transform work process trees into study instrument items b. Assess performance of tasks by core and support functions c. Measure performance of current system using identified indicators d. Explore relationships between performance and cost</p>	<ul style="list-style-type: none"> ▪ What is the description of the MSS in Chad? ▪ What is the MSS performance of selected health facilities in Chad? (S) ▪ How much does surveillance costs? (F) ▪ What is the relationship between surveillance cost and performance across districts? (F)
<p>Examine the factors that influence surveillance performance</p>	<p>a. Document factors observed at health facilities and attained through health staff interviews b. Describe contextual factors across health facilities and districts</p>	<ul style="list-style-type: none"> ▪ What were the most reported factors that participants believed impacted surveillance and how? (S) ▪ Which factors were observed that appeared to influence surveillance work practice? ▪ How does funding source/policy affect surveillance performance?

MSS: Meningitis surveillance system

(F): Formative evaluation question

Step 2. Selection of study indicators

The indicators selected were measures of achievement and performance for meningitis and IDSR surveillance. These indicators are meant to provide objective information, which facilitates improvement of the system and provides evidence to justify advocacy of resources. Indicators were identified concurrently with logic model components through the literature and policy reviews and were then reviewed to ensure that they could provide information to answer the evaluation questions. The programmatic indicators were mostly quantitative, but contextual indicators were also included, which were informed by qualitative data from key-informant interviews. All indicators were mapped to the logic components (inputs, activities, outputs, and intermediate outcomes) to establish the evaluation blueprint.

The indicators were comprised of metadata, which were collected during the study; this includes numerator, denominator, existing target (if applicable), indicator reference, and data source. Indicators about cost were aligned to the objectives of the cost analysis component, such as cost per function, cost per suspected case, etc. The indicators collected and used for the study are further discussed in Chapter 7. The indicators, in conjunction with the work process tree, were used to develop the final evaluation and assessment tools.

Step 3. Formation of work process tree and study questionnaires

A work process tree was created to express the nonlinear components of each activity or to define alternative routes to produce outputs. The work processes were defined as a set of tasks that were needed to achieve each process listed in the logic model. The first step was to delineate the flow of data into process trees (using information from in-country surveillance informants as well standard operating procedures) into processes (e.g. weekly reporting) and discrete activities/tasks (e.g. send SMS to district surveillance focal point every Monday; send written forms to district surveillance focal point by courier).

Next, each process tree was aligned with the required human and financial resources, if applicable. The last step was to transfer processes and tasks to the appropriate study instrument. Tasks were modified according to the indicator target. Specifically, a mix of question types (e.g. multiple choice, open-ended, ordinal scale, contingency) to estimate the measure of variance around the intended target as well as the implementation of the task itself. For example, if the standard requires each health facility to report weekly, we would ask the following open question: *“How often do you report suspected cases?”* In contrast to *“Do you conduct weekly reporting of suspected cases?”* This former question is more useful to help programme managers make specific corrections to programme health practice. Another example of a set of process-task questionnaire items can be seen in Figure 5.3.

Figure 5.3 Example of work process and tasks concepts as questionnaire items (health facility questions 36 – 41)

Work process: Perform lumbar puncture on suspected case and send CSF to laboratory	
The tasks are listed in the succeeding questions :	
36. Des ponctions lombaires sont-elles habituellement réalisées sur les patients présentant des signes cliniques de méningite avant de commencer à traiter par antibiotiques ? <i>(Are lumbar punctures usually performed on patients who present with clinical signs of meningitis before they are treated with antibiotics ?)</i>	
Toujours <i>(Always)</i> <input type="checkbox"/>	Souvent <i>(Often)</i> <input type="checkbox"/>
Rarement <i>(Rarely)</i> <input type="checkbox"/>	Parfois <i>(Sometimes)</i> <input type="checkbox"/>
37. Quel type d'employé réalise les ponctions lombaires <i>(Which type of employee does the lumbar puncture)?</i> (poste/titre) _____	
38. Combien de ces employés sont actuellement dans l'établissement? <i>(How many of these employees are currently [working] in the health facility?)</i> _____	
39. Combien de tubes de LCR sont normalement prélevés sur un cas suspect de méningite? <i>(How many tubes of CSF are normally removed from a suspected meningitis case?)</i> _____	
40. Quand les prélèvements de LCR sont-ils livrés au laboratoire, cochez la réponse appropriée: <i>(When are the CSF samples delivered to the laboratory, check the appropriate response)</i>	
Immédiatement <i>(immediately)</i> <input type="checkbox"/>	toutes les heures <i>(every hour)</i> <input type="checkbox"/>
chaque demi-journée <i>(each half day)</i> <input type="checkbox"/>	une fois par jour <i>(one time per day)</i> <input type="checkbox"/>
autre <i>(other)</i> <input type="checkbox"/>	
41. Comment les prélèvements sont-ils manipulés et stockés avant le transport vers le laboratoire? <i>(How are the samples handled and stocked prior to transport to the laboratory ?)</i> _____	

Where a resource was needed, relevant sub questions were developed to gather information such as: unit cost, salary, frequency of use, distance, age and condition of equipment. These cost-related variables were ultimately captured in data abstraction

tables nested in the relevant study questionnaire. Figure 5.4 provides an example abstraction table from the health facility questionnaire. After collection of these data, they were entered into Excel spread sheets; this tool is explained further in the following section.

Figure 5.4 Example of question to estimate the value of donations for cost analysis (health facility question 15)

Q. 15. L'établissement a-t-il reçu des donations en nature en 2012? Oui Non; Si oui, compléter le tableau suivant
(Did the establishment receive in-kind donations in 2012? If yes, complete the following table)

Type de donation	Quantité reçue	Valeur de la donation en CFA	Source
a. Véhicule			
b. Ordinateur			
c. Equipement de chaîne du froid			
d. Frigidaire			
e. Autre (spécifier _____)			
f. Autre (spécifier _____)			

In total, the following five study questionnaires were created from this process:

- 124 - item health facility questionnaire
- 40 - item district/regional questionnaire
- 64 - item laboratory questionnaire
- 35 - item central level questionnaire
- 5 - item partner agencies questionnaire

The district/regional questionnaire was used to conduct interviews for both district surveillance focal points and regional surveillance focal points. The national/partner questionnaire was used to conduct interviews for both MSP officials at the central level and in-country international health partners (i.e. WHO, MSF, CDC).

All questionnaires were written in English and a third-party contractor translated them into French. AMP and CSSI then refined these translations. To validate the selection of activities and processes, surveillance and laboratory experts as well as study partners reviewed and provided comments and modifications. Additionally, the study protocol, inclusive of the evaluation plan and study instruments underwent third-party (persons not associated with the study) scientific reviews at LSTHM and WHO-Geneva. The health facility questionnaire can be found in the Appendix 4.

Step 4. Development of data entry and analysis tool for resource utilisation and unit cost data collection

The data entry and analysis tool that was used in the study was built upon an existing tool platform called SurvCost. SurvCost is a spreadsheet-based tool developed to aid public health officials to estimate the costs of IDSR systems at national, region/province, district, and health facility levels¹. The tool has been developed using

¹ SurvCost is a product of the U.S. Centers for Disease Control and Prevention (CDC) in collaboration with the World Health Organization Regional Office for Africa (WHO/AFRO)

Microsoft Excel/Visual Basic. The tool and guidelines can be downloaded at:
<http://www.cdc.gov/globalhealth/dphswd/idsr/tools/survcost.html>

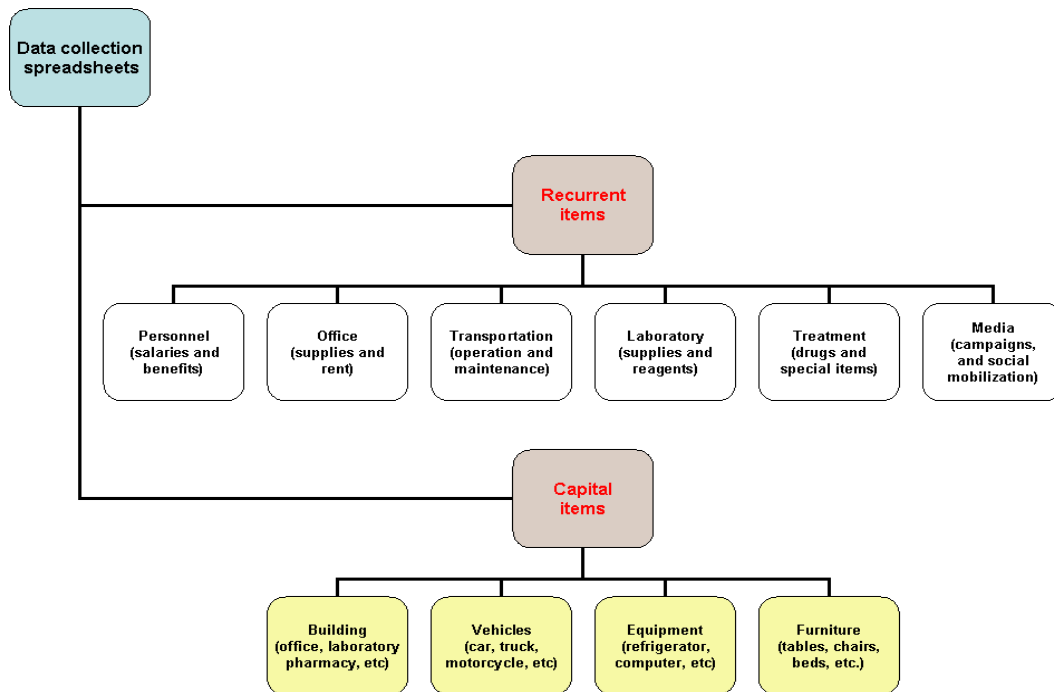
The SurvCost tool is composed of three groups of spreadsheets linked together by formulas:

1. Data Collection or Entry – for gathering information
2. Data Synthesis or Results – calculates costs
3. Data Summary – provides aggregated totals for each category

Figure 5.5 illustrates the structure of the SurvCost data collection spreadsheet template. SurvCost was used as a starting point for designing the data entry and analysis tools used for the study, but as SurvCost was not developed for simultaneously capturing data from many different study units, the structure of the sheets were changed substantially.

Cost-related data for health facilities, district, regional and central surveillance offices were collected during interviews and documented in the questionnaire abstraction tables. Then the data were manually entered into the excel sheets for analysis. The laboratory inventory was entered directly into the data entry sheets.

Figure 5.5 SurvCost data entry spreadsheet structure



Source: Sameda *et al.* (111)

Field test

Field-testing is a commonly used research technique performed to test and establish validity of study instruments. Validity is the degree to which an instrument measures what it is supposed to measure (191). For the present study, this technique as well as expert review was used to increase internal validity of the study questionnaires.

The field test was conducted over two days in September 2013 in N'djamena Nord district. This consisted of testing the health facility, district/regional and laboratory questionnaire during working hours as would happen during the actual data collection period.

The purpose of this field test was to optimise the study questionnaire by testing:

- The comprehension of study items,
- The accuracy of data source for certain questions (e.g. deciphering if the CdZ or the CASE kept a line lists for suspected cases),
- The appropriateness and logic of the questionnaire length and layout, and
- The ability and willingness of participants to answer the questions.

Another aim was to simulate actual field conditions in order to understand the time needed to administer each questionnaire and to inform the data collection schedule. The study team took comprehensive field notes and made edits on the study questionnaire during these visits. The field notes were taken to ensure that a wide breadth of information, including participant feedback was captured. Notes were compared and collated after each site visit. Each interview was recorded and the recording was reviewed during the revision process; this was especially necessary to resolve discordant responses between the interviewers or to clarify intelligible responses. A summary of the field test results is presented in Table 5.10. The central/partner questionnaire was not tested in the field, but was reviewed by surveillance and health economics experts for appropriateness and completeness.

N'djamena Nord, was originally selected for testing purposes only; the baseline questionnaire used for this district was subsequently amended. However, the study team decided to include this district in substitution for an earlier district that was not an urban area. Subsequently, in November 2013, the research assistant returned to N'djamena Nord and collected the missing data that were omitted on the first version of the study tools.

Table 5.10 Summary of questionnaire field test results

Participant/ questionnaire	Duration	Questionnaire modifications	Field notes
CdZ, N'Djamena Nord district/ District and regional questionnaire	1 hour	<ul style="list-style-type: none"> - Added question about CdZ original career or certification (e.g. nurse or physician) - Added the conditional question inquiring if no vehicle was available, did they have a personal vehicle that they use for work - Deleted a confusing question about early notification of evolving outbreaks from district to regional level 	<ul style="list-style-type: none"> - We delivered the questionnaire one week in advance but the CdZ did not review or fill it in before the time of the interview - This was a new CdZ who did not have a lot of knowledge or much of the data that we requested. - He requested that we talk to <i>Médecine Chef du District</i>.
RCS at the Mileze Centre du Santé/ Health facility questionnaire	2 hour 40 min	<ul style="list-style-type: none"> - Added public and private options for 'type of establishment' - Added question to see documentation when specific information was requested - Need to pre-define 'follow up' which should mean to check on confirmed case after release from health facility, and look for persons who may have been exposed to the disease. - Modified questions about specific distance - Added specific questions related to rainy season - Added specific questions about sending forms to district and regional focal points - Moved data about aggregate case totals for other disease to district/regional questionnaire 	<ul style="list-style-type: none"> - Difficulty finding 2012 disease register - Taking pictures of information posted on the wall was useful - RCS seemed happy to complete the interview despite the length, there were two other staff attending to patients - CdZ was with us for the first part of the interview— this seemed to put pressure on the RCS. - Noted that the Likert-scale questions did not translate well in the setting (suggested changing the 5-point scale to a 3 point scale)

Participant/ questionnaire	Duration	Questionnaire modifications	Field notes
Chef du Service du Laboratoire, Hospital de la Paix/ Laboratory questionnaire	2 hours	<ul style="list-style-type: none"> - Moved population data about the local area to the CdZ questionnaire - Modified the analysis table with the recommended analyses reform - Added laboratory support staff to capture the amount of personnel in each laboratory - Added question to document each piece of equipment and respective locations 	<ul style="list-style-type: none"> - We delivered the questionnaire one week in advance and the <i>Chef du Service</i> had completed the first few pages of the questionnaire, at the time of the interview. - Participant was also positive regarding the time length - Necessary to confirm laboratory documentation to confirm that test were done - Excel form was difficult to collect information specific data (e.g. salary) - Prayer on Friday afternoons is necessary consideration for study schedule - <i>Chef du Service</i> agreed to email the list of meningitis-related reagents.

Data collection and management

Preparation and training

The data collection period occurred during September and October 2013. I trained the research assistant (RA) on the structured interview and field notes methods; this entailed going through each questionnaire item and explaining the intended meaning. The purpose of this was to generate good quality data by ensuring that we both had the same baseline knowledge and understanding of the study instruments and procedures. I also prepared interview introduction scripts, which we both practised before the study started. The script included greeting, study introduction, and a request for a verbal consent and recording permission. For most of the interviews, the RA primarily facilitated the introduction. This was important because she is Chadian and when she opened the interview by introducing us as a team, the participants seemed to be more at ease. We were also accompanied by a CSSI driver (also a Chadian) who usually assisted us by bringing in the participant incentive of one dozen bottles of soft drink, one dozen bottles of water, and two packs of biscuits.

Participants

Data for performance assessment, contextual factors, and some information for cost estimates were obtained from the four interview sources (i.e. staff at the health facility, district, region, and central levels). Table 5.11 summarises the relevant surveillance staff who participated in the study by administrative level. At the sub-national level, participants included staff from 42 study sites (See Table 5.8 [p. 139]). Interviews conducted at the central level were conducted with government decision-makers, policy stakeholders, domestic disease programme leads, and international health partners.

Table 5.11 Health care structure and corresponding surveillance staff

<i>Administrative level</i>	<i>Entity</i>	<i>Surveillance contact(s) occupation</i>
National	Ministère de Sante Publique (MSP) National Laboratory (HGRN)	<ul style="list-style-type: none"> ▪ National surveillance coordinator and deputy coordinator ▪ Data manager ▪ National laboratory focal point
Regional	Regional Delegation Regional Laboratory	<ul style="list-style-type: none"> ▪ <i>Chef d'Antenne de Surveillance 'Epidémiologie (CASE):</i> Regional surveillance lead ▪ Regional laboratory Responsable
District	District Hospital District Laboratory	<ul style="list-style-type: none"> ▪ <i>Chef de Zone (CdZ) :</i> District surveillance lead ▪ District surveillance focal point ▪ District laboratory manager
Peripheral	Health Facility	<ul style="list-style-type: none"> ▪ <i>Responsable du Centre de Sante:</i> Health Facility manager

Structured interviews

Structured interviews were used to collect performance and cost data at each administrative level. Question-types included close-ended, open-ended and free-response questions; the latter allowed for personal opinion of challenges, discussion/explanation of disease surveillance in general, and auxiliary information for certain responses. Types of data collected included demographic information of participant and study site, history of surveillance training activities, assessment of meningitis surveillance knowledge and skills (health facility, district/regional), surveillance activities performed, past response activities, surveillance resources, community engagement, and information about integrated surveillance activities. We captured the majority of responses by directly filling in the questionnaire with participants' answers and extracting data from disease registers, reports, etc. Additionally, the health facility questionnaire included a 19 qualitative Likert scale

questions to gauge participant beliefs and opinions about budget, logistics, human resources, and reporting. Specifically, these questions discussed ability to do work, maintenance of systems, staff capacity, capability, and motivation, and opinion regarding timely feedback.

Though the interviews were not self-administered, each participant was given a copy of the questionnaire so that they could follow along and read the question as it was asked. This was to minimise confusion or miscomprehension that could occur due to my accent or limited French ability. Additionally, the RA sat next to each participant and guided him or her along the questionnaire as I read the questions aloud. The RA filled out the questionnaire in front of the participant as they spoke, and I filled out a separate questionnaire, so each participant interview was documented twice. At the end of each interview, we retrieved both questionnaires. During the data entry process, we compared the responses and reviewed the recordings for any discordant or intelligible responses. There were no refusals to participate.

Key informant semi-structured interviews

Throughout the study period key informants (KI) were identified based on their experience with disease surveillance in Chad. The criteria for selecting key informants was that the person must have worked in Chad for at least six months in a surveillance-related role for any vaccine preventable disease, and they must have been working in the sub-Saharan African context for at least three years, in a surveillance-related capacity (Table 5.12 summarises this list by topic.). The interviewed persons included local NGOs, Ministry officials, and partner organisation staff. KI discussions did not follow a conventional topics list since different KIs for contacted to inform different components of the research study. Rather, KIs were approached to fill knowledge gaps about certain aspects of the research, which were identified prior to each interview and served to guide the discussion. Some informants helped to inform the process of describing the surveillance system, some KI's were asked to provide information about

the challenges and/or benefits of the national meningitis surveillance system, and some KIs were asked about specific recommendations to improve the system. Eighteen potential KIs were solicited to participate, but due to scheduling and travel, I was not able to speak to two individuals. In total, I conducted sixteen face-to-face interviews.

Table 5.12 Key Informant participants and topic summary

	KI role	KI organisation	Topic discussed
1.	Data Manager	MSP	Chad meningitis surveillance description
2.	Researcher/ Epidemiologist	CSSI/MSP	Chad meningitis surveillance description
3.	MenAfriCar-Chad coordinator	CSSI	Chad meningitis surveillance description
4.	Laboratory technician	HGRN	Laboratory role, Chad meningitis surveillance description
5.	Epidemiologist/ Technical officer	CDC-Atlanta	IDSR and Polio activities
6.	Epidemiologist/ Technical officer	CDC-Atlanta/WHO	IDSR funding, performance, and needs
7.	Country director	Carter Centre	IDSR, guinea worm programme activities
8.	Medical coordinator, Chad	MSF-France	Moissala district meningitis surveillance
9.	Field lead Moissala	MSF-France	Moissala district meningitis surveillance
10.	Administrator	MFB	Chad salary structure for government employees
11.	Assistant administrator	CSSI	Chad salary structure for government employees
12.	Surveillance officer	WHO/Chad	WHO role in Chad meningitis surveillance
13.	Immunisation and vaccines development country lead	WHO/Chad	Suggestion for surveillance strategy
14.	Supplies manager	WHO/Chad	Unit cost for resources
15.	Chef de Zone Koumra	MSP	Suggestions for surveillance improvements
16.	Chef de Zone Goundi	MSP	Suggestions for surveillance improvements

CDC: Centers for Disease Control and Prevention

HGRN: Hospital Général Référence National

KI: Key informant

MFB: Ministry of Finance and Budget

MSF: Médecins Sans Frontières

MSP: Ministère Santé Publique

A semi-structured format was used to allow for a conversational, but still focused conversation. During each interview I guided the KI through pre-defined topics of interests. Each interview began with more general questions about the Chad surveillance and health system, and then we discussed specific topics and issues that were relevant to the KIs expertise and experience. While some questions were phrased ahead of time, many of the questions were created in response to the KI's response or to probe for more information. This flexible format was chosen to compensate for my limited local knowledge and allowed for new information to emerge. I took comprehensive notes and synthesised them as required to inform the respective research component. Depending on the time constraints of the participant, these interviews ranged from 20 to 70 minutes. A few times I arranged to meet with the KI between meetings and so I asked very specific questions about their work or experience in a certain district. While most KIs were interviewed before or during the main data collection period, selected study participants (e.g. CdZs from certain districts) were approached and asked to participate in an interview to provide additional insight on surveillance issues.

Record review

At each health facility a retrospective record review was conducted to verify suspected meningitis case registration. This usually occurred near the beginning of the interview and involved me searching through the registers for suspected cases during the previous 28 days as well as during 12 March through 8 Avril 2012. The purpose of the 'previous 28 days' period, was as a quality check to verify if actions recently performed matched with general participant responses regarding surveillance activities (i.e. to ensure that reality matched with what participants may have thought were the expected answer). We selected the '12 March through 8 Avril 2012' period because those dates coincided with the 11th through 15th epidemiologic weeks—this period was well into the high incidence of meningitis in the previous four years in Chad.

If within the previous 28 days a suspected meningitis case was noted in the register, I asked the participant for a copy of the case- or weekly-reporting form that included the suspected case. This usually was not available at the health facility due to SMS reporting, lack of archives, and other reasons that are detailed in Section 5.2.4. In any case, if a form was found, one to three cases (but often times more) were randomly selected to verify that the case was reported to the district level.

Collection of resource utilisation data

Data was collected for costing by interviewing surveillance-related staff and stakeholders at the different health levels and reviewing relevant documents and by collection of accountancy records and financial statements. As mentioned above, a Microsoft excel-based tool was developed for data entry of cost-related information. Data on unit costs and quantities of regional and national laboratory supplies were collected through a separate inventory (i.e. apart from the laboratory structured interview) and entered into the excel tool. Specific unit costs of surveillance-related resources were collected from a variety of sources, including salary scales from the Ministry of Finances and Budget (*Ministère des Finances et du Budget*), accounts and invoices, partner agencies engaged in procuring surveillance supplies, and from potential suppliers.

Collection of contextual factors

Contextual questions intended to assess unique factors about the health facility, were included in the HF questionnaire. These included distance from district hospital, type of area (i.e. urban or rural), number of health staff, accessibility (e.g. paved or dirt road, difficult or easy access), and source of financial support. Contextual factors were captured using four methods:

1. Reported context-related factors from the literature,
2. Key informant interviews,

3. Context-related tasks that emerged from WPA exercise, and
4. Direct observations at study site during health facility visits.

Data collection experience

The data collection experience was pleasant due to the hospitable nature of the Chadian culture as well as the positive reception of our incentives. The major challenges were the distance between districts and sometimes health facilities, as well as my language barrier during the earlier interviews. Though the RA spoke fluent French, her limited experience in research studies made it difficult to ask probing questions when needed.

Quality assurance

A high level of field supervision was maintained during the fieldwork period. The RA and I worked closely on all field activities. Each questionnaire was checked before data entry for completeness. Missing or incomprehensible data necessitated the study team calling the participants to provide the correct information. Questionnaire data were entered manually shortly after each interview. I entered data for my questionnaire and the RA entered data for her questionnaire (i.e. the same questionnaire data was entered by two different people), so double data entry occurred. Afterwards, the study team physically convened to synthesize data, review all responses, and resolve discrepancies in real time. After the data collection period, upon arrival to London, all raw data were cleaned and coded. Inconsistent data were rechecked against the paper questionnaires and corrected where possible.

Figure 5.6 Chief laboratory technician preparing to analyse CSF at the national laboratory, N'djamena



Figure 5.7 The study team with the technicians at Koumra district laboratory



Figure 5.8 An in-progress interview with the Moissala Chef de Zone



Figure 5.9 An in-progress interview with the Responsable of Dele Centre de Santé, Moundou



Data analysis

I performed data analysis in London. When necessary, the RA and the lead laboratory technician provided requested necessary outstanding data, via email. Expert input from study collaborators and external colleagues was also required to complete the data analysis.

Performance assessment

Questionnaire data were summarised using frequency counts, measures of central tendency and proportions. Data were presented to describe the distribution of key variables, including: study site, surveillance strategy, environmental factors, funding-support mechanism, number and type of staff, suspected meningitis cases, source information of surveillance materials and equipment, and process and structural surveillance-related variables. Data on the contextual factors were analysed and summary measures of means, ranges, and standard deviations generated. Data were presented by health facility, district, and laboratories. The performance assessment at the health facility level looked at the system as a whole rather than comparing them by surveillance strategy, since this comparison was primarily intended to understand the incremental cost of transitioning strategies. The subnational (health facility, lab, district offices) performance assessment gauged whether the system was able to complete activities as expected by the MSP, in accordance to standards.

Indicators were measured using two techniques. First, performance was quantitatively assessed by a calculation of programme data, which were then compared to expected performance targets, derived from study indicators. This analysis continued to categorise surveillance functions as low, medium, or high performance based on percentage of attained indicators. The second level was to qualitatively¹ characterise the surveillance system by using selected surveillance characteristics. This assessment included the surveillance core functions and corresponding activities, 'detection and

¹ Data were analysed using nominal qualitative categorization; the use of *qualitative* here is not intended to imply a qualitative research approach

registration', 'reporting and analysis' and 'feedback'. Frequency distribution tables were created for the performance indicators and stratified by administrative level and by district strategy. The methods for the performance assessment are presented in further detail in Chapter 7.

Cost-analysis

First, the total and average across study districts costs of existing ES and CBS of meningitis surveillance systems in Chad were estimated. Then the incremental costs of upgrading these systems to an operational standard, which include integrated surveillance system with other diseases, were estimated.

Broad types of costs were analysed by:

- Meningitis surveillance activities
- By surveillance strategy
- Surveillance core and support functions

Mean costs were calculated per 100,000 population and per capita according to surveillance strategy. To inform the efficiency of the in-place surveillance system, mean costs per suspected case, per investigated case, and per confirmed case were also estimated. Methods applied for estimating each type of cost are described in more detail in Chapter 8.

Average cost were compared for potential differences between district surveillance strategies. Total system cost along with the performance analysis was performed to inform the best-fit surveillance strategy for the Chad context.

Creating an operational standard

The 'operational standard' is defined as the comprehensive set of meningitis surveillance activities that comply with the guidelines for case-based bacterial meningitis surveillance customised to country circumstances. This upgrading method was informed by the WPA framework and utilizes the logic model and the work

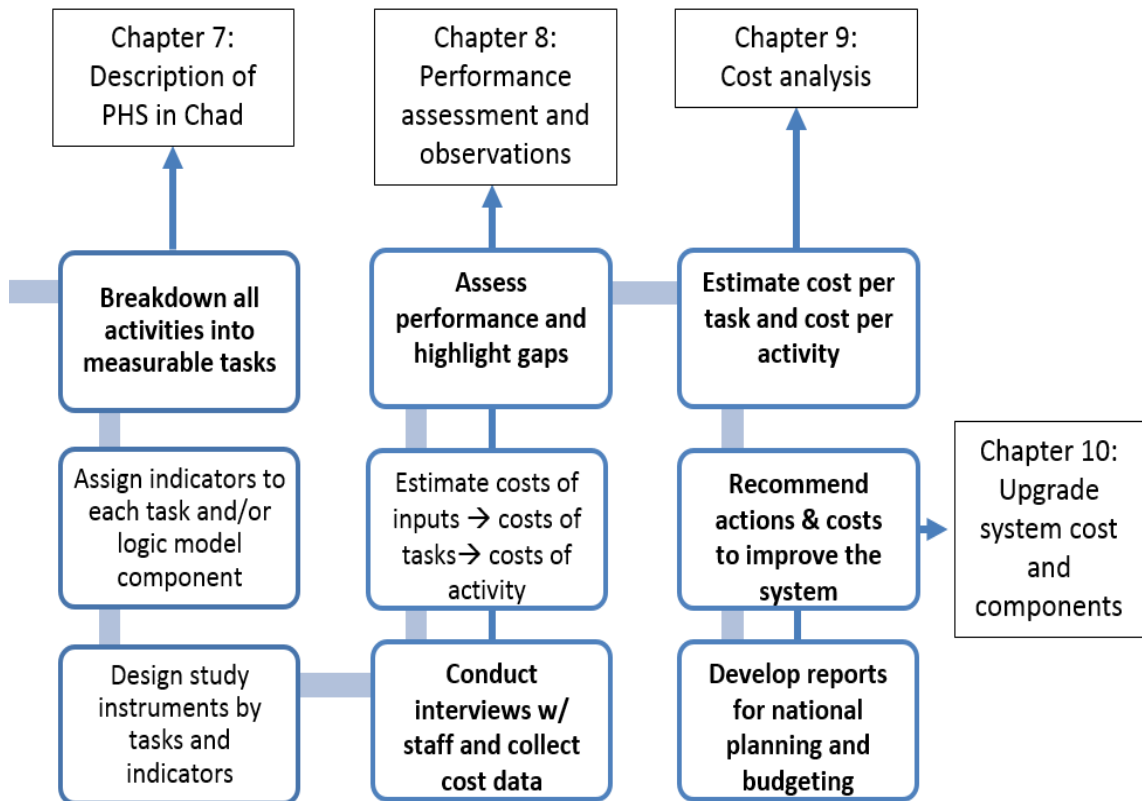
process trees to define the programme gaps and identify the needs at core function and/or administrative levels. Detailed methods applied to upgrading the system are presented in Chapter 9.

Dissemination meeting

In March 2014, a dissemination meeting in N'djamena was organised and attended by study collaborators, MSP officials, and partners. During this meeting the study team presented the preliminary study results, and participants were trained on completing surveillance forms.

Figure 5.10 shows how the results chapter are aligned to the PhD research activities presented earlier. Each results chapter further describes specific methods and outcomes.

Figure 5.10 Results chapters and affiliated research activities



5.3 Ethical approval

Political buy-in was a large component of this study—as it should be when objectively evaluating a health system, and especially as an outside institution. With this understanding, the study commenced with an introduction and exploratory visit during the months of April and June 2013. The primary aim of this visit was to describe the study objectives and assess the perceived value of the study to primary stakeholders (i.e. the Chadian government, international partners, and CSSI—the local technical collaborator). We explained that the anticipated study results were to equip policy makers and external stakeholders with information to determine the most feasible and effective meningitis surveillance strategy for Chad.

Ministry of Health officials reviewed and approved our overall study as well as the request to access and analyse sensitive financial expense data and interviews with health facility staff. They also guided selection of potential study sites. I then embarked on introductory visits to the pre-selected study sites with one research assistant, Ms. Haoua Omar and the CSSI study liaison, Dr. Jacque Toralta. Our team completed an introduction tour to each of the seven districts where study authorizations were obtained from each regional governor. Soon after, the LSHTM Research Ethics Committee granted the study ethical approval. Also, as this study was low risk to all participants, it received an exemption from the WHO Ethics Review Committee.

To ensure confidentiality, all persons interviewed were assigned a unique study number that was used for data storage and analysis allowing personal identifiers to be omitted. All the information provided in the study was anonymised. Participants were verbally briefed on the purpose of the study and data collection methods, and informed consent was obtained. We also asked permission to record at the beginning of each interview. All study questionnaires have been stored in protected rooms and the pertaining databases are secure and shared only among team members from WHO, LSHTM and AMP.

6 Public health surveillance in Chad described using work process analytic tools

A clear description of the surveillance system is a crucial first step in understanding it. CDC and WHO suggest engaging stakeholder's at all pertinent government levels as well as auxiliary professional and private organisations (8, 31). The product of such engagement should result in an explicit understanding of:

- the public health importance and specific objectives of the system,
- the resources used to operate the system, and
- the priority diseases and health-related events under surveillance in the respective country.

In this chapter I present the overarching public health surveillance system in Chad, followed by a description of the design and operational components of the meningitis surveillance system. The ensuing descriptions are the result of stakeholder input and empirical observations as previously described.

6.1 Public health surveillance structure

The health system in Chad is composed of a private and public sector. The Chad Ministère Santé Publique (MSP) in 2012 was organised into one central level and two intermediate levels, which includes 23 regional health delegations (*Délégations Sanitaires Régionales*) and 70 health districts (*Districts Sanitaires*). There are 1165 peripheral “zones of responsibility”; each zone includes a number of health facilities. This health infrastructure covers 69% of the country (Chad 2012 Polio certification report), the rest of the country is either unserved or inaccessible.

The MSP operates through a hierarchy, with the national level officials directly overseeing the intermediate level, which in turn supervises the peripheral level. At each administrative level, SSEI surveillance staff or health facility staff undertake daily

surveillance duties. Table 6.1 summarises the surveillance staff at each administrative level.

Table 6.1 Health care structure and corresponding surveillance staff

Administrative level	Entity	Surveillance staff positions
Central	Ministère de la sante publique (MSP) National lab (HGRN)	<ul style="list-style-type: none"> ▪ National surveillance coordinator and deputy coordinator ▪ Data manager ▪ National laboratory focal point
Regional	Regional delegation Regional laboratory	<ul style="list-style-type: none"> ▪ ‘<i>Chef d’Antenne de Surveillance d’Epidémiologie</i>’ (CASE-Area surveillance lead) ▪ Regional laboratory Responsible
District	District hospital District laboratory	<ul style="list-style-type: none"> ▪ ‘<i>Chef de Zone</i>’ (CdZ -Zone surveillance lead) ▪ District surveillance focal point ▪ District laboratory Responsible
Peripheral	Health facility	<ul style="list-style-type: none"> ▪ ‘<i>Responsable du Centre de Sante</i>’ (RCS) (Health facility manager)

The MSP in Chad coordinates all communicable disease surveillance through the Integrated Epidemiological Surveillance Service (“*Service de Surveillance Épidémiologique Intégrée*” [SSEI]), who works closely with specific disease programmes including the Expanded Programme of Immunisation (EPI). While the national surveillance strategy is labelled “integrated”, these disease programmes largely operate in a vertical manner (i.e. through parallel systems) at the subnational level. This includes separate systems for EPI, specific priority diseases (e.g. polio, guinea worm, and malaria), nutrition and several other conditions. Efforts to integrate surveillance activities are largely realised through weekly review meetings of the National Committee for Epidemic Control (“*Comité Technique national de Lutte contre les Épidémies*” [CTNLE]). However, this integration does not trickle down to where it is most needed. CTNLE includes representatives from all disease programmes as well as national and international

partners. The chief communicable disease surveillance partners in Chad are the WHO, MSF, The Carter Centre, and the US Centers for Disease Control and Prevention (CDC).

In Chad, the CTNLE makes the ultimate decision on national notifiable (or priority) diseases and health events to be monitored; this process is accomplished by considering incidence and prevalence rates, outbreak-potential, and severity. In addition, external entities have successfully added to country priorities by funding and supporting disease-specific initiatives such as polio and guinea worm eradication. Meningitis is a national notifiable disease under the integrated surveillance program, along with those listed in Table 6.2. There are, in addition, disease specific surveillance systems for onchocerciasis, preventing mother-to-child transmission of HIV, trypanosomiasis and tuberculosis.

Table 6.2 Notifiable diseases under surveillance in Chad, 2012

Diseases marked for eradication	Diseases marked for elimination	Diseases with epidemic potential	Diseases targeted for reduction of incidence and prevalence	Diseases under surveillance
Guinea worm Poliomyelitis	Neonatal tetanus Measles	Cholera Yellow Fever Meningitis	Malaria	Influenza A (H1N1) Avian Flu Hepatitis E Malnutrition

While most of the health districts are under the direction of the MSP, several are operated by private entities. In the Chad study two districts, Goundi and Moissala, were examples of this. Goundi has been operated by a Spanish missionary organisation. Several years of support has developed Goundi to a well-known district for health services in the region; the district hospital regularly serves patients from around Chad. Moissala district was operated by MSF-France. Moissala is 30 kilometres from the

Central Africa Republic border, and MSF ensures that health-related services, including meningitis are robust to sustain an influx of fleeing refugees from conflict areas. These districts are called 'private' districts and receive minimal financial support from the MSP but are still a part of the administrative supervisory structure.

6.2 Logic model for meningitis surveillance in Chad

I spoke to ten key informants in order to understand the activities related to meningitis and integrated disease surveillance and to detail the presumed flow of epidemiologic and laboratory surveillance data. This information was used to identify specific activities and individual tasks for conducting meningitis surveillance. This was imported into a logic model framework, which was organized by functional components of disease surveillance (i.e. detect and confirmation, reporting and data analysis, case investigation and response, supervision and feedback, and monitoring and evaluation.). Using an activities-centred "mapping-outward" method the logic model was constructed by first systematically categorising the activities by administrative level (i.e. health facility, district, regional, and central) and existing surveillance strategy (i.e. ES, CBS). The activities were then represented and validated by the local surveillance experts. Figure 6.1 shows the activity portion of the Chad meningitis surveillance system logic model.

Next, the inputs (e.g. financial resources, relevant policies, skills, training required to fulfil the activities) were identified and mapped to the relevant core functions. The outputs were mapped as the expected products (i.e. documents, sub-activities) resulting from the required programme activities. The intermediate outcomes were identified to obtain measurable changes of accomplished activities that should lead to attainment of programme objectives (i.e. long-term outcomes). The intermediate outcomes as well as some of the outputs were extracted from high-level meningitis programme and IDSR indicators.

Lastly, the long-term outcomes in this logic model correspond to the intended impact of meningitis surveillance on the health system and as a service that prevents or limits the damage inflicted by disease on the population. This includes important IDSR fundamentals such as “prompt detection”, “rapid confirmation” “up to date information”, “early response”, and “increased quality and ability of the system”.

The full logic model is presented in Appendix 2. The logic model depicts the “ideal” meningitis system for Chad, and this was used to construct the next set of tools of the WPA framework.

Figure 6.1 Excerpt of Chad logic model, 'meningitis activities' section

	Detect/ Laboratory confirmation	Report and analysis	Investigation/ Response	Supervision and Feedback	Monitoring and Evaluation***
ACTIVITIES					
Health Facility	Diagnose suspected case Refer patient to district hospital for LP (CBS) or Conduct LP at health facility (ES) Provide treatment	Notify CdZ /Regularly send line list to CDZ	If there is a case, RCS conducts active surveillance and IEC activities	Inform patient of lab results	
District	Pick up CSF, send to reference lab with surveillance form Perform rapid diagnostic tests Send CSF to national or regional laboratory Report results to CdZ	Notify CASE Regularly compile and send line list to CASE Aggregate data send to CASE Develop weekly epidemic curve Inform lab results to reporting clinician at health facility	If there is a case, CdZ supports health facility with active surveillance and IEC activities If there is an outbreak conduct mass immunisation campaign targeting the entire district	Weekly surveillance visits to 2 to 3 health facilities Monthly meetings with clinicians at health facilities	
Region	Perform diagnostic tests (Regional reference laboratory) Send confirmed cases to national laboratory	Regularly report aggregate data to national level Aggregate data send to SSEI	If there is an outbreak RRT must support and evaluate affected district(s) surveillance and laboratory activities.	Weekly surveillance visits to 2 to 3 health facilities	Monitor epidemic trends and thresholds
Central	Perform diagnostic tests Report results to national epidemiologic surveillance team Ship 15% of positive specimen to Oslo, Norway for quality assurance and control (QAQC) and molecular analysis	Regularly report aggregate country data to WHO and country partners Create weekly map showing the alert and epidemic districts Analyse laboratory results by district and for the country	If there is an outbreak RRT must support and evaluate affected district(s) surveillance and laboratory activities.	Biannual QAQC for some labs and regional laboratory Biannual surveillance and laboratory supervision visits Weekly surveillance bulletin	Monitor the circulation, distribution and evolution of Nm serogroups and other pathogens. Monitor the antibiotic resistance profile of Nm. Monitor the circulation, distribution and evolution of Nm strains (by sequence-typing) Evaluate control strategies

6.3 Meningitis surveillance by IDSR function

Case detection

The case definitions for a suspected adult and infant case of meningitis used in Chad are:

'Any adult with acute onset of fever (> 38.5 ° C or rectal temperature of 38.0 ° C axillary temperature) with one of the following signs: neck stiffness, neurological disorder or other meningeal signs.'

And,

'Any infant with sudden onset of fever (> 38.5 ° C or rectal temperature of 38.0 ° C axillary temperature) with one of the following signs: neck stiffness or soft neck, bulging fontanelle, cap look, convulsion or other meningeal signs' (192).

Suspected cases were detected mainly through patients presenting at **health facilities**. The MSP policy was that a doctor must perform a lumbar puncture at the health facility and send the sample to a district laboratory. However, due to a shortage of doctors, the health facility *Responsible* (i.e. Manager), which were mainly nurses, had been granted permission to perform lumbar punctures at the health facility. Many health facilities referred suspected meningitis patients directly to the district hospitals for lumbar puncture, as their staff did not have the necessary skills.

Information, education, and communication (IEC) activities were also part of case detection activities. These were conducted as early morning sessions to inform the community, of the signs and symptoms of notifiable diseases, including meningitis.

Laboratory confirmation

The CSF was generally sent from the health facility in a trans-isolate (TI) medium, to be tested at the **district laboratory** for diagnosis using cytology, gram staining and/or by a

rapid latex test (Pastorex [(Bio-Rad rapid agglutination test))). If there was no functional district or regional laboratory, the CSF sample was sent directly to the national reference laboratory in N'djamena. This occurred in 14% (n=3) of the 21 health facilities. According to the national meningitis treatment protocol, patients should receive antibiotics immediately after a lumbar puncture. However, 57% (n=12) of health facilities in the sample reported that they often treated suspected cases with antibiotics before the patient proceeded to the district hospital for the lumbar puncture procedure.

The regional laboratory in Moundou was equipped to perform all of the tests at the district level and could as well grow a culture from the specimen to identify the causative agent. They also performed tests of sensibility to antibiotics, and serological tests to determine the serogroup. However, it did not perform any meningitis-related analysis in 2012 due to lack of numerous supplies, including gram stain kits and rapid latex tests. **The national laboratory** is currently equipped to perform all of the tests at the district and the regional levels as well as DNA extraction followed by gel-based PCR to confirm diagnosis.

Reporting and analyses

In Chad, most districts employ enhanced surveillance alongside weekly routine EPI disease surveillance; suspected cases were reported even when there are no cases, which is referred to as “zero” reporting. The health facility *Responsable du centre de santé (RCS)* initiates reporting of suspected meningitis cases by notifying their respective CdZ or zone focal point. Epidemiological data at the health facilities are recorded in clinical registers¹; weekly data counts are usually transmitted to the CdZ by text message. Each month, total suspected cases are counted from the register and then

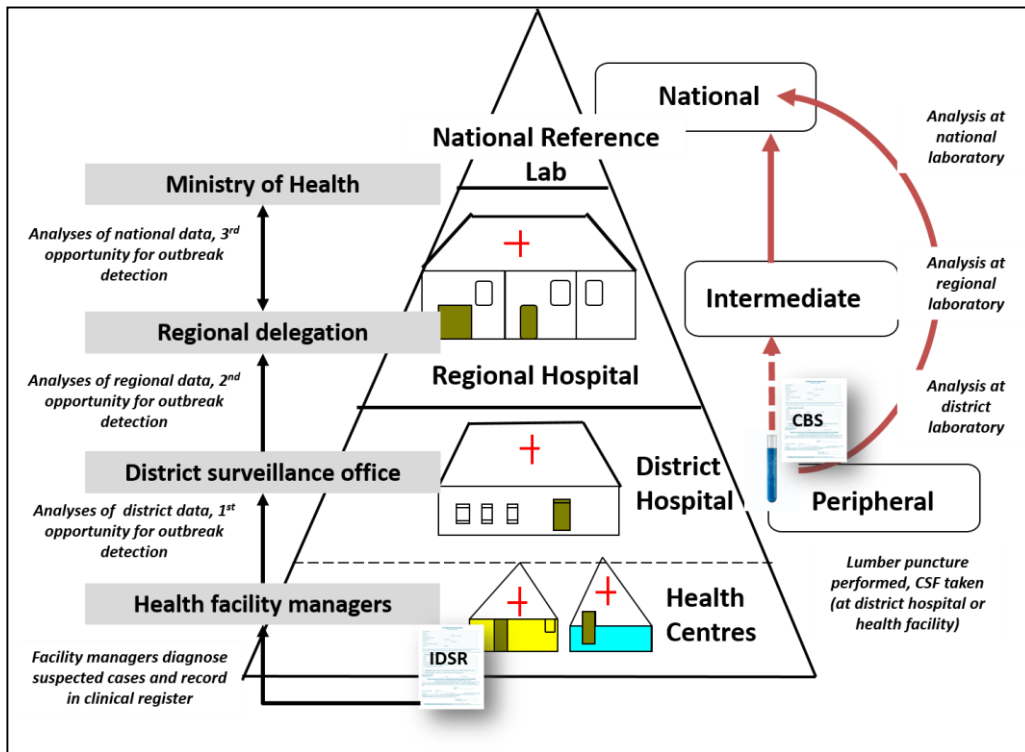
¹ Availability and utilization of clinical registers varied within the study sample. Most times a generic notebook or programme specific (i.e. mother and child) register was used and discarded after some months. It was difficult to keep these records due to lack of archival fixtures for storage and protection of documents.

transferred to a standardised paper forms, this was occurring at 90% (n = 19) of the sample Health facilities. Typically, these forms were sent via a local courier to the CdZ at each month's end. The **CdZ** was responsible for obtaining data from all health facilities within his/her district. In some instances, the CdZ travelled to the health facility and collected the paper forms. The CdZ sent the data to the regional surveillance lead (i.e. CASE) by weekly texts and by monthly courier.

The **CASE** for each region collates the data from the multiple CdZs throughout his/her region and then reviews the data of each district for data quality (e.g. duplications, completeness, and inconsistencies). If there were any issues with the data, the CASE would contact the CdZ immediately. Once resolved, the CASE aggregates and analyses the data for the district and sends a report to the central level (i.e. SSEI) each week by phone and each month by courier or by email. At the regional office, 100% of the CASE's in this study used a laptop to summarise data and enter it in an Excel sheet. Furthermore, each month all CASE's used a standard MS Word form to report regional data to the central level. No quality assurance measures (e.g. double data entry) were systematically occurring.

At the central level, the **SSEI** data manager reviews and aggregates data from all regions, and then presents a national summary of all integrated diseases at the weekly CTNLE meetings. The summary includes a weekly and running sum of case and death counts, case fatality rates, and districts with reported suspected cases for each disease. Additionally, an epidemic trend graph is generated for each disease displaying the epidemiologic weekly disease trends from the current and previous year. Data is managed in a national Microsoft Excel and presented as a weekly PowerPoint presentation. Finally, each week, the SSEI data manager sends this information to the **WHO Inter-Country Support Team** in Ouagadougou, Burkina Faso. Figure 6.2 depicts the flow of data. This diagram was constructed post-field visit.

Figure 6.2 Chad meningitis surveillance case detection, reporting and analysis system



IDSR: Integrated disease surveillance and response [form]

CBS: Case-based surveillance [form]

Dotted red line symbolizes that this pathway was not observed in 2012 in the study districts, but participants reported the occurrence in previous years.

Supervision and feedback

Following receipt of a CSF specimen by the laboratory, there are specified time limits for results to be reported to the facility that sent the sample(s). To inform adequate response efforts, CdZs should receive the results within **48 hours**; regional delegations within **five days**; and national level focal points within **seven days** upon reception of the sample. In actuality, these response times were rarely to never followed.

Feedback was predominantly provided in the form of supervision of sub-national level surveillance activities. CdZs and CASE's were responsible for providing support to health centres and to oversee implementation of surveillance procedures as a system

quality check. Table 6.3 describes the prioritization method used to support health facilities. Additionally, the national surveillance and laboratory cadre had the responsibility for undertaking field visits to selected health facilities and district and regional surveillance offices at least **two times per month** if resources are available. Due to lack of resources, such a visit occurred once in 2012.

There is no written feedback medium (e.g. surveillance bulletin). So other than the rare supervision visits, peripheral health staff relied on communication from the national laboratory focal point through district lab personnel to discover the results of suspected cases. It was not clear why there is no other designated focal point to relay this information.

Table 6.3 Health facility supervision visit schedule

<p>Priority 1: Receives supervision once per week</p>	<ul style="list-style-type: none"> ▪ Health facility has a high frequency of disease cases, a large population (i.e. urban zone), or has identified at least one case of polio. ▪ Responsible is new (i.e. has been working at the health facility for less than one year.)
<p>Priority 2: Receives supervision twice per month</p>	<ul style="list-style-type: none"> ▪ Health facility is in a rural and low disease risk area.
<p>Priority 3: Receives supervision once per month</p>	<ul style="list-style-type: none"> ▪ Low frequency of reported cases and health facility is in a rural area. ▪ <i>Responsible</i> is experienced and has been at health facility a prolonged period of time.

Case investigation

Active case detection or search: About half of the health facilities in the study performed regular active case search in some form. This is a targeted surveillance strategy where the health staff reach out to the community and should regularly screen the population to find cases of meningitis or other health conditions. This can occur during weekly visits to villages for information, education, and communication forums

on a priority disease as well as door-to-door monitoring for clinical signs of disease in the population. This surveillance method is a strong component of IDSR and underscored in many programmes, including the polio eradication initiative.

Follow up case investigation: Most of the health facilities in the study performed follow up case investigations. This is the active case search that occurs after a suspected case is confirmed by laboratory analysis. The *Responsable* or other health staff goes to check the health status of the suspected case and also assesses close contacts and other possible populations exposed to the infectious person(s) (e.g. schoolmates or church congregations). If more cases are found, a vaccination campaign, quarantine, or other intervention methods are employed to contain the outbreak and interrupt further transmission. This method is standard surveillance practice and also included in the national protocol of Chad.

Response

For meningococcal meningitis, the WHO guidance on alert and epidemic thresholds for enhanced surveillance is shown in Table 6.4. If there are enough cases in a district to meet the alert threshold, detailed data are recorded on a line list. CSF samples are sent to the national laboratory for confirmation and serotyping. If the epidemic threshold is reached, mass vaccination campaigns are normally implemented at the district level using the appropriate polysaccharide vaccine, targeting 2 -29 year olds. At this point, approximately **5-10 CSF specimens** per week are collected and sent to the national reference laboratory. This was done for both enhanced and case-based surveillance strategies.

Table 6.4 Alert and epidemic thresholds for meningococcal meningitis

Population size	Alert thresholds	Epidemic thresholds
Above 30,000	Attack rate of five cases/100,000 persons per week	Attack rate of 15 cases/100,000 persons per week
Less than 30,000	Two cases in one week or an increase in cases compared to previous non-epidemic years in district populations	Five cases in one week or the doubling of the number of cases over a 3-week period

Source: WHO Regional Office for Africa (49)

6.4 Conclusion

The Chad meningitis surveillance system is situated within IDSR system. The key informants provided a scheme of how the system works as well as where it deviates from national protocol and standard operating procedures. In general, the CDSS operated as both a shared system in some areas and as multiple parallel, disease-specific systems in other areas. Regular case reporting to the next level was systematic and operational across all of the diseases. In other areas, such as active case search, response and feedback, processes and resources from established systems, such as polio, were not leveraged for meningitis surveillance. While several of the processes outlined in the national standard operating procedures were adhered to, there were areas that could not be properly facilitated. One important example of this was feedback of final case status of analysed CSF. Overall, the absence of written dissemination methods as well as automatic feedback mechanisms driven by trained and dedicated personnel were hindrances to several surveillance system processes.

7 Performance assessment and observations

This chapter presents the performance assessment of CDSS in Chad, with an emphasis on meningitis and IDSR activities. Our evaluation examined the resources needed to perform surveillance functions and activities. Also presented here are descriptive observations of the study sites; these notes intend to supplement performance indicators and elucidate study results. Recommendations for modifications to the implementation strategy, planned activities, and resource allocations, are likewise presented in this chapter.

There are four main results sections stemming from this study component: Section 7.2.1 provides an overview of the study sample and Section 7.2.2 briefly presents the contextual factors for the study regions. Section 7.2.3 discusses the performance findings and observations at sub-national study sites. Section 7.2.4 appraises the overall quality of the meningitis surveillance and IDSR in Chad to inform the “best-fit” (i.e. upgraded) strategy decision through a critical review of selected surveillance characteristics¹. The chapter concludes with a discussion of methodological issues and summary of findings.

¹ Chapter 9 describes the upgraded system cost and components, which were derived as a result of the performance and quality assessments presented in this chapter.

7.1 Methods

7.1.1 Definitions

The following definitions were applied for this assessment:

Performance

Performance was defined as the system's ability to achieve selected standard programmatic indicators for meningitis and IDSR. The categorisation of performance is further quantified in the next *Assessment of Health facilities and districts* subsection.

Standard vs. supporting indicators

Indicators from authoritative (e.g. WHO, CDC) and other published sources were defined as "standard indicators". Other indicators were developed by the study team and were largely derived from best field practices. There are referred to as "supporting indicators".

Contextual factors

In public health research, 'context' has several definitions; the following definitions are helpful to guide understanding of this concept as used in this thesis.

- a. *The social, organisational, and political setting of a public health intervention (193); and*
- b. *the external factors, institutions, interests, and ideas that influence decision making (194).*

Likewise, contextual factors could be defined as the relevant characteristics or features of such entities. While traditional programme evaluations consider assumptions or context in relation to the programme, I found that existing CDSS evaluation frameworks did not systematically capture or analyse contextual factors. While this isn't the central theme of my research, I decided to expand the thesis to see if it would be useful in aiding programme managers with prioritisation or discover additional

gaps and impediments. My *a priori* theory is that there are palpable obstacles to disease surveillance systems, especially in a low-income settings, which affect the execution, ability, and ultimately the performance of public health practice. Further, contextual factors are key to explaining the external validity of our study and the WPA framework, as it will describe the extent to which the results can be generalised in other settings.

Few frameworks for capturing contextual factors for public health systems exist; however, there is considerable guidance in health policy development and evidence-based policy decision literature (193-198). Inspired by these studies as well as social ecological approaches which provide well-founded models for examining such factors (199), I decided to focus on the influence of multiple “environments” on surveillance systems. I integrated the contextual factor component as a policy analysis component of the WPA. In the present study I focus on the context levels of ‘practice’, ‘organisation’, and ‘environment/infrastructure’ with the intent to provide more clarity and understanding of potentially critical factors that may impact meningitis surveillance performance and cost.

7.1.2 Assessment of health facilities and districts

The performance areas targeted in this assessment were the sub-national level activities for detection, confirmation, reporting and analysis activities. A total of 31 indicators were identified or developed to assess the performance and to more accurately estimate the incremental costs of improving the surveillance system in order to comply with operational standards. These were incorporated into the data collection questionnaires. The indicators were selected or developed if they were: 1) reliable, 2) obtainable, and 3) allowed us to provide improved estimates of cost of a well-functioning system.

Indicators that were derived from authoritative guidance on meningitis surveillance include those from the Paediatric Bacterial Meningitis (PBM) surveillance network

assessment strategy (189) (which was expanded to include blood cultures for pneumonia and now goes by the name, Invasive Bacterial Vaccine Preventable Diseases Laboratory Network [IB-VPD]) (200). The IB-VPD network aims to provide participating countries with local data to guide new vaccine introduction. A table of these indicators are located in the Appendix 3.

Detailed observations

In order to determine why certain activities were working or not working at the sub-national level, a work process tree (which was incorporated in the study questionnaire) was generated from the Chad PHSS description to guide detailed observations, which identified the capacity, behavioural, and organisational factors that hampered or helped the execution of each task. Table 7.1 provides the work process trees of the necessary meningitis surveillance tasks that should occur according to surveillance activity.

Table 7.1 Work process analytic summary of expected surveillance tasks at sub-national levels

Tasks at health facility level	<p>At the health facility these main activities should occur to detect and register a case of meningitis:</p> <ol style="list-style-type: none"> 1. Sick person arrives at the health facility 2. Health facility staff clinically diagnose sick person with meningitis 3. Health facility staff records patient details into the clinical register and onto the tally sheet 4. Health facility staff refers patient to district hospital or performs lumbar puncture him/herself 5. Health facility provides antibiotic treatment to patient 6. Health facility staff follows up patient and other close contacts <p>Reporting at the health facility requires the following activities:</p> <ol style="list-style-type: none"> 1. RCS completes and submits a weekly and monthly reporting to CdZ by the appropriate means at the designated time 2. RCS completes a case investigation form for each suspected case of meningitis and sends it to district lab with accompanying CSF specimen (CBS districts only) 3. RCS reports number of suspected cases that were referred to district hospitals, if applicable 4. RCS completes an on-going monthly line list of suspected meningitis cases and keeps the list at health facility for potential case investigation activities.
Tasks at laboratories	<p>District and national laboratories are primarily responsible for confirmation of the causative agent and reports (feedforward and feedback) to the appropriate levels, this requires the following activities:</p> <ol style="list-style-type: none"> 1. Laboratory staff receive the CSF from the health facility (sometimes via the CdZ); 2. Laboratory staff performs appropriate analysis and provides result; 3. District laboratory completes appropriate sample collection form; 4. National laboratory provides results to district laboratory; 5. District laboratory provides results to CdZ 6. National laboratory sends results to WHO collaborating centre for further analyses and quality control.

Tasks at district and regional levels	<p>The regional (CASE) and district surveillance officers (CdZ or Point Focal) are the direct Ministry of Health authorities that are both directly responsible for supporting their assigned health facilities in their area of responsibility (e.g. zone or region). Surveillance at these levels require the following activities:</p> <ol style="list-style-type: none"> 1. Provide periodic supervision to health facilities, which includes supplying necessary materials; 2. Obtain weekly and monthly [suspected] case counts; 3. Retrieve specimen for certain diseases and deliver to district laboratory and in some cases, send to national laboratory; 4. Complete line list and develop trend of suspected cases for outbreak-prone notifiable diseases (e.g., meningitis, polio); 5. Report aggregate case counts to next higher level (i.e. regional or national); 6. Support health facilities in response and active case search activities; 7. Receive and report laboratory results and provide to district laboratory and health facilities; 8. Provide periodic surveillance trainings to health facilities and district surveillance officers (CASE only).
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Final list of indicators

Many researchers have difficulties collecting data in resource poor setting due to issues of access and availability – we had this issue as well. We found a lack of availability of paper or electronic archived surveillance data at the health facilities and in some cases at the office of the CdZ. Several indicators could not be assessed due to missing data or because activities related to the indicator were not practiced in Chad. Moreover, available data were mostly collected at the national level. Very limited data were available from the study districts and the health facilities. Consequently, only 12 of the 31 surveillance performance indicators included in the study protocol could be collected. The 12 indicators are summarised in Table 7.2.

While the inability to collect important data was a serious limitation, all of the original 31 indicators were useful in constructing the recommended operational standard, which will be discussed in Chapter 9.

Table 7.2 Meningitis surveillance performance indicators collected in the study

Indicator	Target	Surveillance functions
1. Percent of staff that know the case definition of meningitis*	NA	Detection
2. Percent of health facilities with case definition of meningitis displayed*	NA	Detection
3. Average number of staff at health facilities*	NA	Detection
4. Average length of employment of professional staff at health facility*	NA	Detection
5. Average length of employment of district surveillance lead*	NA	Detection
6. Percent of probable bacterial meningitis cases with a known outcome recorded	90%	Laboratory confirmation
7. Percent of suspected pneumococcal meningitis cases identified*	NA	Laboratory confirmation
8. Percent of CSF contamination	≤ 5%	Laboratory confirmation
9. Percent of CSF specimens forwarded to the reference laboratory for PCR and genotyping	20%	Laboratory confirmation
10. Proportion of districts in which a current line graph of weekly trend analysis of meningitis is available	80%	Reporting and analysis
11. Percent health facilities that report meningitis data on time to the district (weekly)	80%	Reporting and analysis
12. Number of trained staff in surveillance methods*	NA	Reporting and analysis

* Denotes supportive indicators created by research team

Moreover, we considered the influence of certain contextual factors, which emerged from interviews and observations, on ability to conduct surveillance activities.

Assessment of overall system quality

The surveillance system was further evaluated by assessing selected surveillance attributes to qualitatively compare surveillance systems in the WHO Meningitis Surveillance strategy document (80). Since the objective of our study was to provide

information to assist Chadian decision makers choose an optimal strategy with consideration to their capacities and needs, I decided that looking at quality attributes of the entire system was an appropriate way to understand supplemental performance data and a useful way to depict the current surveillance system. Additionally, these categories of interests are commonly promoted by other authoritative sources (31) as practical considerations for national surveillance systems. This assessment is based on information gathered through the study and by central staff and partners.

In the analysis, the surveillance attributes of interest (informativeness, sustainability, resource intensiveness, flexibility, and simplicity) were evaluated by core function activities. An ordinal scale to understand the current needs in terms of desired complexity of the system (i.e. surveillance strategy objectives) and resources needed to support a sustainable system. In the scale, a score of '4' represents the optimal situation and a score of '1' represents the least optimal situation for the category of interest. The categories are described in Table 7.3. The results were then examined in relation to the *Epidemic meningitis surveillance in the African meningitis belt: Deciding on the most appropriate approach* guidance document (80) (Table 2.8 [p57] and Table 2.9 [p58]) to inform the feasible operational standard used for the upgraded system model. In this document resources need for each recommended surveillance approach are plotted on spider charts. These visualization supports are intended to help countries decide on the most appropriate strategy. Likewise, at the end of section 7.2.3, I also construct a spider chart of the Chad meningitis surveillance system based on the system quality assessment results to inform a best-fit approach.

Table 7.3 Analytic framework to qualitatively assess existing surveillance functions

Categories of interest	Description	Scale
Informativeness	The amount of information generated by the system and what we learn from it. This feature does not account for the quality or precision of the data.	(1) Weak (least optimal) (2) Moderate (3) High (4) Very high (optimal)

Sustainability	The likelihood that the system can be maintained in the long term.	(1) Not at all (least optimal) (2) Somewhat (3) Moderately (4) Very (optimal).
Resource-Intensiveness	Human, financial, and logistical resources needed to setup and run the system	(1) Very high (least optimal) (2) High (3) Moderate (4) Small (optimal)
Flexibility	The ease with which the system and facility can be adapted to integrate into other systems.	(1) Not flexible (least optimal) (2) Slightly flexible (3) Flexible (4) Very flexible (optimal)
Simplicity	Overall functioning of the system	1) Very complex (least optimal) (2) Relatively complex (3) Simple (4) Very simple (optimal)

7.2 Results

7.2.1 Description of sample

In total, 47 structured interviews with 53 interviewees¹ were conducted to assess surveillance performance. The sample included RCS (n=21), laboratory managers (n=9), CdZs and/or district focal points (n=12), CASE (n=4), central level MSP/SSIE staff (n=4) and partners (n=3). The study team jointly performed all interviews at the sub-national level; while I alone interviewed or had discussions with central level and partner organisation participants. All but one of the sub-national participants were Chadian natives; the exception was a Spanish RCS. The partner sample included two American and one Cameroonian national.

7.2.2 Health facility contexts

¹ At two district offices and one laboratory more than one participant was interviewed.

Table 7.4 provides a summary of common factors noted to potentially influence the performance of the health facilities. Practice factors were most proximal to the health facilities daily function. Understanding the population demands, workforce capacity, and capability to perform surveillance duties could provide an explanation to strong, weak, or missing surveillance functions. The environmental/infrastructure factors include characteristics that affect surveillance activities like follow up or community engagement. These factors could also explain certain surveillance indicators, such as *number of detected cases*, by providing information about environmental realities that could hamper health facility access and utilisation. The organisational factors appeared as underlying economic initiatives or programme policies that provided structure and facilitated resources to and support at the health facilities. One example of this was the Results-based Financing Programme. This World Bank funded pilot programme supported select districts in Chad from 2011-2013 and focused on improving mother and child outcomes; though, several objectives were focused on improving and incentivising clinic management. I observed that the health facilities that participated in this programme were ostensibly cleaner and more organised. Figure 7.1 juxtaposes two health facilities –one that participated in the pilot and one that did not.

Factors such as ‘office organisation/ storage capacity’, emerged through my observations of how certain structures inhibited or facilitated surveillance activities. In the case of office organisation and storage space, I noted that most of the health facilities lacked structures such as files and desk, and therefore could not store surveillance forms or keep copies of reports. Table 7.4 also shows the heterogeneity of the health facilities within and between regions. While we were not able to include a comprehensive collection of contextual factors, the factors displayed here could contribute to a further systematic investigation of other contextual factors as well as an analytical understanding of association and distribution across health facilities.

Figure 7.1 Two health facility exteriors to highlight impact of Results-based Financing pilot



Moriku CDS (Guelengdeng district), on the top, did not participate in the Results-based Financing Programme pilot. Kabo 8 (Moissala district), the health facility on the bottom, did participate in the Results-based Financing Programme pilot.

Table 7.4 Summary of select contextual factors of health facilities across study regions, 2012

		Region				
		N'djamena (n = 3)	Mayo-Kebi Est (n = 6)	Mandoul (n = 9)	Logone Occidental (n = 3)	
Practice	Population	< 10,000	1	1	0	0
		10,000 – 20,000	1	4	7	1
		> 20,000	1	1	2	1
	Number of staff	1-2	1	4	7	0
		3-4	0	2	2	0
		> 5	2	0	0	3
	Access to vehicle ^b	Yes	0	3	3	0
		No	3	3	6	3
	Nomad population	Yes	0	0	3	1
		No	3	6	6	2
	Office organisation/ storage capacity	Poor		1	2	0
		Average	ND	1	2	1
Good			1	3	2	

			Region			
			N'djamena	Mayo-Kebi Est	Mandoul	Logone Occidental
			(n = 3)	(n = 6)	(n = 9)	(n = 3)
				ND = 3	ND = 2	
	Supervision in the past 3 months?	Yes	1	5	6	2
		No	2	1	1	1
					ND = 2	
	Community supported? ^a	Yes	3	6	8	3
		No	0	0	1	0
Environment/ Infrastructure	Type of facility	Urban	1	2	2	2
		Rural	2	4	7	1
	Road type	Paved	1	1	1	1
		Gravel	0	0	2	1
		Dirt	2	5	6	1
	Availability of public transport	Bad	3	5	7	0
		Medium	0	1	2	2
		Good	0	0	0	1
	Distance to district hospital	≤ 5 km	0	2	2	2
		6 -15 km	3	0	1	0

			Region			
			N'djamena	Mayo-Kebi Est	Mandoul	Logone Occidental
			(n = 3)	(n = 6)	(n = 9)	(n = 3)
Organisation	Distance from health facility	16 -25 km	0	1	3	0
		26+ km	0	3	3	1
	Flooding impacted health facility services in 2012?	Yes	3	3	4	2
		No	0	3	5	1
	Has a guinea worm programme ^c	Yes	0	3	6	0
		No	3	3	3	3
	Participates in the results-based financing programme ^d	Yes	0	3	3	0
		No	3	3	6	3
	Financial support for health facility	Public only	3	3	2	1
		Religious	0	1	4	1
Private ^e		0	2	3	1	

a Community supported refers to financial and volunteer support from community to health facility

b Refers to access to ambulance or motorbike for surveillance activities

c The ongoing Carter Centre Guinea worm intensive surveillance programme in select districts in Chad

d In Chad this programme is called *Financement Base sur les Resultats*.

e Private includes local and international Non-governmental organisations

ND: No data available or data missing

7.2.3 Performance of sub-national and laboratory sites

Health facilities (n = 21)

Detection and registration of suspected meningitis cases

- Percent of health facilities with case definition of meningitis displayed.

Ten out of 21 (48%) of health facilities had a paper copy of the case definition for bacterial meningitis. This is an important indication of precision in detecting suspected meningitis cases. In eradication/elimination disease programmes, like polio and measles, it is recommended that 80% of health facilities have a posted case definition. Hence, this indicator was not met.

- Percent of staff that know the case definition of meningitis.

Participants were asked to retort the clinical signs or a suspected case of meningitis. Out of 34 health staff asked, 33 (97%) correctly responded with the case definition of bacterial meningitis.

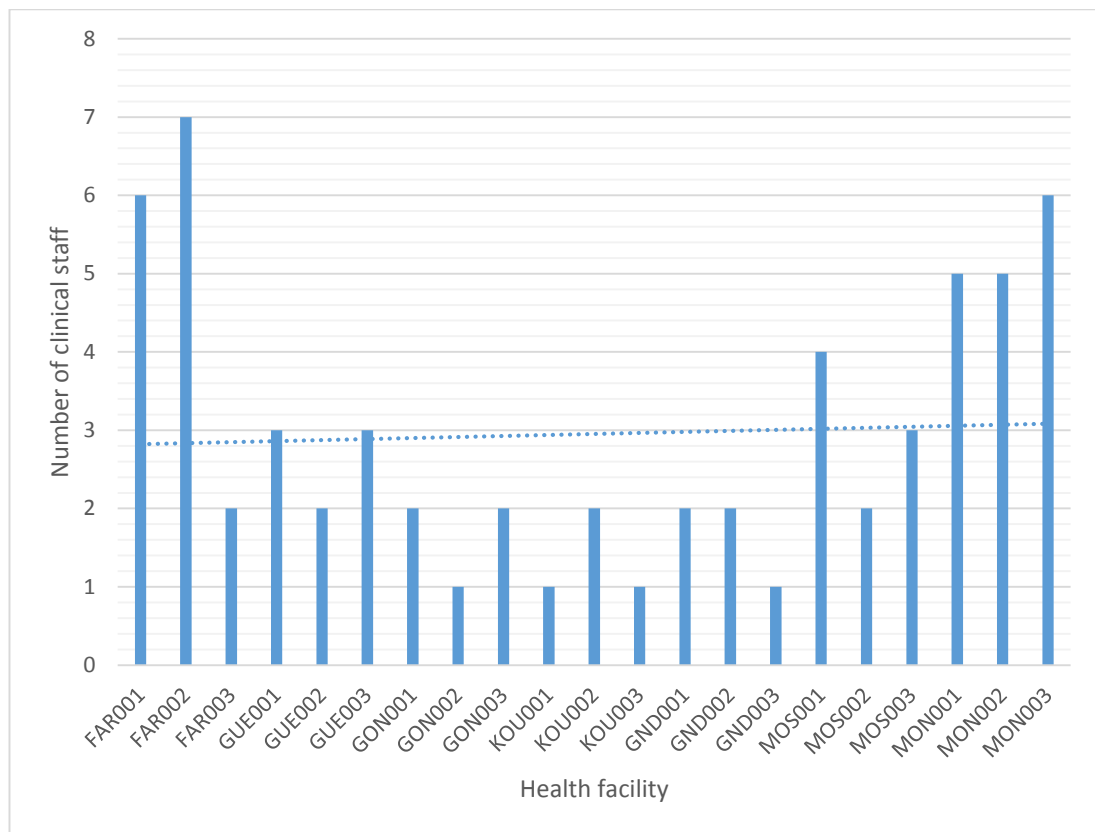
- Average number of staff at health facilities.

There was an average of three clinical staff in each health facility (range 1-8). This represents staff that were specifically involved in diagnosis of meningitis. The distribution of this indicator is presented in Figure 7.2 below.

- Average length of employment of professional staff at health facility.

Across the 21 health facilities, the average employment of clinical staff relevant for meningitis diagnosis was 2.6 years. The average employment per facility ranged from 8 months to 5 years.

Figure 7.2 Distribution of clinical staff* across study health facilities (n = 21)



* Clinical staff defined as persons who had completed diploma programme or specific professional training for the position.

Observations on case detection and reporting at the health facility

The actual proportion of the Chadian population that will go to the health facility when they become ill is not well known, nor was it captured in this study. However, most RCS reported conducting multiple outreach clinics per month for immunization activities, though 43% said they did not have adequate resources (e.g., transport, materials) to support these activities (n =9). Additionally, every health facility reported conducting information education and communication (IEC) regularly. I observed several of these short educational sessions that centred on diseases with high-incidence in the particular season. IEC was conducted usually in the early morning shortly after the health facility opened and mostly to an audience of women and children. Finally, 100% of participants reported a community organisation or volunteer network associated with the health facility, the average number of volunteers was 30 (range, 2 –

132; SD = 28). Chad has a history of local supported and managed health facilities and the collaboration often consisted of regular meetings where health staff could include committee members and volunteers in health activities, such as active case searches. Most of the health facilities did not have any reliable documentation to support that these activities had happened for meningitis specifically, but it was noted that districts which had a strong Guinea worm programme had a stronger and more structured collaboration between community and health facility. These efforts are useful in extending the reach of the clinic and increasing the probability to detect cases.

Some reported perceived barriers for the community to access the health facility, included far average distances from villages to health facilities, flooding in the rainy season (71%, n = 15), and poor public transport (66%, n =14). Most sick persons walk to the health facility or are carried (bicycle, push cart) by relatives in order to get there (See Table 7.5) It is hard to imagine that people would go to such efforts for milder symptoms, and so several cases may never reach the health facility. Public transportation, namely a *clandoman* (motorcyclist) was accessible for 33% health facilities at an average cost of CSF 2733 (US\$ 5.50) for a return trip (n = 7).

Table 7.5 Means of transporting meningitis patients when referred to the district hospital

Type of transport	Number of health facility staff reporting this method* (n=21)
Motorbike	18
Chariot (Wagon pulled by an animal)	14
By Foot	10
Bicycle	7
<i>Pusse-Pusse</i> (Cart pulled by a person)	3
By Vehicle	3
Family or neighbours	2

*Most interviewees named multiple means

In general, the observations and interviews at the health facilities revealed that staff were very aware of the health events that affect their communities. They also had a

good understanding of the national notifiable diseases and associated specimen for collection. Most health facilities had staff that were very knowledgeable about the case definition of meningitis and confident in the recent vaccination campaigns—though, this led to the belief that all meningitis was gone. Most were not aware that although NmA had been significantly reduced, other pathogens and serogroups exist. This may have affected their diagnosing pattern and indeed, some RCS disclosed that they were now less mindful of presumptive meningitis cases once someone presented with febrile illness during meningitis season. This finding was mainly observed at districts employing partial case based surveillance (i.e. Gounou-Gaya, Guelengdeng and N'Djamena Nord). Additionally, the lack of a displayed case definition was troubling, as this is a fail-safe visible reminder to the health staff of considering meningitis as a possible cause in persons presenting with a febrile illness and other meningeal signs.

There was a universal lack of understanding regarding what persons could or should conduct the lumbar puncture; there was also no meningitis SOPs observed in most health facilities. Several RCS in the ES and PCBS districts reported that there was a national policy that only doctors could perform lumbar punctures, meaning they refer patients to district hospitals where doctors are present. Yet, in many of these health facilities there was no system to ensure patients with suspected meningitis could get to a doctor (who were generally only available at the district hospital). The average distance to the district hospital was 18 km (one-way) (range, 1 to 45; SD = 15.26), and public transportation was limited. The reported average for this distance was 62 minutes (range, 10 to 120; SD = 33.20). This time was thought to be doubled during raining season. It can be assumed that sick persons could decide to go home instead of exerting themselves to get to the district hospital for proper diagnosis. In Moissala, the only district doing exclusive CBS, patients were referred directly to the district and it was ensured that patients arrived to hospital for the lumbar puncture procedure and treatment. All transport costs for patient and specimen transport in Moissala were paid by MSF. However, in nearly all the other districts, health facility staff reported starting antibiotic treatment before performing a lumbar puncture or referring the patient to the district hospital. While this is against protocol it could improve the likelihood of recovery and transmission if patients do not pursue further tests and treatment.

There was a problem of lack of quality clinical registers across health facilities. This was very concerning because the register is the primary data source for epidemiological information. The MSP sparingly provided registers throughout the year (this was validated by CdZ). The official government monthly registers were substandard—they were thin paper-covered ruled notebooks containing approximately 100 pages. However, there were no gridlines or pre-filled fields, so the RCS write by hand gridlines and included variables, such as name, date of birth, sex, village, etc., resulting in inconsistency on data fields used across the health facilities—even within the same district. Also, since registers were not provided as needed (i.e. one notebook/register per month), health facilities purchased their own or use other designated programme folders. An example of the government register and a makeshift notebook register can be found in Figure 7.3.

There was also great variation in how the register and EPI tally sheets were used. Most of the RCS filled in the register during the patient consultation or directly after. It seemed that many of the RCS or attending staff did not utilize the tally sheet simultaneously while receiving and registering patients and so many times this was done just at the point of weekly reporting (which defeats the purpose as a quality-check mechanism). This could be due to trying to avoid having too many data tools on oft-cluttered desks (Figure 7.4). A more inclusive register could be offered that includes a tally sheet—this would better facilitate more accurate count of suspected cases.

Furthermore lack of archival ability, due to flimsy or missing registers and a lack of satisfactory storage units (e.g. desk, cabinets to protect filled data tools from the harsh Chadian environment and exposure), was noted in 10 out of 21 (46%) of health facilities. This resulted in the disposal of worn and often illegible registers. Generally, the earliest register available in the health facility was the one from the previous year (2012); though in some health facilities with high patient volume only the current year was available.

Finally, the ability to detect close contacts seemed very unlikely due to the burden of work that most RCS had to do. Large programmes that were more of a national priority, like polio, malnutrition, and guinea worm, and the Expanded Programme on

Immunisation required specific weekly activities, which were often meant to be exclusive—so a low level of integration was practiced and “add-on” activities for meningitis and other diseases were not observed. For instance, though our visits occurred during malaria season, I did not observe any shared activities for malaria and guinea worm; however, in some health facilities there were joint activities for malaria and malnutrition.

Figure 7.3 An official government register (l) and personal notebook register (r)

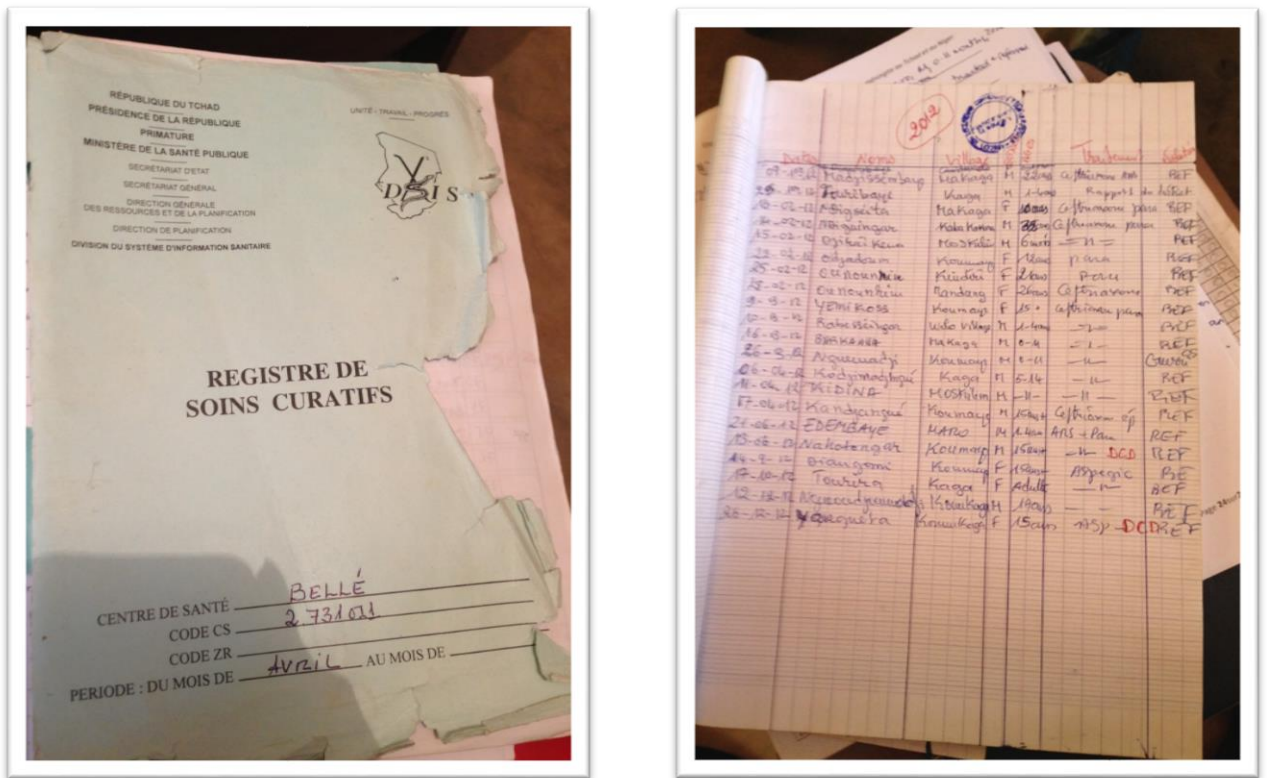


Figure 7.4 The Research Assistant interviewing a *Responsable* at his cluttered desk



Bessada centre de sante, Koumra

Reporting of meningitis surveillance data

- Percent of health facilities that report meningitis data on time (weekly) to the district

This indicator measures the key surveillance performance indicator of timeliness. CdZ's reported that 89% of total health facilities in their districts reported weekly surveillance data on time (n = 116). This indicator meets the 80% standard of health facilities that must submit reports on time to the district.

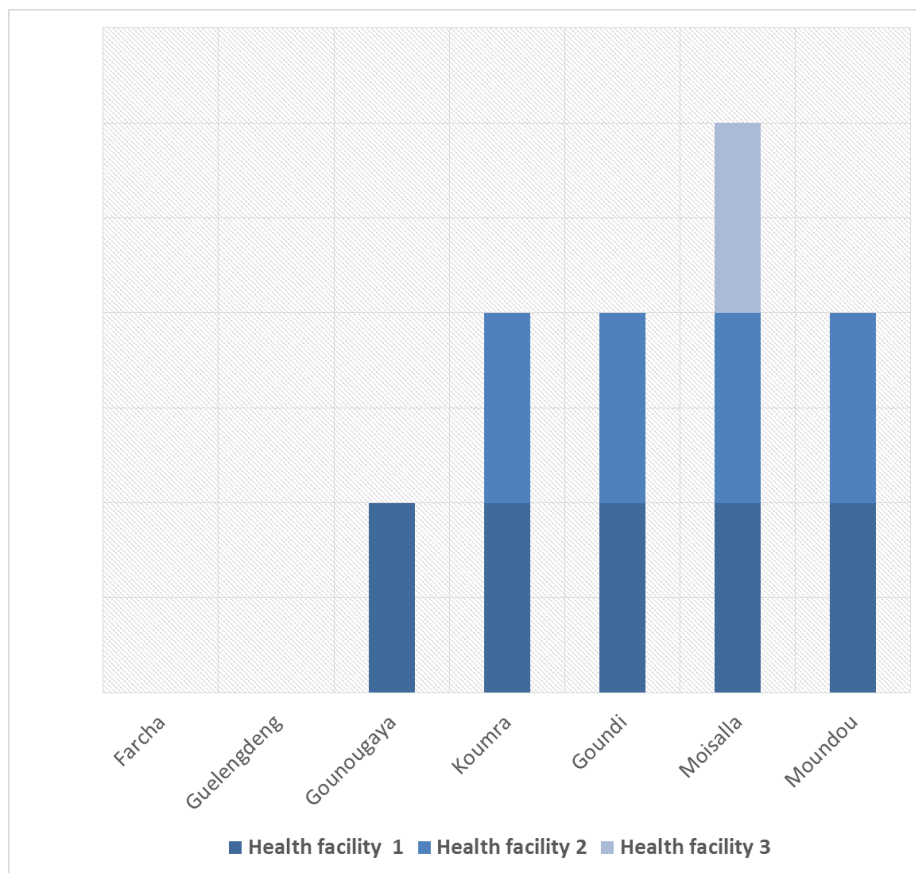
- Number of trained staff in surveillance methods

This supporting indicator was created based on literature that supports positive correlation between districts where surveillance-related staff receive training and more accurate and timely reporting of suspected cases (41). At each health facility, we asked if any of the current staff had ever received IDSR training. If yes, they were asked when the last time training was received.

Forty-seven percent of RCS reported that at least one health facility staff had ever received some type of IDSR training (n = 10). This training was either formal or on-the-job. Out of those ten, nine received training in 2012. Most of these trainings were provided at the district level and organized by the CdZ and the CASE. Staff in Moissala received training from the district as well as a training from MSF-France on case based surveillance.

Figure 7.5 shows the proportion of study health facilities in each district where staff received training in 2012.

Figure 7.5 Number health facilities that had staff who received surveillance training in 2012

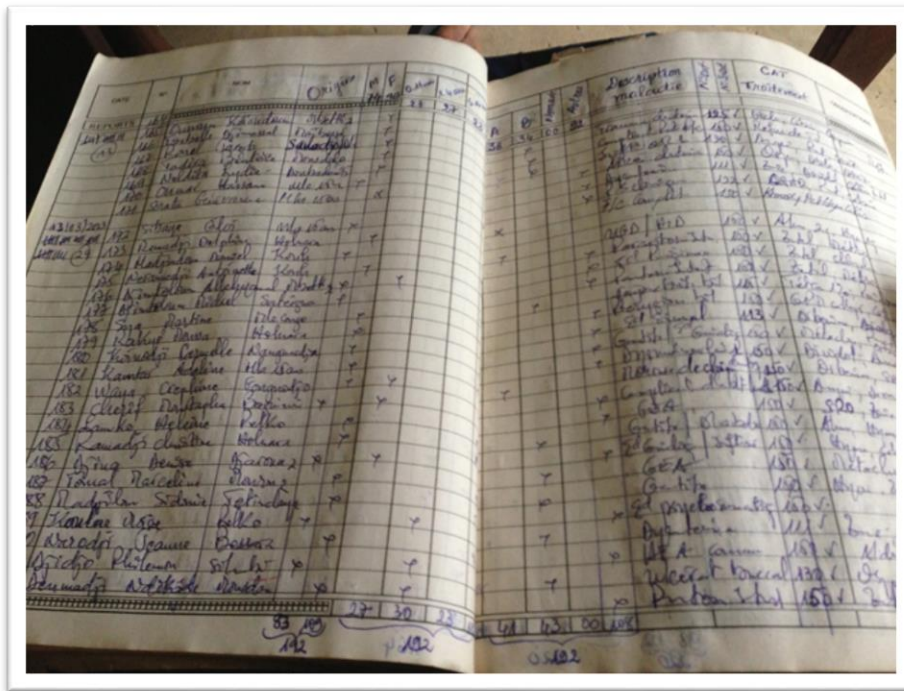


Observations on health facility reporting

Generally, health facilities in the same district were consistent with what day and by what medium they reported surveillance information. The CdZ designated which day that data were to be sent from the health facilities and he would usually call or visit a health facility if data were not reported in a timely manner. One participant reported faulty telephone network as a barrier to reporting on time, and two CdZs (29%) reported that they regularly travelled to health facilities to collect weekly data. Routine IDSR data forms were not available at every health facility. It appeared that many RCS simply retroactively tallied counts each week by reviewing diagnoses recorded in the register and then transmitted these counts to the CdZ by short message service (SMS).

This method is prone to error as handwriting was not always legible—in several instances the writer was not able to understand what they had written (Figure 7.6).

Figure 7.6 A handwritten register that is difficult to decipher



Standard MSP authorised routine reporting forms for weekly and monthly aggregate data and line list forms were found at most health facilities. In several instances, the original hand-written forms were not available at the health facility. This was partially attributed to the lack of archival structures. Additionally, the CdZ generally distributed a limited amount of reporting forms to the health facility (due to limited photocopy access and/or funds)—so it was not practical to handwrite two copies of each report (i.e., one to keep for health facility records and one to hand off to the CdZ). This finding casted doubt on high rates of timely reporting across districts, it also revealed potential issues in the reporting chain. Given the missing forms, it was not possible to track cases across health levels in order to test the functionality of reporting.

Three different formats for immediate case-based notification and sample collection forms were found at health facilities:

Form 1: An older version of the official MSP form, which includes two distinct pages; one for the case notification and one for CSF sample collection (Figure 7.7). This form was intended for integrated disease reporting and was issued by the SSEI. It included check boxes for nine other diseases.

Form 2: The latest official MSP form included in the annex of the WHO-AFRO SOPs for case-based meningitis. This form included check boxes for cholera, bloody diarrhoea or meningitis (Figure 7.8).

Form 3: MenAfriCar case notification form and sample collect form; these forms were utilized in the three districts that our studies shared as well as the MSF supported districts (Figure 7.9).

The lack of standardized reporting formats resulted in inconsistent reporting both within and across districts. It also added to the confusion and work burden of health staff; in the Moissala district laboratory, which is supported by MSF as well as part of the government entities, technicians reported filling out both form 1 and form 3 and sending the respective forms to the national laboratory and MSF. Disparate forms were also observed at some district surveillance offices, indicating inconsistencies in the type of reported information.

Health facility staff also noted that there were several other forms that needed to be filled out from other national programmes, namely expanded programme on immunisation (EPI), nutrition, and Family well-being (i.e. family planning) programmes. These programmes required different data collection and used different reporting forms that needed to be submitted at differing time points. Line lists containing descriptive information for individual suspected meningitis cases were not available at any of the health facilities.

When asked, several of the RCS in the CBS districts did not understand the difference between the case notification form and the case investigation form. This was particularly observed in Goundi, which is not a CBS district but uses forms from MSF and MSP. The research assistant provided real-time instructions to the RCS who stated they did not understand the forms. The lack of understanding of how to use

surveillance tools may be attributed to the fact less than half of the health facilities reported that their staff attended any type of IDSR training in the past 2 years (as was mentioned above). Accordingly, 43% of RCS requested that training and knowledge transfer of disease surveillance procedures be prioritised to improve reporting of meningitis and other priority diseases (n =9).

Figure 7.7 Form 1 – Government integrated disease case notification and sample collection form

Formulaire d'Investigation

République de Tchad
Ministère de la Santé Publique
Service de Surveillance Épidémiologique Intégrée

Fiche de Notification - de la Formation Sanitaire/Agent de Santé au District de Santé

Choléra
 Typhoïde
 Dysentéerie
 Malaria
 Méningite
 Paludisme
 Fièvre Jaune
 Autre

Nom du malade: Kourai Jambé
 Age: 6 ans
 Sexe: M F

Domicile du Malade: Village/Quartier Baïdou
 District de résidence: Gaoua-Gaya

Date de collecte de l'échantillon: 15/03/13
 Date de notification Form: 15/03/13
 Date de la dernière vaccination: 15/03/13

Personne faisant la Déclaration: Bahassa
 Signature: [Signature]
 Date Envoi Fiche au District: 15/03/13

Formulaire de Prélèvement d'échantillon

République de Tchad
Ministère de la Santé Publique
Service de Surveillance Épidémiologique Intégrée

Pour la formation sanitaire: Si l'échantillon est collecté, Compléter les informations suivantes. Envoyer une copie de cette fiche au labo, avec l'échantillon.
 Date de collecte de l'échantillon: 15/03/13 Source de l'échantillon: labo LCR Autre

Pour le Laboratoire: REMPLIR cette section et retourner la fiche à l'équipe du district et au clinicien.
 Date réception échantillon au laboratoire: 15/03/13 Conditions des échantillons: Alcool Non séché

Maladie/Affection	Type de test	Résultats (P=Pos A=Atteint)	Maladie / Affection de	Type de test	Résultats
Choléra	Culture	+ - P	Fièvre Jaune	IgM	+ - P
Méningite	Examen Direct	+ - P	Rougeole	IgM	+ - P
			Rubéole	IgM	+ - P
N. meningitidis	Culture	+ - P	EVI	IgM	+ - P
H. pneumoniae	Culture	+ - P	Dhsh	IgM	+ - P
N. meningitidis	Culture	+ - P	CCIP	IgM	+ - P
H. pneumoniae	Lanes	+ - P	Lane	IgM	+ - P
H. pneumoniae	Lanes	+ - P	Marburg	IgM	+ - P
Stigella dysenteriae	Culture	SD type 1 Autre diag. Pas diag			
Psitt	Culture	+ - P			
	IFA-1-64	+ - P			

Date expédition résultats au district: 1/1
 Date de réception des résultats par le district: 1/1
 Date d'envoi des résultats au clinicien par le district: 1/1

NOTE: le district doit s'assurer que les résultats sont parvenus aux cliniciens. L'absence de cette procédure va entraver la notification des faits car par les cliniciens

Figure 7.9 Form 3 – MenAfriCar case notification and specimen collection forms

The image shows two forms side-by-side, both titled 'Fiche de rapport de cas suspect de méningite (MCRF)' and 'Fiche de Liquide Cephalosporin (LCRF)'. Both forms are designed for use in the surveillance of Case by Case (SCC) and the study of Vaccine Effectiveness (VES). They include fields for Site ID, Person ID, and Survey Code. The forms contain numerous questions (Q1-Q17) regarding patient demographics, clinical history, and laboratory results. The right form (LCRF) includes additional questions (Q18-Q20) related to the specimen collection process and laboratory findings.

District and national laboratories (n = 8)

- Percent of CSF contamination at national laboratory.

This indicator is affected by several factors including proper handling, packaging, storage, and transport of the CSF. These tasks are generally completed at the district laboratories. To meet this indicator less than or equal to 5% of samples should arrive to the laboratory in a contaminated state. Out of the 345 specimens received by the national laboratory in 2012, **88 (26%) of the samples were too contaminated to produce reliable results or determine any result at all** (see Table 7.6). Thus, the target of 5% was not achieved.

- Percent of probable bacterial meningitis cases with a known outcome recorded

In 2012, 345 CSF samples were sent from the district to the national laboratory for confirmation out of the total 3,795 suspected cases reported. Out of this total, 238 samples (169 sterile and 69 positive) had a known outcome (i.e. were in a state for the national laboratory to determine a conclusive result). Hence, approximately **6% of probable meningitis cases had a known outcome reported**. To achieve this target 90% of suspected cases should have a known outcome, representing a considerable deficiency in the abilities to meet this indicator.

- Percent of CSF specimens forwarded by the national reference laboratory for PCR and genotyping

Five out of 88 eligible specimens (i.e. total CSF analysed minus contaminated and sterile samples), or 5.68%, were analysed using PCR methods at the national reference laboratory. This is a relatively low number because the laboratory currently uses gel-based PCR, which is very time-consuming. For this reason, the national reference laboratory sent 59 out of 69 eligible specimens (i.e. suspected cases) to the WHO collaborating laboratory centre in Oslo, Norway for genotyping and confirmation. Hence, in total **86% of CSF samples were confirmed by PCR**. This indicator thus meets the required 20% of specimens that should be forwarded to a reference laboratory for PCR and genotyping.

- Percent of suspected pneumococcal meningitis cases identified

This indicator assesses continuing detection of all probable meningitis pathogens under surveillance. As Chad has not yet introduced pneumococcal vaccine, the number of cases confirmed with this bacterium should not change over time, but the proportion of all confirmed cases that are pneumococcal should increase due to Hib and MenAfriVac® introductions (Hib vaccine was introduced into Chad in 2008 (201).) The percentage of confirmed pneumococcal meningitis out of total positive cases was 9.52%, 4.17% and 8.70% in 2010, 2011 and 2012, respectively. **In 2013, this increased to 20% showing an expected higher detection of pneumococcal cases due to the decrease in NmA.**

Table 7.6 2010-2013 laboratory meningitis CSF analysis results, Chad

	2010	2011	2012	2013**
Suspected cases	3,058	5,960	3,795	242
Total CSF received and analysed at national laboratory	272	405	345	105
Number (%) of probable bacterial meningitis cases with a known outcome recorded**	72 (2%)	227 (4%)	238 (6%)	87 (4%)
Contaminated upon receipt	5	0	88	30
Sterile	51	107	169	67
Positive cases	21	120	69	20
NmA	19	114	63	3
NmW	ND	1	4	2
Pneumo	2	5	6	12
Hib	2	1	0	5
NmX	ND	2	3	0
% of positive cases of total CSF	8%	30%	20%	19%

CSF: Cerebral spinal fluid

* A probable case is defined as suspected case with a lumbar puncture that produced CSF examined and considered for further diagnostic analyses for meningitis

† Sterile samples + positive cases = probable cases with known outcome

** The large drop in suspected cases is observed after the 2011/2012 introduction of MenAfrivac®

Source: National reference laboratory, Chad

Observations at district and national laboratory

Laboratory operations for confirmation of meningitis

SOPs for meningitis diagnostic tests were observed in six of seven district labs and at the national laboratory. The source of the SOPs were either MSP, MSF or the MenAfriCar protocols. Laboratories at the district were generally minimally equipped, but were purportedly capable of performing the required meningitis analysis. The capacity and work load of laboratories in regards to bacteriology and meningitis analyses varied significantly and did not depend on population. There were several possible reasons for this that were observed:

- The three district laboratories (Gounou-Gaya, Guelengdeng, and N'djamena Nord) that reported zero or very low numbers of analysis were the districts where residents received the conjugate vaccine during the December 2011 vaccination campaign. This is compared to Goundi, Koumra, Moissala and Moundou districts who received the vaccine later.
- Moundou laboratory was on strike for three months in 2012, which may account for their overall "low" bacteriological analyses.
- Moundou regional laboratory did not receive any CSF¹ in 2012.
- Goundi laboratory, privately supported by a foreign catholic organisation, had superior health services and received an influx of people seeking treatment.
- There were reported meningitis outbreaks in Koumra, Goundi, and Moissala from 4 March to 5 May 2012.

Table 7.7 provides an overview of district laboratories analyses with factors that may influence quantity of CSF samples received.

¹ In 2012, the district laboratory in Moundou sent CSF samples directly to the National level instead of to the Regional laboratory. It was unclear why this happened.

Table 7.7 Summary of CSF analysed in 2012 district health laboratories

District	MenAfriVac campaign(s)	Number of CSF samples received/ analysed	Number of CSF samples confirmed	Total number of samples analysed in bacteriology lab	Total district population reported	Specific barriers reported
Gonou-Gaya	December 2011	0	0	382	293,583	Stock out of reagents and tests. Laboratory staff has RCS duties for performing LP and transporting CSF
Guelengdeng	December 2011	0	0	329	214,254	Does not receive feedback from national lab
N'Djamena Nord	December 2011	5/5 – all by cell counts and Pastorex ;	2 serogroup W, 3 negative	24,014	166,100	Guidance on quality control; expired reagents; Health facilities treat before LP
Koumra	Feb-April 2012	38/38 – all by Pastorex	13 Nm A	944	189,029	Electricity only from 8am – 2pm
Goundi	March 2012	170/170 – all by cell counts	63	33,536	158,379	Stock out of reagents and tests
Moissala	April 2012	253/253 – Pastorex only	77	253	260,145	None reported
Mondou	October 2012	0	0	753	393,876	Lack of reagents, tests, and coordination with health facilities, 3 month strike

RCS: Responsable du centre de sante

LP: Lumbar puncture

CSF: Cerebral spinal fluid

Quality assurance and control

There seemed to be no uniform method for internal or external quality control. One district laboratory reported calibrating instruments once a week, but were unsure of further measures for internal quality control. Another laboratory reported using the control media included in the Pastorex kit to do quality control. All district laboratories reported that external quality control measures were in place and referred to sending samples with a positive confirmation to the national laboratory, for additional analysis and final confirmation. As explained, the national laboratory sends more than required amount of samples to the external WHO reference laboratory for external confirmation, which is also a quality control measure; the chief laboratory technician in Chad was quite motivated in ensuring that the national diagnostic capability was reliable.

Ability of laboratory staff to perform meningitis diagnostic activities

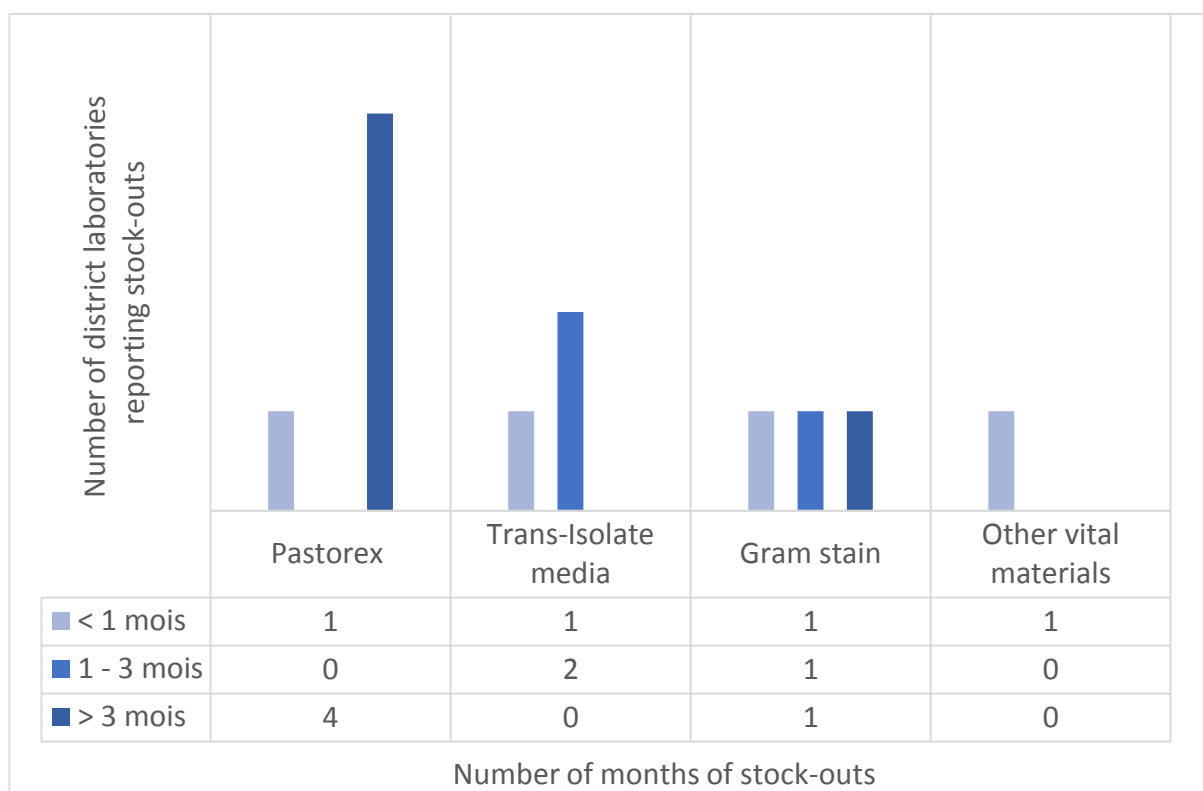
For 2012, an absence of required laboratory analyses kits and reagents (i.e. “stock-out”) was observed at six district laboratories and the regional laboratory. Also, all district laboratories reported running out of essential materials or reagents for meningitis analyses within the past one- and three-months (See Figure 7.10). Pastorex, which is very valuable for rapid diagnosis, confirmation and response activities at the peripheral level, was overwhelmingly lacking. This test is only supplied to the district laboratories from WHO via distribution from the national laboratory staff (generally, when they are able to conduct supervision visits). The average time reported for Pastorex stock out was 8.4 months (range 1 to 24 months). Moundou, the regional reference laboratory, reported that their supplies of Pastorex, T-I media¹, and Gram stain kit had expired more than two years before the time of the interview. This was alarming because it seemed that Moundou laboratory was capable to do these tests and provide reliable confirmations to this region, yet was excluded from the laboratory diagnostic pathway of meningitis. In addition to stock-out, expired bottles of T-I were observed at several district laboratories.

¹ Trans-Isolate (TI) medium, was developed for the transport of primary cultures of cerebrospinal fluids from patients with bacterial meningitis

Most district laboratories were using microscopes that were over a decade old. There was an average of five staff at each laboratory, yet most only had one functioning microscope. In general, staff reported that they were confident in their ability to properly handle, package, and send CSF to the next laboratory level for analyses. This was consistently reported, though staff also reported that they lacked the necessary materials, such as the bio-hazard transport box supplied by the WHO, to send the samples. Moreover, disparate means of sending samples were observed. Moissala district, funded by MSF, used the World Food Programme in-country airplane to send all their samples to N'Djamena. They also used, as was the case with the national reference laboratory, an international courier service to send samples to the Oslo reference laboratory. The other districts reported several sample-transport means, including sending the sample on the "market-bus", giving the sample to the CdZ or CASE who personally transported it to N'Djamena, and disposing the sample with a WHO staff member who had a vehicle. Overall, all the laboratories reported having some capacity to store samples in the short-term by using the T-I medium, or in refrigerators or freezers.

Every district laboratory except Moissala reported a stock within the past year of a reagent essential for meningitis analysis. The most common missing reagent was Pastorex, with five of the district laboratories reporting stock out within the last three months. At the national level, the reagents necessary for PCR were not available for most of the year, which is why only five samples were analysed using the PCR method.

Figure 7.10 Districts reporting recent stock-out of required laboratory reagents and materials for meningitis diagnostic tests (n = 5)



Human capacity and ability to report meningitis results

Overall, all laboratories were well organised and kept good documentation (i.e. laboratory registers) of analyses completed. There were no issues getting data for total amount of bacteriological tests performed and specific information about meningitis analyses and outcomes. None of the laboratories used computers to input data, except at the national laboratory where the chief technician used her personal computer to store laboratory data on Excel. All other laboratories used handwritten registers. The laboratories were typically contained within a district, regional, or national hospital campus, so they were generally well supported with electricity and refrigerator units. The exception was Koumra district, which reported electricity rations at the hospital.

District and regional laboratory staff reported feeling overburdened particularly during the peak meningitis season. Several district laboratories reported that during this time staff were committed to 24-hour availability rotas. At the national level, shortage of staff was a persistent year-round issue. The responsibility of laboratory staff in regards

to meningitis seemed to vary greatly at the district level. One laboratory technician reported performing lumbar punctures at health facilities. Several others reported having to go to health facilities to pick up CSF using the district hospital vehicles (e.g., ambulances) or personal motorbikes.

There was inconsistency regarding how case-information for samples were reported. Several district laboratory staff stated that sample collection forms were filled out and given to the CdZ with the CSF sample for transport to the national level. Alternatively, other staff sent the CSF directly to the national laboratory with the sample collection form or with some other paper containing some details about the suspected case. In several cases, the laboratory staff provided case data to the CdZ monthly. This prompted several CdZs to merely report confirmed cases from district laboratories instead of suspected cases reported by the health facilities.

Four district laboratories reported receiving training during 2012. Three different sponsors were reported to support the trainings, indicating no coordination between the organisations. Reported sponsors included WHO in collaboration with the MSP, CSSI for MenAfriCar, and the European Union. It is possible that the participant who reported being trained by an EU staff was mistaken in their understanding, because this was a MenAfriCar supported district. Three other districts reported receiving training within five years before 2012 from MSF or WHO.

Several district laboratories reported not receiving feedback from the national laboratory on samples that were sent for confirmation. At the national level, there was inconsistency in who the feedback was reported to. Sometimes the chief laboratorian called the chief of a district laboratory and other times results were reported from the national data manager to the CASE and CdZ who may or may not inform the laboratory focal point. Feedback from the district laboratory to the health facility was rarely completed and there seemed to be confusion around which surveillance officer was responsible for this task.

District and regional offices (n = 11)

CdZ and CASE

- *Number of trained staff in surveillance methods*

One out of the four CASE's reported ever receiving formal training in IDSR. Four out of seven (57%) CdZ's reported receiving formal training in IDSR, all were held in 2012. The trainings attended by CdZ's were focused on surveillance methods at the district level, and an average of 2.75 persons attended the training session. Participants in addition to the CdZs included district laboratory responsible, district chief medical officer and district health nurses. Out of the three CdZ's that did not receive training, one had not received training yet because he was hired after the training was complete. The WHO, UNICEF, and MSF France provided funding and some technical support for trainings for both health facility staff and CdZs.

- *Proportion of districts in which a current line graph of weekly trend analysis of meningitis is available*

Existence of an up-to-date disease trend line is an indication that surveillance staff continuously analyse the data they receive. Monitored changes in trends can provide a trigger for early outbreak response and control measures. For this indicator, we first looked for the line graph displayed in the office of the CdZ or CASE and if it was not displayed we asked if there was a graph available. 100% of CdZs and 100% of CASEs made available a current line graph of weekly trend analysis. This indicator thus meets the at least 80% standard.

- *Average length of employment of district surveillance lead*

CdZ's had an average length of employment in that role of 63.2 months (5 years). Of the seven CdZ's, three had been employed in their post for less than two years. The average length of employment ranged from 8 months to 12 years.

Observations: District and regional surveillance offices

Personnel at the district and regional level were generally highly trained nurses and other health staff with significant experience in managing disease surveillance and other disease programmes. In all the offices of the CASE and CdZ, population estimates and immunization parameters were available. Several staff reported lack of confidence in the population data and reported that other NGO's had conducted local censuses reporting vastly different numbers. Chad has never conducted a demographic health survey (DHS), and so antiquated and politically biased census data are used. This

undermines the ability to calculate disease thresholds. It appeared that CdZ's did not know or were not able to assess thresholds; it is likely that the line graphs were used to detect outbreaks. At the CASE level, aggregate data were collected and reviewed before reporting to the national level, though again no sophisticated analysis was performed in accordance to meningitis standard operating procedures.

All of the CdZ's reported wearing "multiple hats" and acted as the focal point for several national health programmes, namely malaria and EPI. While some larger districts like Moundou and Moissala had several focal points to assist the CdZ with his duties, other districts such as Goundi and Koumra reported feeling overburdened due to lack of assisting personnel. At this level, CdZ's and CASE's are responsible for providing surveillance forms to the health facilities. This was primarily a CdZ duty. Several CdZ's lamented about the out of pocket costs to make these copies, which includes the petrol costs to go into town and then the price of the phot copies. Only the Goundi CdZ had a photocopy machine in (or near) his office. Other personal expenses used for surveillance duties included internet modems and personal laptop computers, which the government did not provide to any CdZ's or CASE's.

The district and regional surveillance offices require a lot of travel due to constant supervision visits to health facilities as well as their role in supporting immunization activities, which includes mobile supplemental immunization activity campaigns. Though essential to their role, only 43% of CdZs had any type of vehicle accessible to them. This was better amongst the CASE's, with 75% reporting access to a vehicle.

7.2.4 Overall system assessment findings

Table 7.3, which was presented in the methods section of this chapters, provided the definitions and scale measures used in the following section. Though each category of interest is captured slightly differently, all of the attributes are qualitatively assessed and paired with a rating. '1' is the least optimal score and '4' is the optimal score.

Informativeness of system rating: Moderate (2)

The surveillance data from the reporting system in Chad produces sufficient information to make public health decisions around disease characteristics. This is shown by a high reporting rate among the districts in the study. The clinical data submitted by district/reference laboratories is however not sufficient and may not reflect an accurate representation of bacterial strains in Chad for bacterial meningitis. For these reasons, the informativeness of the system is rated as 'moderate'.

Sustainability of the current system: Not at all sustainable (1)

All the health centre *Responsible* held dual job responsibilities as both primary clinician at the health facility and the IDSR focal point. This meant that in addition to daily consultation and treatment of patients and clinical management duties, the Responsible also did the monitoring and reporting for IDSR and other disease programmes. This phenomena of "wearing multiple hats" was also noted at the district level amongst the CdZs who were also programmatic district leads for vaccine and malaria programmes, which require additional responsibilities that cannot be subsumed under the disease surveillance focal point role. Participants reported that there is insufficient human and financial support to sustain the current system. Most participants cited a lack of training and motivation as barriers to an effective and reliable system. This issue of having a very limited skilled workforce was echoed on every administrative level. In light of these very serious obstacles, the sustainability of the system is rated as 'Not at all sustainable'.

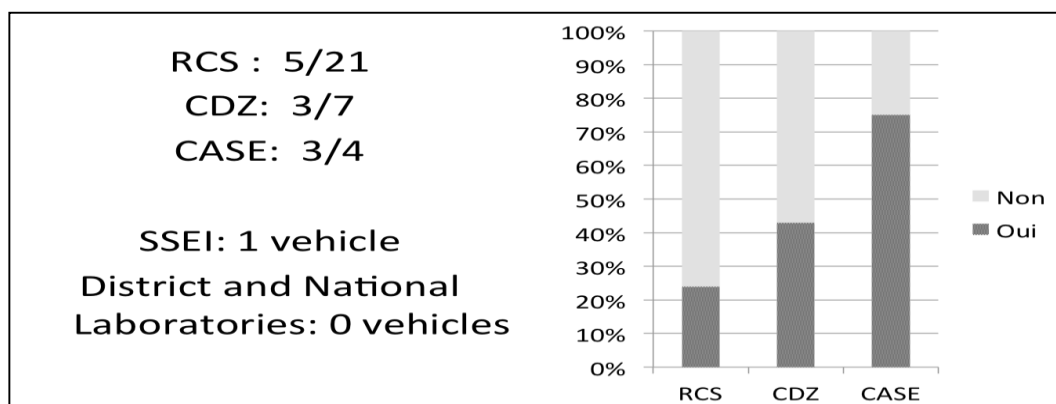
Resource-intensiveness of the system: High (2)

For optimal performance of an integrated surveillance system, human resources needs to be addressed in a way that provides a pool of skilled public health workers that can appropriately perform surveillance functions. We found that on average there was 3 formally trained health staff per health facility. On average, these health facilities had catchment areas of 18,833 populations, which translate to **0.167 health staff per 1000 population**. The WHO defines a country to be in “critical shortage” of health workers when it meets both of two separate conditions. These are: 1) the sum of employed doctors, nurses, and midwives is equal to or less than 2.28 per 1,000 population, and 2) fewer than 80% of births are attended by skilled health personnel (94). Based on this classification Chad is **13 times below** the critical shortage threshold for health workers.

A functional system must satisfy financial and logistical resources to a level where required surveillance functions can be performed. The activities that correlate with investigation and response require that the RCS, CDZ, and CASE travel throughout their designated areas, yet access to vehicles (including motorbikes) was generally low (Figure 7.11).

The laboratory is another system that requires continued replenishment of materials, reagents, and upkeep of equipment for accurate confirmation. As described in the performance assessment, several of the study district laboratories experienced stock-out of essential tests to perform meningitis analysis. Due to the aforementioned factors, the rating for resource intensiveness of the current system is determined to be ‘high’.

Figure 7.11 Percent of study surveillance staff with access to vehicles



RCS = Responsable du Centre de Sante; CDZ = Chef de Zone; CASE = Chef d'Antenne de Surveillance Épidémiologie; SSEI = Service de Surveillance Epidémiologique Intégrée

Flexibility of the system and facility to be adapted to integrate into other systems:

Flexible (3)

Although Chad is organized around an integrated surveillance system, this approach has not been applied systematically. At the central level, the weekly CTNLE meetings are well organized and allow cross sharing of disease information as well as an opportunity for collaboration between disease programmes and partners. On the sub-national levels disease programmes do not demonstrate the same coordination and collaboration efforts. At these levels, surveillance and monitoring of certain disease programmes are performed separately from the surveillance and monitoring of other diseases. This is antagonistic to the IDSR process and is usually an added obligation for the Responsible or CdZ who may be partially funded by a partner organization for only certain diseases. At the health facility level this is particularly evident in terms of completing disease surveillance forms. The integrated surveillance form is well understood and completed by the health facilities, but the case-based forms are often overlooked for some diseases. When IDSR is not comprehensively implemented, different surveillance methods across disease programmes can result in unreliable data and redundant work tasks.

The weekly meetings at the central level provide a platform for cross-collaboration and sharing of ideas. The public health surveillance leadership in Chad can use this committee to streamline surveillance components, including condensing and improving existing data forms, eliminating redundant processes of collecting the same data on multiple forms, scheduling IDSR trainings, and sharing resources (e.g. financial, human, equipment). In summary, the current Chadian IDSR system, which includes meningitis surveillance, has several important components in place and shows an opportunity for improvement at sub-national levels; and so I rate this as a flexible system.

Simplicity and overall functioning of the system: Relatively complex (2)

Theoretically, the meningitis surveillance system in Chad is straightforward. The data and specimen networks are clearly defined, and the surveillance positions at each administrative level have outlined roles and responsibilities. However, in practice, several aspects of the system are confusing and unachievable. The lack of a clear and feasible policy on which qualified personnel should perform lumbar punctures has possibly led to many missed cases, and poses a serious risk to the patient if the procedure is performed incorrectly or in subpar conditions. The lack of training in integrated surveillance methods has also resulted in inaccurate and missing data. We found that several health facilities were using a surveillance method contrary to the district strategy. Finally, the inconsistent financial support to laboratories and surveillance officials hinder a continuous, functional and reliable system. These issues contribute to a relatively complex system.

The performance assessment results are summarised in Table 7.8.

Table 7.8 Summary of performance assessment results

Informative -ness	Sustainability	Resource- intensiveness	Flexibility	Simplicity
Moderately informative	Some-what sustainable	High resource need	Flexible	Relatively complex
2	1	2	3	2

Comparison of Chad meningitis and WHO surveillance strategies

This assessment demonstrated some of the reasons why meningitis surveillance in Chad was operating in a complex and less than efficient system. The study aimed to provide decision makers and stakeholders with practical details and information to inform the transition to a more feasible and sustainable surveillance strategy to monitor the efficacy of MenAfriVac®. In alignment with the WHO guidance, the assessments, such as this one, should facilitate a structured, transparent and evidenced-based selection process (202).

The qualitative assessment and rating of the Chad meningitis surveillance aforementioned system attributes produced the spider chart in Figure 7.12. This chart was compared to the WHO charts, which graphically display the key features of the different surveillance strategies (Figure 7.13). In combination with a high knowledge of the Chad context, the charts provides visual support to guide selecting a new strategy. As shown in Figure 7.12, the current system could protracted to a sentinel case-based surveillance strategy without having to considerably alter the current system. Two areas would need to be enhanced to achieve this transition. The first is *informativeness*, which can be improved by systematic case-based data collection as well as ensuring laboratories have the capacity to analyse and diagnose CSF. The second area is *sustainability*; this could be optimised by strategic selection of sentinel district and laboratories, and also by training and actual integration of surveillance duties across all disease programmes. These findings were used to inform a three-district sentinel surveillance plan that Dr. Griffiths and I developed and recommended to the WHO Chad country office (Further described in Chapter 9).

Figure 7.12 Characteristics of meningitis surveillance in Chad according to WHO categories

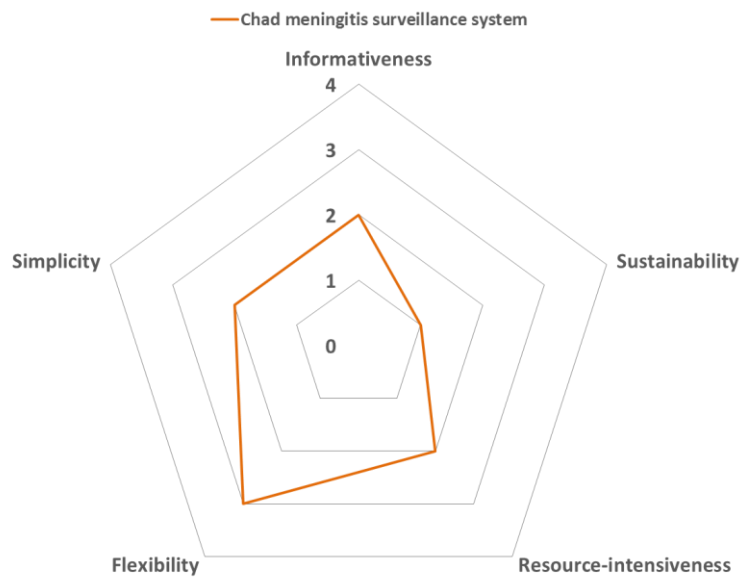
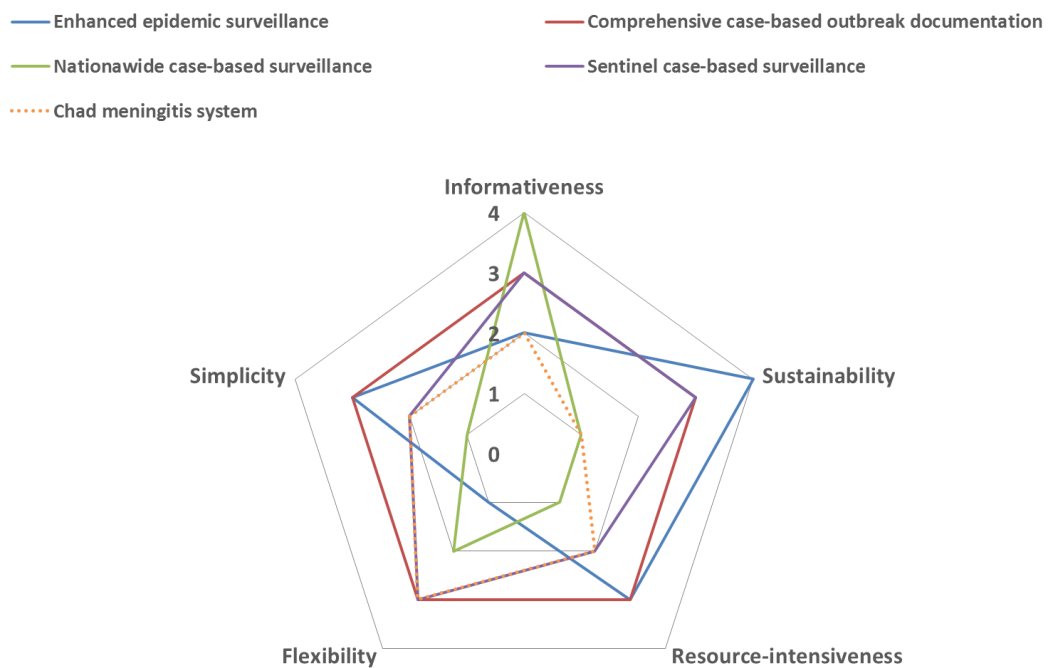


Figure 7.13 Chad meningitis system in relation to WHO meningitis surveillance strategies



Adapted from *Epidemic meningitis surveillance in the African meningitis belt: Deciding on the most appropriate approach*, WHO (202)

7.3 Methodological issues and data limitations

At health facilities, information on the number of lumbar punctures performed and the number of suspected cases referred to district hospital were rarely collected, and if they were collected it was not done in a consistent manner. This is reflected in a 0% match rate between CdZ data and health facility data for suspected cases (This is shown in Table 7.9). The discrepancy of data is also reflected in the numbers of suspected cases reported by the CdZs versus the number of CSF samples analysed in the district laboratories. In Goundi and N'Djamena Nord, there were more CSF samples analysed in the laboratory than reported suspected clinical cases by the CdZs. A comparison between number of cases reported for 2012 by the Cdzs during the study and the numbers that were reported to WHO is shown in Table 7.10.

There are likely reasons for the inconsistencies and lack of data. Firstly, at the peripheral level, there was an absence of organizational structures, such as desks, cabinets, storage containers, waterproof folders and storage units. Secondly, it was reported during the dissemination meeting that some CdZs were only reporting laboratory confirmed cases and not all suspected cases. There may be other issues that are still unknown.

The data discrepancies inhibit the ability to truly assess the surveillance system using the epidemiological indicators recommended by the WHO, especially the data used to assess surveillance specificity and sensitivity. Primary data is only captured at peripheral and district levels; these cannot be obtained at the regional and national levels, which only receive aggregate data.

Table 7.9 Comparison of reported cases and laboratory investigations in study districts, 2012

	Population	Number of suspected meningitis cases reported by Chef de Zones	Number of CSF meningitis samples analysed in district laboratory	Number of CSF meningitis samples sent to N'Djamena	Suspected cases per 100,000 people
Enhanced surveillance districts					
Koumra	189,029	53	38	38	28
Goundi	158,379	141	170*	15	89
Moundou	393,876	43	0	0	11
Case based surveillance districts**					
Moissala	260,145	388	388	71	149
Gounou-Gaya	293,583	NA	0	0	0
Guelengdeng	214,254	0	0	0	0
N'Djamena Nord	166,100	0	5*	NA	0

* Instances where the laboratory analysed more samples than were reported by the district surveillance officers.

** Moissala is a comprehensive case-based surveillance district; Gonou-gaya, Guelengdeng, and N'Djamena Nord are partial case-based surveillance districts.

Table 7.10 Reported meningitis cases by Chef de Zone, and as received by WHO from the Chad MoH, 2012

	Population	Chef de Zone	WHO
Koumra	189,029	53	78
Goundi	158,379	141	121
Moundou	393,876	43	26
Moissala	260,145	388	345
Gounou-Gaya	293,583	*	11
Guelengdeng	214,254	0	1
N'Djamena Nord	166,100	0	0

*No cases were reported from these districts

7.4 Conclusion

This chapter presented the findings of the subnational performance assessment of the Chad meningitis system. In general, staff across levels were informed and experienced in surveillance, but lacked supportive structures and resources to optimally conduct activities. Since the national vaccination with MenAfriVac[®], there has been a substantial decrease in reported meningitis cases in Chad. As the new vaccine has been shown to be highly effective, this is in no doubt partly due to a real decrease in cases. However, three of our seven study district detected no clinical meningitis cases during 2012 and only a total of 15 during 2013. This is concerning, especially since the pneumococcal conjugate vaccine has not yet been introduced in Chad. It is likely that meningitis cases are occurring, but the health system and associated surveillance structures in these districts are too weak to detect and report cases.

The assessment found particular weaknesses with regard to detection and confirmation across study levels. Alternatively, the strongest functions were data reporting [timeliness] and the analytic capacity of the national reference laboratory. Specific hindrances to detection and confirmation included unclear policies, missing reagents, and inadequate transportation to complete surveillance activities. Supportive functions were lacking in most districts, and most participants requested frequent training for staff on meningitis and IDSR procedures. Significant amounts of missing data presented a challenge to accurately track the number of cases detected at health facilities, the number of lumbar punctures performed, and the number of CSF samples sent to the laboratories.

The challenges and gaps identified in the subnational assessment were considered in the overall system assessment, which found that the current system was complex and inefficient. Based on WHO guidance, a sentinel district case-based surveillance system was recommended as a feasible and optimal system for Chad meningitis surveillance (this is further explained in Chapter 9).

8 Cost analysis

Conducting costing studies in low and middle income countries (LMIC) countries is a complex task. As discussed in the background, many challenges are generated due to missing data such as incomplete patient disease registers, lack of accurate financial records, or the scarcity of record keeping for the numerous donated equipment and materials (113). This was the case in our study which had a primary objective of estimating the costs of meningitis surveillance in order to inform Chad's decision-making on the best strategy to implement.

In this chapter I describe the procedures we employed to perform a cost analysis. Section 8.1 describes the techniques used to collect resource utilisation and unit cost data. Section 8.2 presents the results by performance of health facilities and health districts and as incremental costs. Section 8.3 and 8.4 summarises the key findings of these results.

8.1 Methods

8.1.1 General approach

The health sector in Chad is financed through three sources: 1) the national budget, 2) donor funds from NGOs and international organisations and 3) populations that contribute to health financing through cost recovery. Disease surveillance is publicly funded. We chose an all-payer perspective, which entails incorporating costs from the government, international partner agencies and other funding sources.

Data were collected retrospectively, and resource utilisation and costs were measured for 2012¹. Economic and financial costs were estimated. Economic costs include a valuation of all inputs needed for the surveillance, including valuation of time, supplies, and equipment. Any donated items and volunteer time were valued at the market rate. Financial costs only included financial expenses for the surveillance activities. Due to

¹ In the case of the Moundou regional laboratory where no meningitis activities were performed in 2012, resource utilisation and costs from 2011 were used.

lack of data, it was not possible to include facility and laboratory overhead costs, such as building and electricity costs, of which surveillance in any case would be allocated an extremely small proportion. Hence, the estimates are slightly underestimating the true economic costs.

Data were collected in local currency and all costs were converted to 2012 US\$ using the average 2012 exchange rate of 1 US\$ = 496.766 XAF.

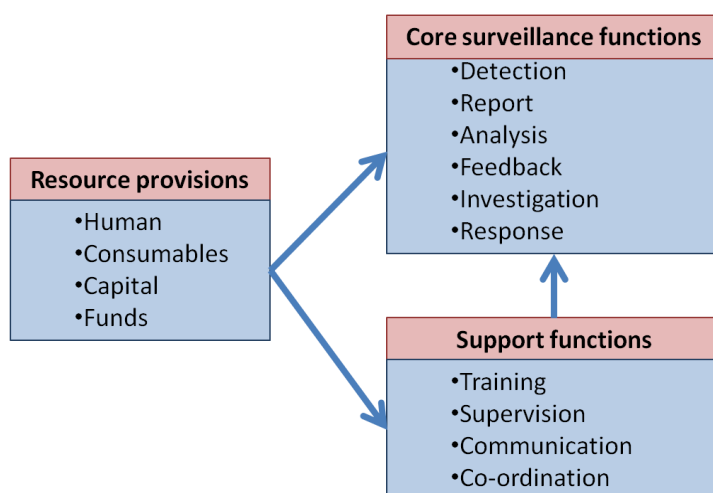
Both recurrent and capital cost were valued (Table 8.1). A 5% discount rate was applied for annualising capital costs to reflect the opportunity costs of investing in capital equipment. This rate followed the recommendation of SurvCosts (105). Programme-specific as well as shared costs were valued. Shared costs included personnel, vehicles, and laboratory equipment.

Table 8.1 Resources included in the cost analysis

Capital items	Recurrent items
Programme vehicles	Personnel (salaries, benefits, per diems, etc.)
Equipment (e.g. refrigerator, computer, microscope, etc.)	Office (supplies)
	Transportation (vehicle operation and maintenance)
	Laboratory materials and supplies

Cost items were categorized according to a modified version of the recommended structure of IDSR core and support functions (Figure 8.1). In the study the ‘investigation’ function was interpreted as *laboratory* investigation and confirmation. *Case investigation* was the only component of response included. The costs of reactive meningococcal vaccination campaigns were not included.

Figure 8.1 Framework used for categorising costs



Source: WHO Regional Office for Africa (2010) (45)

The data collected were used to estimate the costs per detected case and per sample processed in the laboratories. Additionally, to inform on efficiency of the systems of surveillance in place, mean costs per suspected case, per investigated case and per confirmed case, were also estimated. Mean costs of the current surveillance system were also analysed by costs per 100,000 population and per capita for each surveillance strategy and surveillance function. Descriptive statistics around the mean cost estimates, such as range and standard deviation, were calculated.

The denominators for per 100,000 population and per capita were arrived from population data for the respective study unit. Hence, for health facilities, the denominator was the catchment population, for a district it was the total population in the district, and for a region it was the total population in the respective region. For costs on a national level, the total population was used in the denominator. The population estimates were based on those reported by the MoH (2012). Data were collated and analysed using pre-designed Excel spreadsheets detailed in Section 5.2.4.

8.1.2 Collection of resource utilisation data

The unit of analysis was surveillance activities. To estimate these costs an ingredients data collection approach (i.e. “bottom up” costing) was undertaken. This approach was selected to provide a high level of detail of the surveillance programme by capturing the

fundamental resources required. Costs for surveillance activities were captured from self-reported data; participants were asked the mean amount of time (in minutes) they spent on each meningitis-related surveillance activity. This was done for each function to make it easier for participants to recall. Other data on resource quantities, specifically in the laboratories, were taken from observations and available documents, such as financial reports. This information was used to populate a spreadsheet of resource estimates.

Allocation of shared costs to meningitis surveillance was made by recording what resource quantity was used for all disease surveillance activities, and then what proportion of those activities were used for meningitis surveillance, based on actual use of resources and estimates of staff workload for each category of resources. If the latter was difficult to estimate by respondents, a tracing ratio based on the number of core diseases that are part of the surveillance system, was used.

The ingredient exercise was facilitated by examining the processes of each activity and delineating the resources. The step-by-step procedures were already included in the health facility level-specific questionnaires (as explained in Section 5.2.4). During the interviews, staff at health facilities, in the district health offices and in the laboratories were asked to describe step-by-step procedures of their meningitis surveillance activities, to approximate the time spent and frequency of each activity, distance travelled to complete certain activities, and equipment and supplies used. Table 8.2 describes each study instrument and the specific resource utilisation data collected at each study site.

Table 8.2 Resource utilisation by data source

Study instrument	Resource utilisation data
Health facility questionnaire	<ul style="list-style-type: none"> - Health facility funding source or method - Age and size (i.e. number of beds) of facility - Donated items and donor source - Number of employees, role, and salary, length of employment - Distance to health facility for staff and surrounding villages - Number of days patient stayed - Frequency of surveillance activities - Time spent on surveillance activities - Materials and mode of communication used for surveillance activities - Availability of vehicle/ mode of transportation for patients - Volunteer activities - Staff training (duration, payment, funder) - Frequency of, time spent on, and materials needed for surveillance-related meetings - Frequency and length of times of IEC activities, if applicable - Patient transport costs, if possible - Specimen transport costs, if possible - Funding source for case-based surveillance, if applicable
District/regional surveillance office questionnaire	<ul style="list-style-type: none"> - Employer information - Personal qualifications and role of interviewee - Length of employment - Number of focal points that share responsibilities at the district or regional level - Office space - Training received and given - Frequency of, time spent on, and materials needed for meetings - Frequency of and time spent on surveillance activities - Surveillance supervision activities, frequency and processes - Frequency of meningitis and IDSR surveillance activities - Details of active surveillance activities - Other major roles and activities (for other disease programmes) - Personal costs associated with meningitis surveillance (E.g. patient transport, payment of photo copying surveillance forms) - Transportation information (E.g. vehicle rented, permanent vehicle at disposal) - Vehicle information - Equipment and materials used for meningitis surveillance activities
Laboratory questionnaire	<ul style="list-style-type: none"> - Number of meningitis cases analysed in 2012 - Number of employees, role, and salary - Time spent on meningitis-related activities - Types of analysis performed at the laboratory and CSF analysed by test type

Study instrument	Resource utilisation data
	<ul style="list-style-type: none"> - Other laboratory activities and resources related to CSF analyses - Laboratory consumables and materials used for CSF analyses - Quantity and purpose of laboratory equipment - Specimen shipment costs and materials - Frequency and activities of internal and external quality control - Outstanding needs to improve each activity (collected for upgrading exercise) - Staff training (duration, payment, funder) - Frequency of, time spent on, and materials needed for meetings - Laboratory budget and process for making orders - Frequency of reagent and material stock outs (i.e. to exhaust supply of a needed item)
Central-level surveillance office questionnaire	<ul style="list-style-type: none"> - Number and frequency of national feedback reports - State budget for the control of epidemics (E.g. planning, training) - Resources used and time spent for case investigation - Resource for coordination of IDSR-related meetings - Price and equipment and vehicles used for IDSR-related activities - Percent of use of equipment used for meningitis surveillance - Funding source for equipment - Information on buildings used for surveillance (E.g. year of acquisition, price bought) - Time of significant staff on meningitis surveillance activities - Funding sources of other relevant equipment, materials, and supplies
Technical partner/funder questionnaire	<ul style="list-style-type: none"> - Budget, expenses, and finances of institution for surveillance of meningitis in 2012 (E.g. monitoring, evaluation, coordination, maintenance of vehicles) - Information of financed vehicles used in 2012 for implementation of surveillance of meningitis - Information of staff involved in disease surveillance in 2012 - Salary of support staff for disease surveillance in 2012 - Funding sources of other relevant equipment, materials, and supplies

CSF: Cerebral spinal fluid

HF: Health facility

IDSR: Integrated disease surveillance and response

IEC: Information, education, and communication Collection of unit cost data

Unit costs of identified resources involved in surveillance were identified by reviewing equipment and materials orders, budgets and other financial records obtained from government records or partner organisations. In order to calculate salary costs, we collected information on all staff implicated in meningitis surveillance at the health facilities, laboratories, and district and regional surveillance offices. Total annual salary costs were calculated by determining salary grade from participants reporting of years

worked and education, then multiplying the number of each salary category by the salary grade midpoints. Salary scales were obtained from the Ministry of Finances and Budget.

Unit costs were also ascertained from organisations providing donor support across surveillance activities. This includes WHO, CDC, MenAfriCar, and Médecines sans Frontières. These estimates were cross checked with local procurement officers and laboratory experts.

8.1.3 Sensitivity Analysis

A sensitivity analysis assesses the impact of structural and parameter uncertainties on the result. For this study, a probabilistic uncertainty analysis was undertaken in order to not only provide estimates of mean expected costs and effects, but also accompanying uncertainty ranges. A Monte-Carlo simulation was used to evaluate the effects of uncertainty by running a large number of and drawing distributions from uncertain parameters resulting in a probability distribution for the overall results (203).

I ran 10,000 Monte Carlo simulations using Oracle Crystal Ball© software. Individual parameters were attached to a statistical distribution and repeated random samples were selected. The analysis generates single bars representing multiple univariate sensitivity analysis showing the varying effects on the meningitis surveillance activity costs when choosing the higher and lower values of selected parameters. I sought to look for ranges around the core surveillance function estimates. In each surveillance function (i.e. detection and confirmation, reporting, supervision and feedback and communication), I focus only on the variables that could have considerable uncertainty or are of particular interest. The limited list of uncertain variables in each function listed in Table 8.3 reflects the reality that most of the variables collected had fixed values or the intra-variable differences were incidental in the Chadian context (e.g. salaries for health facility staff, time for laboratory analysis, text message charges).

A triangular distribution was used for all simulations. Triangular distribution is a useful and simple technique for describing ranges; specifically, the minimum, maximum, and

most expected values. It has been criticised for being a convenient-to-fit model, which is limited to demonstrating linear relationships that cannot reflect the dynamism of certain risk factors. Nonetheless, I selected this distribution because I think it is most appropriate given my particular parameters of interests and because it allowed me to illustrate a likely distribution since I do not have the data needed to determine the exact distribution (204) (205).

Table 8.3 Assumptions used in the probabilistic uncertainty analysis

Surveillance function	Uncertainty parameter	Base case	Assumptions used in uncertainty
Detection and confirmation	Number of CSF analysed per year	Range between facilities: 0 – 253 Mean: 67	25% less than and 25% greater than the base case
Reporting	None	N/A	N/A
Supervision and Feedback	Number of CDZ per district	Range: 1 – 3 CDZ per district Mean: 1.6	One less and one more CDZ in each district
Communication (IEC)	Number of health facilities per district	Range: 8 – 27 health facilities per district Mean: 17	25% less than and 25% greater than the base case

Justification for parameter selection

I chose a minimum and maximum around the bases case of each parameter. The base case in this refers to the raw data collected for each variable.

The parameter of ‘CSF analysed’ was chosen due to several issues surrounding meningitis detection, which have already been discussed. If these issues are resolved, there is a possibility that more CSF will be analysed in certain districts and less in other districts. The assumption of 25% less than and 25% more than the base case (of each district) was selected as an arbitrary approach to reflect the possible range of probabilities for varying scenarios of the number of CSF received by each district laboratory that then undergo analysis.

‘Number of CdZ’ was selected for the uncertainty analysis due to the varying number of CdZs in the study districts. Further variation may be observed once the

costs are extrapolated for the entire country. I adjusted this between one more or less than the current number of CdZs per district – which produces one to three CdZ's. This is also the minimum and maximum numbers observed in the study districts.

Likewise, 'number of health facilities' was selected due to the possibility of variation in health facilities within the country. Twenty-five percent greater and less than the base case were again used as the assumptions to reflect the highest and lowest expected probabilities. For example, in N'djamena Nord, where there are 10 health facilities, 25% less than the base case (i.e. 10 health facilities) is 7.5 health facilities and 25% more is 12.5 health facilities. These values were used in the uncertainty analysis.

8.2 Results

8.2.1 Activity costs analysis in study districts

Table 8.4 presents the ten distinct surveillance activities that costs were calculated for. In this section, costs per detected case for each of these activities are presented. These are subsequently extrapolated to total cost estimates in the next section.

Table 8.4 Meningitis surveillance activities used for the cost estimates

	Activity	Responsible staff
1	Lumbar puncture	Health facility <i>Responsable</i> Physician in district hospitals
2	Transport of CSF from health facility to district laboratory	Health facility staff CdZ in some districts
3	District laboratory investigation	District laboratory staff
4	Transport of CSF from district to national laboratory	CASE, CdZ, district laboratory staff
5	National laboratory investigation	National laboratory staff
6	Transport and laboratory investigation of CSF in Oslo for quality control	National laboratory staff, WHO and Oslo laboratory staff
7	Surveillance case investigation/ Follow-up of confirmed cases	CdZ and health facility staff
8	Reporting and data analysis	Health facility staff reports to CdZ CdZ reports to CASE CASE reports to SSEI
9	Supervision and feedback	CdZ, CASE – weekly National (biannually) National laboratory (biannually)
10	Information, education, and communication	Health facility staff

CSF: Cerebrospinal Fluid, CASE: Chef d'Antenne de Surveillance épidémiologie, CdZ: Chef de zone, SSEI: Integrated Epidemiological Surveillance Service

1. Lumbar puncture

A lumbar puncture kit and staff time are the only two resources required to perform a lumbar puncture. Lumbar punctures were always performed on site in 11 of the 21 health facilities (52%). Two facilities reported that they sometimes performed LPs and

one facility only rarely did them. In the remaining seven facilities, patients were always referred to the district hospital for lumbar punctures.

In the 14 facilities performing lumbar punctures, these were done by the health facility *Responsible*, who was usually a qualified nurse. According to WHO guidance, if possible, three tubes of CSF should be collected for microbiology, chemistry and cytology (206). In 11 of the 14 facilities only one tube of CSF was filled (79%), and in the remaining three two tubes were routinely filled. Lumbar puncture kits are distributed to health facilities from the national level. The kits, pictured in Figure 8.2, used in Chad are manufactured by Medical Expert Group and purchased at a price of **US\$ 19** per kit.

Figure 8.2 Contents of lumbar puncture kit¹



Source: WHO and CDC laboratory manual (2011) (206)

In the 13 health facilities where lumbar punctures were performed, staff reported a wide variation in the time it took to complete the clinical diagnosis, the lumbar puncture and filling in the reporting forms (Table 8.5). The average time for all three activities was 39 minutes (range, 8 to 105 minutes; SD = 28). The average of **39 minutes**

¹ The kits contain two sterile drapes, three cleaning sponges, a 20 gauge spinal needle, a 25 gauge and a 20 gauge needle for anaesthetic infiltration, a 3cc syringe, a vial of 1% lidocaine for anaesthesia, a pressure manometer with tubing, four collection vials and a Band-Aid.

was used in the cost estimates. In the facilities where lumbar punctures were not performed, mean staff time spent on clinical diagnosis and completion of patient records was 7 (SD = 4) and 5 minutes (SD = 2.3), respectively.

Table 8.5 Reported minutes of staff time used on lumbar puncture procedures

Activity	Mean	Min	Max
Clinical diagnosis (n=13)	14	3	60
Lumbar puncture (n=13)	13	4	30
Completing forms (n=10)	11	1	30
<i>Total</i>	39	8	105

The average monthly salary of medical staff in primary health care facilities was US\$ 336 and it was US\$ 1,059 for physicians in district hospitals. This translates to salary costs per minute of US\$ 0.03 and US\$ 0.11. When assuming that 52% of all lumbar punctures are undertaken at primary health facilities (as in the study sample) and the remaining 48% at district hospitals, the weighted estimated average costs of performing lumbar puncture amount to US\$ 22 (Table 8.6).

Table 8.6 Estimated costs of performing a lumbar puncture (2013 US\$)

Item	Health facilities	District hospitals	Weighted average*
Lumbar puncture kit	19	19	19
Salary costs	1.38	4.34	2.80
<i>Total</i>	21	24	22

* When assuming 52% of lumbar punctures undertaken at primary health facilities and 48% at district hospitals.

2. *Transportation of CSF from health facility to district laboratory*

The following resources are needed in order to package and transport the CSF to the district laboratory:

- Trans-Isolate medium
- Mode of transportation
- Health facility staff time

N. meningitidis, *S. Pneumoniae* and *H. influenzae* are demanding and fragile bacteria that should be examined as soon as possible after collection to increase the chance of isolating the clinical specimen. Hence, it is essential to transport the CSF tube to the laboratory straight after the lumbar puncture. In nine facilities, tubes were sent to the laboratory immediately and in two facilities this was done once per day. Procedures for transporting CSF were available from 11 facilities. Staff in nine facilities reported that they place the CSF tube in a cold box with ice packs or in a fridge with ice packs. Two facilities did not use ice packs.

If CSF cannot be processed within one hour, it should be inoculated into Trans-Isolate (T-I) medium, which is a growth as well as a holding and transport medium (206). This was however not available in any of the facilities. Data on resources spent on transporting CSF to the district laboratory were available from 13 health facilities. The average travel time for a return trip to the district laboratory was 62 minutes (range, 10 to 120 minutes; SD = 32) (Table 8.7). The staff member transporting the CSF was in all cases the same person who had performed the lumbar puncture (the health facility *Responsible*). The mode of transport was most frequently a motorbike. For the few facilities which were in close proximity to the laboratory, the specimens were delivered by walking. For the cost estimates, we assumed a mean distance of 36 km for a round trip on a motorbike and that the transport took 62 minutes of staff time. Mean cost estimates per CSF transported are summarised Table 8.8.

Table 8.7 Distances and times to transport CSF to the district laboratory (n=13)

Health facility study code	Distance to district laboratory (one way) (km)	Minutes of travel for return trip
FAR002	6	30
FAR003	6	60
GUE001	35	60
GUE002	45	120
GON001	35	90
GON002	5	60
GON003	25	60
KOU001	16	50
KOU002	16	10

KOU003	7	20
MOU001	5	120
MOU002	38	70
MON003	1	60
<i>Average</i>	18	62

Table 8.8 Cost estimates of transporting CSF to district laboratory

Item	2012 US\$
Staff time for transport	2.18
Petrol*	1.69
Motorbike depreciation**	1.59
Total	5.46

*Petrol price per litre: US\$ 1.38. Distance per litre: 30 km

**Price of motorbike from new: US\$ 6,352. Assumed expected life: 4 years.

3. *District laboratory investigation*

At district laboratories the following three tests should be performed on CSF:

- Cytology
- Gram stain
- Latex agglutination

Regional laboratories should in addition to the above three tests also undertake culture, sero-grouping and antibiotic sensitivity. However as explained in Chapter 7, Moundou regional laboratory lacked supplies for bacterial analysis and no CSFs had been received or analysed during 2012. Hence, we excluded regional laboratories from the analysis of current costs. However, in the extrapolations for scaling up the surveillance system, estimates are provided for regional laboratories using data collected at the national laboratory.

Staff at the laboratories in N'djamena Nord, Guelengdeng, Gounou-Gaya, Koumra and Moissala were all employed by the MSP. Staff at the laboratory in Goundi were paid by the community fund. N'Djamena Nord, Guelengdeng and Gounou-Gaya had received support from external donors, including UNICEF, WHO, World Vision and MSF.

A microscope is needed to perform cytology and gram stain. A centrifuge is also needed for a gram stain. Latex agglutination is performed using a Pastorex kit and no equipment is needed. Resources in the district laboratories used for performing the tests are:

- Microscope and centrifuge
- Laboratory supplies
- Laboratory staff time

Staff reported that took on average ten minutes (range, 5 to 10 minutes) to do a gram stain, nine minutes (range, 3 to 20 minutes) to complete cytology and 15 minutes (range, 10 to 50 minutes) to complete the latex agglutination. Cost estimates of the three tests are summarised in Table 8.9.

Total costs per test if all three procedures are performed amounts to **US\$ 12.77**.

Table 8.9 Costs of CSF laboratory analyses at district laboratories (2012 US\$)

	Unit of measure	Unit costs (US\$)	Quantity per sample	Costs per sample (US\$)
CYTOLOGY				
Gloves	Pair	0.02	1	0.02
Slides	Each	0.12	2	0.25
Slide covers	Each	0.12	2	0.25
Staff salary	Min	0.08	9	0.74
Microscope	Capital			0.05
<i>Total</i>				1.30
GRAM STAIN				
Gloves	Pair	0.02	1.00	0.02
Gram staining kit	Each	64.94	0.02	0.98
Slides	Each	0.12	3.00	0.37
Slide covers	Each	0.12	3.00	0.37
Immersion oil (200 ml)	ml	26.10	0.00	0.02
Staff salary	Min	0.08	10.00	0.83
Centrifuge	Capital	0.08		0.03
Microscope	Capital			0.05
<i>Total</i>				2.67

PASTOREX				
Gloves	Pair	0.02	1	0.02
Pastorex kit	Each	175	0.043	7.59
Staff salary	Min	0.08	15	1.24
Total				8.85
Costs of all three tests				12.77

* Purchase price of microscope: US\$ 1,678. Purchase price for centrifuge: US\$ 325. It was assumed that both pieces of equipment are used 20 times per day in the laboratory. Expected life expectancy assumed as 10 years for both microscope and centrifuge.

4. Transport of CSF from district to national laboratory

A proportion of CSF samples are sent to the national reference laboratory in N'Djamena for laboratory confirmation. However, due to lack of supplies in some laboratories, samples are also sent directly to the national reference laboratory from the health facilities. The following resources are needed in order to package and transport the CSF to the national laboratory:

- Trans-Isolate medium
- Triple Packaging
- Transport means

The proportion of samples sent to the national laboratory during 2010-2012 ranged from 6%-9% of suspected meningitis cases (Table 8.10). In 2013, the percentage was considerably higher due to a substantial decrease in detected cases following introduction of MenAfriVac®.

Table 8.10 Proportion of reported meningitis cases with CSF analysed at the national laboratory

Year	Number of reported meningitis cases	Number of CSF samples received by the national laboratory	Percentages of cases with CSF analysed at national laboratory
2010	3,058	272	8.89 %
2011	5,960	405	6.79 %
2012	3,795	345	9.09 %
2013	242	149	61.57 %

Source: Chad National Reference Laboratory

All district laboratories used T-I media and triple packaging when sending the samples to N'djamena. The T-I tube is labelled with the identity of the patient, the name of the health facility, date and time of collection, and the sample number. There is no standard system for transporting the specimens. The district laboratories used different methods, depending on the distance to N'djamena. These methods are summarised in Table 8.11.

Table 8.11 Methods of transport of CSF from district laboratories to the national laboratory

District	Packaging	Transport method
N'Djamena Nord)	NA	NA
Guelengdeng	NA	Motorbike by health staff
Gounougaya	Triple packaging with T-I media	Motorbike by health staff
Koumra	Triple packaging with T-I media provided by MSF	Sends to MSF in Moissala who send it by courier
Goundi	Triple packaging with T-I media	Uses the Koumra hospital vehicle or sends by market bus
Moissala	Triple packaging with T-I media	MSF sends by courier or World Food Programme airplane
Mondou (Regional)	Triple packaging with T-I media	By market Bus, WHO or Focal Point takes it

The Norwegian Institute of Public Health (NIPH) produces T-I and donates this for free to MSF in Chad. The NIPH has estimated the production costs of T-I to be US\$ 3 per unit. The price of one box of triple packaging when procured by MSF is US\$ 32. These are re-usable and we assumed that each box is used ten times. Hence, a unit costs of US\$ 3.20. Due to the various methods of transport of the specimens, it is difficult to arrive at an average cost per sample transported. Moundou reported that they spent between 1,000 and 2,500 CFA (US\$ 2-US\$ 5) for transporting a sample on the market bus to N'Djamena. US\$ 5 per sample was assumed, but this is a minimum costs as the other means of transport would be more expensive. The total transport costs per sample is summarised in Table 8.12.

Table 8.12 Costs of transporting CSF samples from district laboratories to the national laboratory

	Unit costs (US\$)	Quantity per sample	Total costs (US\$)
Triple packaging	32	0.10	3.22
T-I media	3	1	3.00
Transport	5.29	1	5.29
<i>Total</i>			<i>11.51</i>

5. National laboratory investigation

When the samples arrive at the national laboratory the following tests are performed:

- Cytology
- Gram stain
- Latex agglutination
- Culture
- Serogrouping

In the reference laboratory in N'Djamena, confirmation and serogrouping is undertaken with conventional gel-based PCR and not real-time PCR. Gel-based PCR is time-consuming and compared to real-time PCR it includes a risk of contamination. The use of real-time PCR have expanded rapidly in recent years, but due to the expense of the equipment, the laboratory in N'Djamena has not been able to introduce it. As a result, the laboratory sends a relatively high proportion of their samples for processing at the international reference laboratory in Oslo, Norway, as explained in Chapter 7. Only five CSFs were processed by gel-based PCR during 2012. We excluded this cost from the estimates of current meningitis surveillance costs. However, for the cost estimates of upgrading to an operational standard we estimated the costs of implementing real-time PCR in the national laboratory in N'Djamena.

Costs of processing CSF samples at the national laboratory are summarised in Table 8.13 and Table 8.14.

The cytology, gram stain and Latex agglutination tests are slightly more expensive in the national laboratory than in the districts due to higher salary levels of laboratory staff.

Table 8.13 Costs of cytology, gram stain and Pastorex in the national reference laboratory

	Unit of measure	Unit costs (US\$)	Quantity per sample	Costs per sample (US\$)
CYTOLOGY				
Gloves	Pair	0.02	1	0.02
Slides	Each	0.12	2	0.25
Slide covers	Each	0.12	2	0.25
Staff salary	Min	0.11	9	0.97
Microscope	Capital			0.05
<i>Total</i>				1.53
GRAM STAIN				
Gloves	Pair	0.02	1	0.02
Gram staining kit	Each	64.94	0.02	0.98
Slides	Each	0.12	3	0.37
Slide covers	Each	0.12	3	0.37
Immersion oil (200 ml)	ml	26.1	0.00075	0.02
Staff salary	Min	0.11	10	1.08
Centrifuge	Capital			0.03
Microscope	Capital			0.05
<i>Total</i>				2.92
PASTOREX				
Gloves	Pair	0.015681	1	0.02
Pastorex kit	Each	175	0.04	7.59
Staff salary	Min	0.11	15	1.62
<i>Total</i>				9.23

Table 8.14 Costs of culture and serogroup determination in the national reference laboratory

	Unit of measure	Unit costs (US\$)	Quantity per sample	Costs per sample (US\$)
CULTURE				
<i>Negative and contaminated CSF</i>				
Gloves	Pair	0.02	1	0.02
Blood agar plate	Each	1.29	1	1.29
Agar chocolate plate	ml	1.3	1	1.3
BHI broth (25x10 ml)	ml	0.17	1	0.17
Pipette 1 ml	Each	0.08	4	0.32
Pipette tip	Each	0.04	4	0.17
Loops 1ul	Each	0.36	3	1.09
Loops 10ul	Each	0.05	3	0.16
Staff salary	Min	0.11	20	2.16
<i>Total</i>				6.66
<i>Positive CSF</i>				
Gloves	Pair	0.02	1	0.02
Blood agar plate	Each	1.29	1	1.29
Agar chocolate plate	Each	1.3	1	1.3
BHI broth (25x10 ml)	ml	0.17	1	0.17
Pipette 1 ml	Each	0.08	4	0.32
Pipette tip	Each	0.04	4	0.17
Loops 1ul	Each	0.36	3	1.09
Loops 10ul	Each	0.36	3	1.09
Pipette tip 1000ul	Each	0.05	5	0.27
Ampicilline disc	Each	0.04	1	0.04
Amoxycilline disc	Each	0.04	1	0.04
Cetotaxime disc	Each	0.01	1	0.01
Ceftriaxone disc	Each	0.04	1	0.04
Chloramphenicol disc	Each	0.04	1	0.04
Ciprofloxacin disc	Each	0.04	1	0.04
Cotrimoxazole disc	Each	0.04	1	0.04
Staff salary	Min	0.11	60	6.48

	Unit of measure	Unit costs (US\$)	Quantity per sample	Costs per sample (US\$)
<i>Total</i>				12.42
SEROGROUP DETERMINATION				
Gloves	Pair	0.02	1	0.02
Men A antiserum	ml	4.06	1	4.06
Men X Antiserum	ml	4.34	1	4.34
Men Y Antiserum	ml	4.30	1	4.30
Men W 135 antiserum	ml	3.97	1	3.97
Slides	Each	0.12	3	0.37
Slide covers	Each	0.12	3	0.37
Staff salary	Min	0.11	30	3.24
Microscope	Capital			0.05
<i>Total</i>				20.70

* Purchase price of microscope: US\$ 1,678. Purchase price for centrifuge: US\$ 3625. It was assumed that both pieces of equipment are used 20 times per day in the laboratory pieces. Expected life expectancy assumed as 10 years for both microscope and centrifuge.

6. Transport and laboratory investigation of CSF in Oslo for quality control

The resources needed to transport and analyse CSF from N'djamena to Oslo are:

- Shipping materials
- Shipping costs
- Cost of analysis in Ouagadougou
- Cost of analysis in Oslo

The National Reference Laboratory sends a proportion of CSF samples to the WHO Multi Disease Surveillance Centre in Ouagadougou, Burkina Faso and after analysis in this laboratory, they send the samples to the Norwegian Institute of Public Health (NIPH) in Oslo for further confirmation. The NIPH is a WHO Collaborating Centre for Reference and Research on Meningococci. During 2012 the National Reference Laboratory sent 59 of 69 (86%) positive CSF samples to Ouagadougou and Oslo. During 2013 15 out of 32 samples were sent (47%). The WHO covers the costs of transporting the samples, which is usually done by DHL. We assumed that ten samples were sent in each shipment. We assumed that costs of analysis in the laboratory in Ouagadougou are

similar to that found in the National Reference Laboratory. The NIPH reported the costs of supplies for the tests they do. However, the costs of salaries and overhead costs are not included. Hence, the costs seen in Table 8.15 are under estimated.

Table 8.15 Costs of processing a meningococcal CSF sample in Ouagadougou and Oslo

	Unit costs (US\$)	Quantity per sample	Total costs per sample (US\$)
Courier service to Ouagadougou, Burkina Faso	152	0.10	15
Ouagadougou laboratory analysis	20	1	20
Courier service from Ouagadougou to Oslo	129	0.10	13
<i>Oslo laboratory analysis:</i>			
Culture	3	1	3
Meningococcal serogroup analysis	2	1	2
Meningococcal antibiotic susceptibility by E-test	20	1	20
Meningococcal antibiotic susceptibility by MLST	50	1	50
TOTAL			123

7. Surveillance case investigation/ follow-up of confirmed cases

To conduct a case investigation and follow-up confirmed cases, cost of staff time, petrol and mode of transport must be considered. 48% of health facilities reported that they undertook surveillance investigations in the communities when a case was confirmed (n=11). When this occurred, the *Responsible* went to the home of the patient to brief the family about signs of surveillance and would often search the village for further cases. The case investigation duties were assumed to comprise of the health facility *Responsible* traveling to villages by motorbike. The costs associated to following up and investigating one confirmed case are seen in Table 8.16.

Table 8.16 Costs of investigating one meningitis case (2012 US\$)

	Unit costs	Quantity	Total costs
CdZ salary (minute)	0.05	240	11.64
Petrol (litre)	1.38	1	1.38
Motorbike (hour)	1.53	1	1.53
Total			14.55

8. Reporting and data analysis

Resources used for weekly reporting are staff time and text messages. As mentioned when the Chadian surveillance system was described, surveillance focal points report Meningitis cases along with the other notifiable diseases on a weekly basis. Based on participant responses, the estimated work attributed to reporting meningitis only lasts 15 minutes per week for each surveillance focal point. This number will invariably vary according to the number of cases being reported. The estimated annual costs for each surveillance officer in charge at the respective levels are summarised in Table 8.17.

Resources for data analysis were minimal and it was assumed that analysis and reporting activities were conducted together (i.e. the CdZ receives the weekly data and simultaneously enters the data into a spread sheet). Hence, additional costs were not collected for these data analysis.

Table 8.17 Costs of reporting per surveillance officer at each level (2012 US\$)

	Unit of measure	Quantity per week	Quantity per year	Unit costs	Annual costs
Health centre Responsible to CdZ:					
Staff time	Minutes	15	780	0.05	37.85
Text message charges	Each	2	104	0.05	5.50
Total					43.35
CdZ to CASE:					
Staff time	Minutes	15	780	0.06	46.79
Text message charges	Each	2	104	0.05	5.50
Total					52.30

	Unit of measure	Quantity per week	Quantity per year	Unit costs	Annual costs
<i>CASE to SSEI:</i>					
Staff time	Minutes	15	780	0.09	73.11
Text message charges	Each	2	104	0.05	5.50
<i>Total</i>					78.62

9. Supervision

Resources for supervision visits are:

- Staff time
- Petrol costs (calculated by average distance [km] per month)
- Vehicle usage

As mentioned when the Chadian surveillance system was described, supervision should occur at every level starting with the central to regional, district, and health facility; regional to district and health facility; and district to health facility. All health facilities should be visited at least once per month. However, this does not always happen. During 2012 one supervision visit to a number to regions was undertaken by three national surveillance staff. The costs of this trip are seen in Table 8.18. At the subnational levels, supervision happened an average of two visits per health facility per month. The average amount of time spent per supervision was calculated at 84 minutes per week for supervision activities for the CdZ and 75 minutes per week for CASE. The costs of these trips are seen in Table 8.19.

Table 8.18 Costs of planned supervision trips in one year by national cadre (2012 US\$)

Expense item	Number of days	Per diem	Salary per day	Total	Proportion of activities related to meningitis	Costs for meningitis surveillance supervision
Laboratory manager	10	64	53	1,164	50%	582
Medical doctor	10	64	53	1,164	50%	582
Epidemiologist	10	64	53	1,164	50%	582
			Petrol per day			
Vehicle	10	106	169	2,752	50%	1,376
<i>Total</i>						3,123

Table 8.19 Estimated annual costs of sub-national supervision and feedback activities in study districts (2012 US\$)

	Unit of measure	Quantity per year ^a	Costs per unit ^{b,c}	Average petrol cost	Annual costs
CdZ to health facility					
Staff time	Minutes	4368	0.06		262
Motorbike	Each	4368	0.03	52	183
<i>Total</i>					445
CASE to health facility					
Staff time	Minutes	3900	0.09		351
Vehicle	Each	3900	0.20	52	832
<i>Total</i>					1183

a Based on an average time spent weekly

b Based on average CdZ and CASE salary per minute

c Based on vehicle usage per minute

10. Communication (IEC)

The inputs for communication are staff time (mainly the *Responsible*) and time spent conducting activities per week. The average time the health staff spent on IEC sessions, which are education sessions about seasonal diseases, including meningitis, was 57 minutes a week (SD = 56). This time was divided across the 12 other disease, assuming that an equal amount of time would be spent on each disease throughout the year. The unit costs of these sessions are seen in Table 8.20.

Table 8.20 Communication unit cost summary (2012 US\$)

	Unit costs	Quantity per week	Total costs
<i>Responsible salary (minute)</i>	.05	4.75	.24

Activity costs summary

Table 8.21 presents final the estimated unit costs for each distinctive surveillance activity.

Table 8.21 Surveillance activities unit costs summary (2012 US\$)

	Activity	Unit costs
1	Lumbar puncture per case	22
2	Transport of CSF from health facility to district laboratory per sample	5
3	District laboratory investigation per sample	13
4	Transport of CSF from district to national laboratory per sample	2
5	National laboratory investigation per positive sample	47
6	Transport of CSF to Oslo and Oslo laboratory investigation	123
7	Surveillance investigation of a confirmed case	15
8	Annual reporting and analysis per health facility	43
	Annual reporting and analysis per district officer	52
	Annual reporting and analysis per regional officer	79
9	Annual supervision per district surveillance officer	445
	Annual supervision per regional surveillance officer	1183
	Annual supervision per national cadre trip	3123
10	Coordination activities (IEC) per week	.25

8.2.2 Total costs of meningitis surveillance

Costs by surveillance function

Costs of detection and confirmation

The number of reported cases and the number of CSF samples processed in the study district laboratories were combined with the unit cost estimates for calculating total annual costs of detection and confirmation. Missing and unreliable data did however cause limitations to the estimates. Importantly, when the facilities do not gather data on the number of suspected cases, it is not possible to derive an annual cost estimate because surveillance activities are not conducted that can be attributed to the meningitis.

Table 8.22 shows estimated costs of case detection and confirmation in the seven study districts. As no cases were detected in Moundou, Gounou-Gaya and Guelengdeng, there were no costs for these activities during 2012. The higher amount of cases were detected in the enhanced surveillance districts of Koumra and Goundi due to the 2012 meningococcal meningitis epidemic. Most cases were detected in the MSF supported district of Moissala and the costs in this district were consequently substantially higher than in the other districts. The costs are 24% higher in Moissala than in Goundi.

This function was further stratified by case detection costs and laboratory investigation costs. Case investigation costs included: 'costs of lumbar puncture', 'transport of CSF to district laboratory', 'costs of CSF transport to N'djamena', and 'costs of confirmed cases follow-up'. Cumulatively, case detection amounted to 45 %; the other 55% are attributed to laboratory investigation. Across the seven districts, the estimated average costs was US\$ 28,780 or US\$ 1,718 per 100,000 populations. When extrapolating this to the total population of Chad, which is 12.6 million, **total costs of detection and confirmation in 2012 amounted to approximately US\$ 217,504.**

Costs of data reporting (includes data analysis)

The cost of data reporting and analysis is closely linked to the number of staff working on meningitis surveillance. In the regions these are the health centre *Responsable*, the CdZs and the CASEs. Estimated costs of data reporting in the seven study districts

amounted to US\$ 11, 328 (Table 8.23). This is equivalent to US\$ 676 per 100,000 populations per year. When extrapolating this to the whole country, **the estimated costs of data reporting is US\$ 85,609.**

Table 8.22 Estimated annual costs of meningitis case detection and confirmation in the study districts (2012 US\$)

	No. of CSF analysed in district lab.	Costs of lumbar puncture	Costs of transport of CSF to district lab.	Costs of district lab. analysis	No. of CSF sent to N'Djamena	Costs of CSF transport to N'Djamena	No. of negative or contaminated CSF at nat. ref. lab	No. of positive CSF at nat. ref. lab	Costs of negative and contaminated samples analysis	Costs of positive samples analysis	No. of samples send to Oslo	Costs of transport and processing in Oslo	Costs of confirmed cases follow-up	TOTAL
Koumra	38	845	208	487	38	437	30	8	618	356	6	800	111	3,862
Goundi	170	3,781	928	2,179	15	173	12	3	244	140	3	316	44	7,804
Moundou	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gounou-Gaya	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Guelendeng	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N'Djamena Nord	5	111	27	64	0	0	0	0	0	0	0	0	0	203
Moissala	253	5,626	1,382	3,242	109	1,254	87	22	1,774	1,020	19	2,296	317	16,912
Total		10,363	2,545	5,908		1,864			2,636	1,516		3,412	472	28,780

Table 8.23 Annual costs of data reporting in the study districts (2012 US\$)

	Health centre Responsible to CdZ		CdZ to CASE		CASE to SSEI		Total annual costs			
	Unit costs (US\$)	Quantity (number of health facilities)	Unit costs (US\$)	Quantity (number of health facilities)	Unit costs (US\$)	Quantity (1/number of districts)	Health centre Responsible to CdZ	CdZ to CASE	CASE to SSEI	TOTAL (US\$)
Koumra	43	10	52	10	79	0.25	434	523	20	976
Goundi	43	8	52	8	79	0.25	347	418	20	785
Moundou	43	24	52	24	79	0.25	1,040	1,255	20	2,315
Gounou-Gaya	43	27	52	27	79	0.25	1,170	1,412	20	2,602
Guelengdeng	43	15	52	15	79	0.25	650	784	20	1,454
N'Djamena Nord	43	10	52	10	79	0.25	434	523	20	976
Moissala	43	23	52	23	79	0.25	997	1,203	20	2,220
Total										11,328

Costs of supervision and feedback

Table 8.24 shows estimated costs of supervision and feedback in the study districts. The cost of supervision is also linked to the number of district and regional surveillance staff. Estimated cost of supervision in the seven study districts amount to US\$ 6,967. This is equivalent to US\$ 415 per 100,000 populations per year. The national costs of supervision amounted to US\$ 3,123 or US\$ 24 per 100,000 population. The estimated extrapolated total **cost of supervision in Chad is US\$ 55,582.**

Table 8.24 Annual costs of subnational supervision in the study districts (2012 US\$)

	Unit cost (district)	Number of CdZ	Total district	Unit cost (region)	Number of CASE	Total regional	Total
Koumra	445	2	890	1,183	.25	296	1186
Goundi	445	1	445	1,183	.25	296	741
Moundou	445	3	1,335	1,183	.25	296	1631
Gounou-Gaya	445	1	445	1,183	.25	296	1186
Guelengdeng	445	1	445	1,183	.25	296	741
N'Djamena Nord	445	1	445	1,183	.25	296	741
Moissala	445	2	890	1,183	.25	296	741
Total			4,895			2,072	6,967

Costs of Communication (IEC)

Communication was the only support function other than ‘supervision’ that costs were estimated for. The other two support functions, training and coordination, were not estimated due to marginal attributable costs for meningitis (this is explained more in the discussion section). Communication costs were linked to self-reported cumulative staff time on these activities. The cost of IEC sessions was calculated by multiplying average time spent on activities per health facility across study districts, per year (Table 8.25). The estimated cost is US\$ 1,404 or US\$ 84 per 100,000 population. **The estimated extrapolated total cost of IEC activities in Chad US\$ 10,610.**

Table 8.25 Annual costs information, education, and communication in the study districts (2012 US\$)

	Quantity (no. of HFs)	IEC annual cost	Total
Koumra	10	12	120
Goundi	8	12	96
Moundou	24	12	288
Gounou-Gaya	27	12	324
Guelendeng	15	12	180
N’Djamena Nord	10	12	120
Moissala	23	12	276
<i>Total</i>			1, 404

Total costs of core and support surveillance activities

Table 8.26 summarises the total costs of core and support meningitis surveillance across the seven study districts. Costs were hampered by zero case-reporting in three districts, but Moissala and Goundi reportedly spent (an average of) twice the costs of Koumra district, which was third in cases reported. Similarly, these districts, which are both externally supported, spent much more on per 100,000 population than the other districts.

Table 8.26 Estimated total costs of surveillance functions per 100,000 population in the study districts (2012 US\$)

	Detection and confirmation*	Reporting and analysis	Supervision and feedback	Communication (IEC)	Population	Costs per 100,000 population
Koumra	3,862	976	1,186	120	189,029	3250
Goundi	7,804	785	741	96	158,379	5951
Moundou	0	2,315	1631	288	393,876	1075
Gounou-Gaya	0	2,602	741	324	293,583	1249
Guelengdeng	0	1,454	741	180	214,254	1108
N'Djamena Nord	203	976	741	120	166,100	1228
Moissala	16,912	2,220	1,186	276	260,145	7916
Total	28,780	11,328	6,967	1,404	1,675,366	2,894

When adding up the estimated costs of detection, confirmation, data reporting and analysis, and supervision and communication, the **total costs of meningitis surveillance in Chad was estimated at US\$ 393,000**. This is equivalent to **US\$ 2,894 per 100,000 populations and 0.03 per capita**. Laboratory investigation (and confirmation) comprised 30% of the costs, case detection 25%, supervision 20%, reporting 22%, and communications 3%. Table 8.27 shows the costs per 100,000 of each major functional category. Additionally, most of the surveillance costs were attributed to core functions; supportive functions (i.e. supervision and communication) represented just 23% of the costs. Confirmation and detection, which include laboratory investigation, contributed more than half of the aggregated national costs.

Table 8.27 National extrapolation of meningitis surveillance function total costs (2012 US\$)

	Total costs (Chad)	Costs per 100,000	Costs per person
Confirmation and detection	217,504	2.18	0.017
Reporting and analysis	85,608	0.86	0.007
Supervision*	79,278	0.79	0.006
IEC	10,610	0.11	0.001
Total	393,000	2.18	0.03

*includes sub-national and central supervision activities for one year

Table 8.28 Costs of study districts by surveillance strategy (2012 US\$)

	Total cost	Mean cost per case	Mean cost per 100.000 population	No. of cases	Population	Costs per capita
Sample ENS districts						
Koumra	6,144	162	3,250	38	189,029	
Goundi	9,426	55	5,951	170	158,379	
Moundou	4,234	0	1,075	0	393,876	
TOTAL	19,803					
Average ENS	6,601	72	3,425	69		0.00052
Sample Partial CBS districts						
Gounou-Gaya	3,667	0	1,249	0	293,583	
Guelendeng	2,375	0	1,108	0	214,254	
N'Djamena Nord	2,040	408	1,228	5	166,100	
TOTAL	8,081					
Average partial CBS	2,694	136	1,195	2		0.00021
Sample CBS districts						
Moissala	20,594	81	7,916	253	260,145	
Average exclusive CBS	20,594	81	7916	253		0.00163
National extrapolation						
Total cost ENS in Chad			433,642		12,661,091	
Total cost pCBS in Chad			151,300		12,661,091	
Total cost eCBS			1,002,251		12,661,091	

Table 8.28 details the costs per surveillance strategy and shows that mean cost per case was higher in districts that implemented partial CBS but costs per capita were highest in Moissala, the only district with exclusive CBS. This suggests that higher investment in a non-passive system may improve efficiency. The ENS district had the lowest mean cost per case, which is expected since this is essentially a passive system. Costs per 100,000 in Moissala were more than two and six times the costs of enhance surveillance and partial CBS, respectively. For all of Chad to achieve the case-based surveillance at the Moissala/MSF standard would require nearly triple the current investment.

Probabilistic uncertainty analysis

The probabilistic uncertainty is reported in Table 8.29 and Table 8.30. The probabilistic distribution around the total costs shows a narrow range around the base case; even at the maximum value of the Monte Carlo simulation of US\$ 435,521, the costs per capita remains .03. Since 60% of the simulations produced values less than US\$ 400,000, there is a high probability that the calculated base case costs are useful estimates for planning and decision making (Figure 8.3 & Figure 8.4).

Probabilistic simulation distributions are similar across the three functions and hovers around 15% on each side (minimum and maximum) (Figure 8.5, Figure 8.6, and Figure 8.7.); it is slightly wider for 'supervision and feedback' (Figure 8.6).

Table 8.29 Probabilistic uncertainty analysis (2012, US\$)

Variable	Results
Total costs of meningitis surveillance in Chad Base case	392,994
Simulation results:	
Mean	396,241
St. Deviation	10,482
Minimum	361,836
Maximum	435, 521

Table 8.30 Probabilistic uncertainty analysis by surveillance function (2012, US\$)

Function	Cost per 100,000 population: Base case value:	Min	Max
Detection and confirmation UV*- Number of CSF analysed	28,780	25,060	33,387
Supervision and Feedback UV – Number of CDZs per district	10,088	8,262	11,849

Communication (IEC) UV – Number of health facilities per district	1,404	1,180	1,622
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* UV = uncertainty variable

In conclusion, the sensitivity analysis confirms that the estimated values per function and for the total costs of meningitis surveillance in Chad can be considered reliable in the context of this evaluation. The findings of this probabilistic analysis suggest that the impact of varying the selected parameters is minimal on the total costs (This is illustrated in the following distribution charts in Figure 8.3 thru Figure 8.7).

Figure 8.3 Probability distribution of simulation results for total costs of meningitis surveillance in Chad (2012)

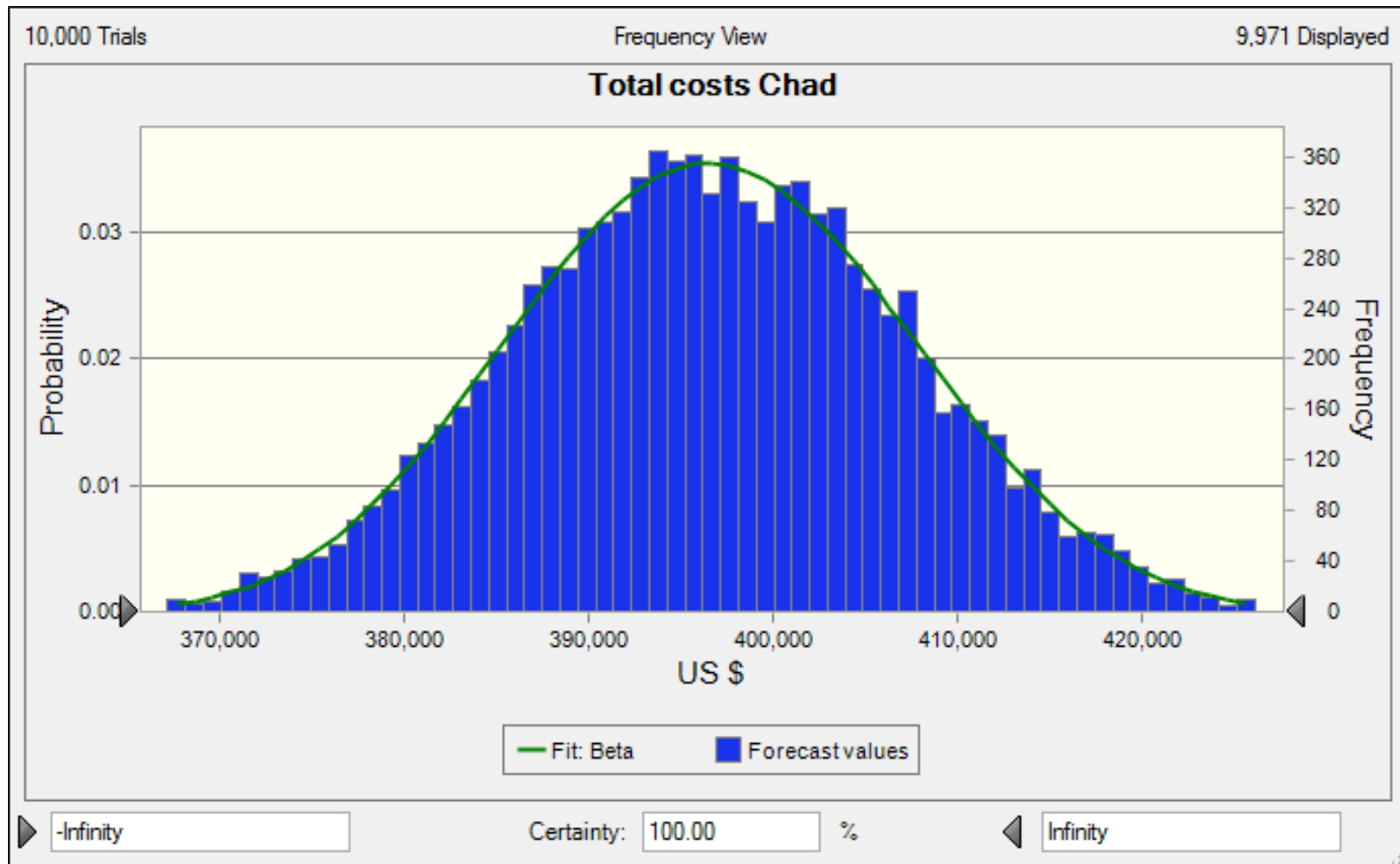


Figure 8.4 Cumulative frequency of simulation results for total costs of meningitis surveillance in Chad (2012)

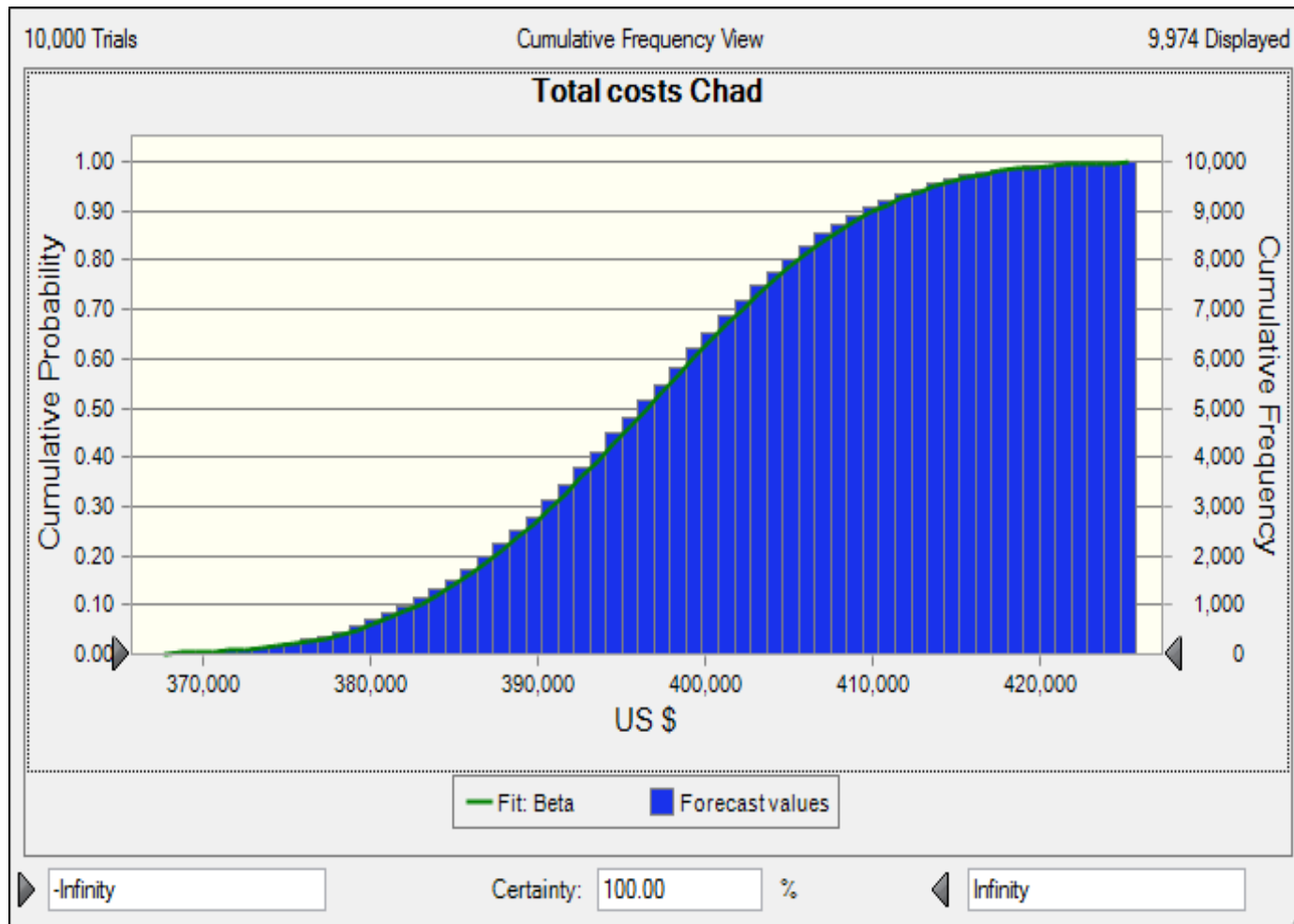


Figure 8.5 Probability distribution of simulation results for detection and confirmation costs

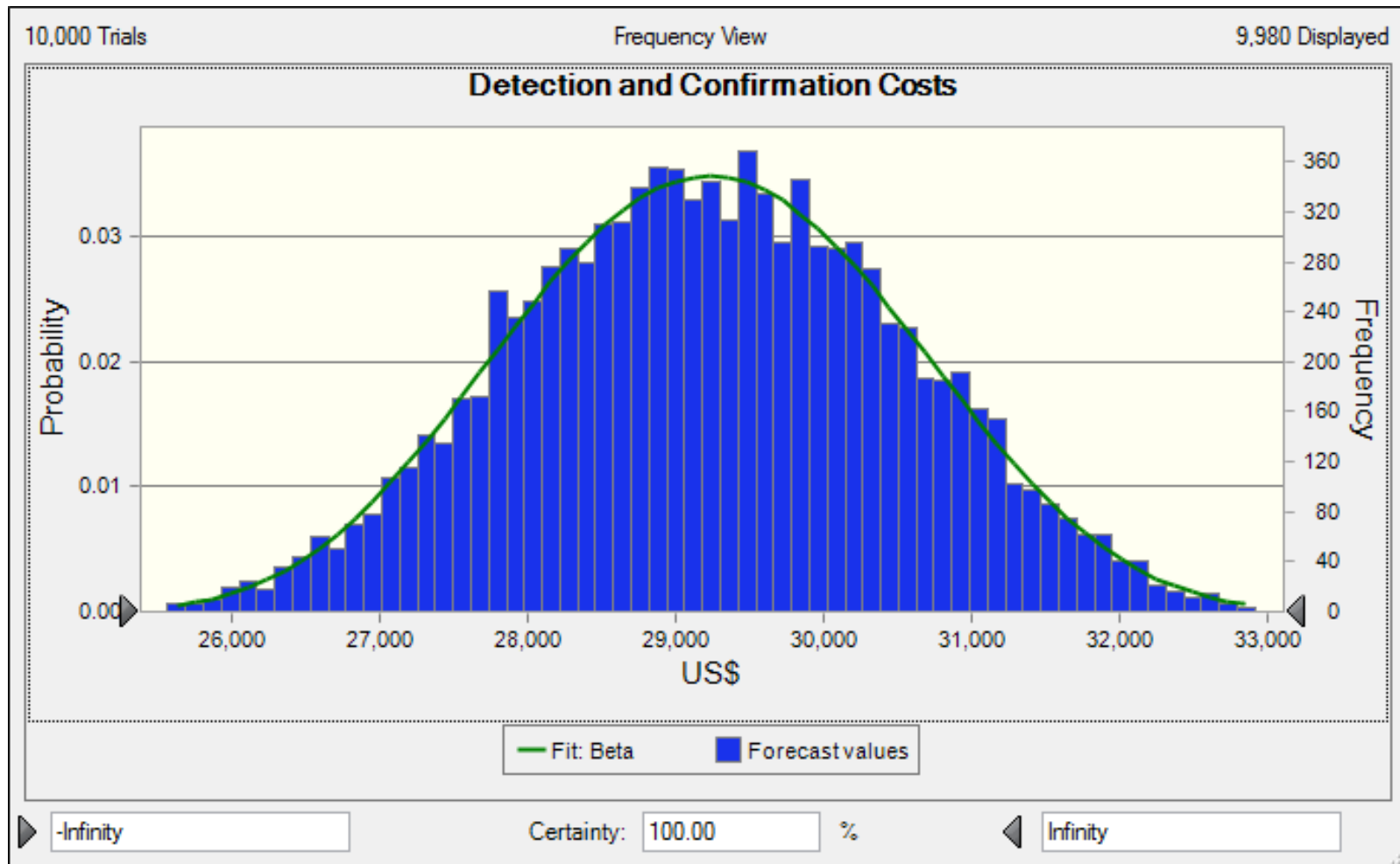


Figure 8.6 Probability distribution of simulation results for supervision and feedback costs

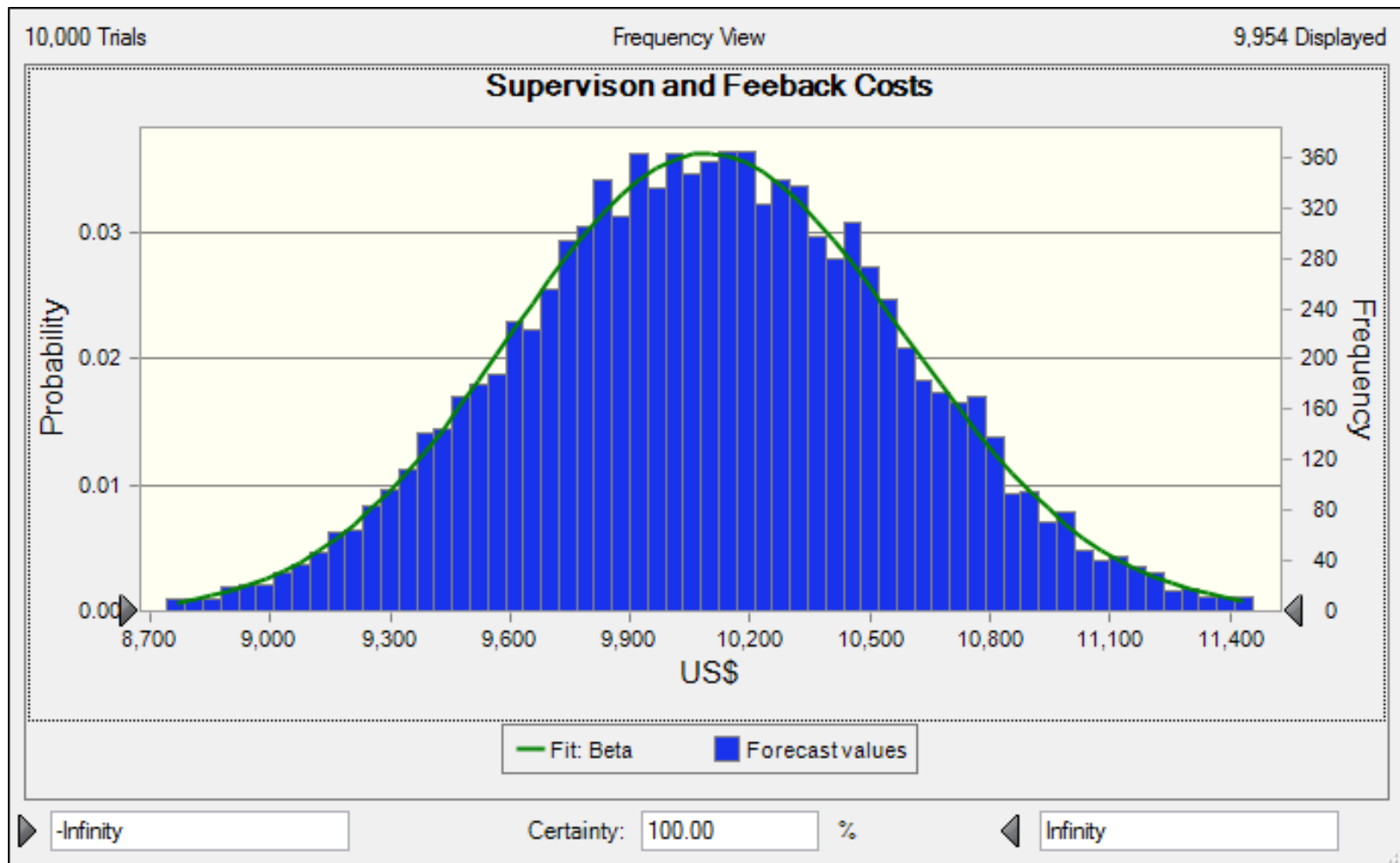
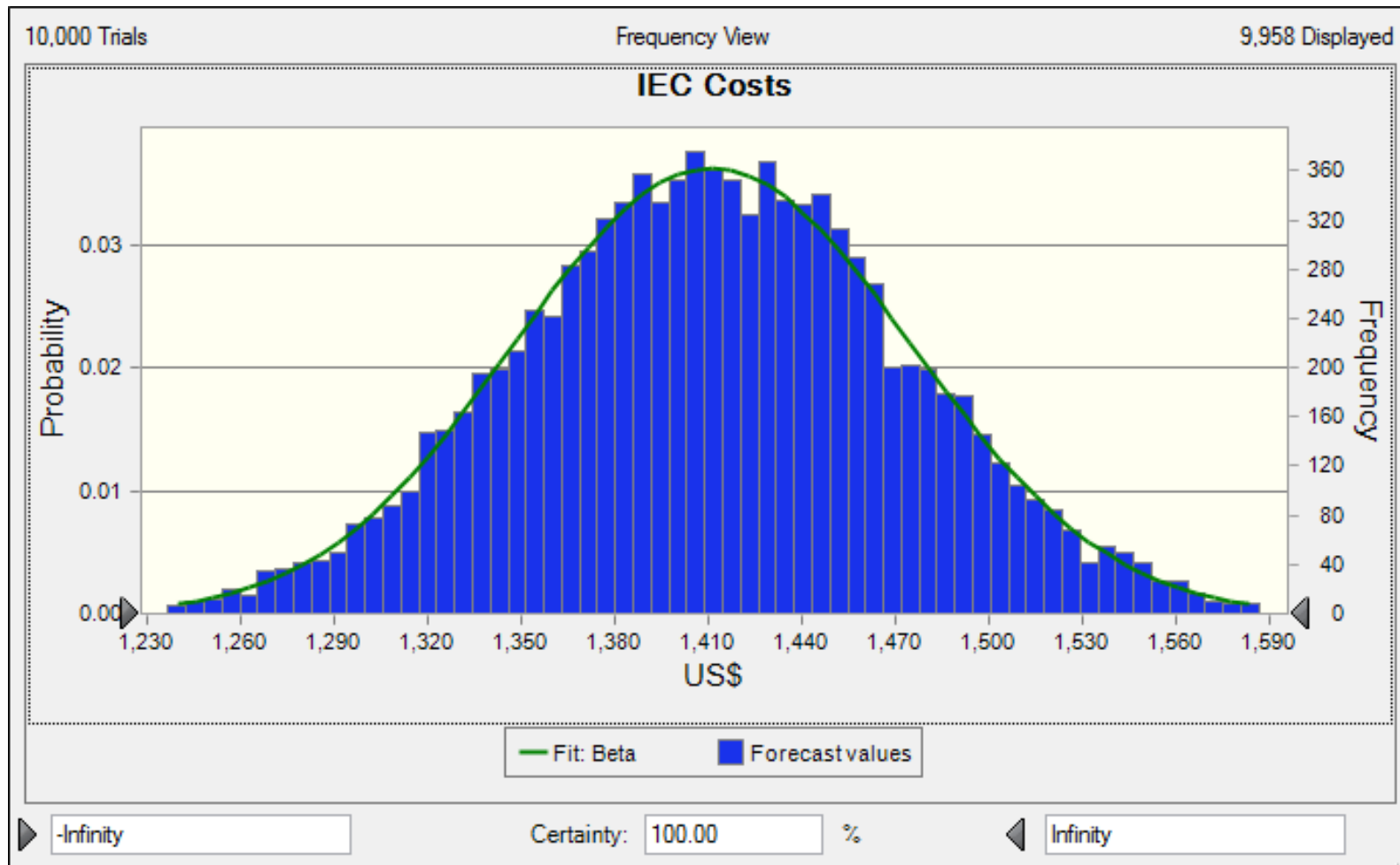


Figure 8.7 Probability distribution of simulation results for information, education, and communication costs



System efficiency

The study also aimed to calculate the efficiency of the current system based on estimated costs. **The intended method, was to use the total aggregate costs of surveillance US\$ 393,000 and calculate the national costs per case of suspected, investigated, and confirmed meningitis cases in 2012.** Unfortunately, the inconsistency between data sources presented a challenge to accurately calculating these indicators at the national level. Four district laboratories (N'djamena Nord, Koumra, Goundi, and Moissala) reported cases in 2012 and these figures were used as the best available denominators to calculate the efficiency indicators.

To determine the estimated costs per suspected (or detected) case, the estimated costs for case detection, reporting and analysis, and IEC activities was calculated. The total costs for laboratory investigation in these districts was used to estimate investigated and confirmed cases, these district totals of these costs are provided in Table 8.31. The following efficiency indicators were calculated:

- US\$ 34 per suspected meningitis case
- US\$ 35 per investigated meningitis case
- US\$ 100 per confirmed meningitis case

Table 8.31 Summary of reporting district laboratories costs for efficiency indicators, n = 4 (2012, \$US)

Total CSF received and analysed	Total CSF confirmed	Total surveillance costs (US\$, 2012)	Total laboratory investigation	Total case detection, reporting, and IEC
<i>466</i>	<i>158</i>	<i>38,204</i>	<i>15,830</i>	<i>18,520</i>

8.3 Comparison of Chad surveillance costs with other cost study results

The purpose of conducting this cost-analysis for CDSS was to aid decision makers in Chad determine the cost of the current surveillance system. The cost analysis performed for this study is primarily intended to guide management and inform budget development. While some surveillance cost studies have been undertaken since the WHO guidelines were published, the evidence is still scarce. Still, the available studies show similar findings, which are summarised in Table 8.32.

In 2012, the annual costs for meningitis in Chad was approximately US\$ 393,000 (US\$ 2,894 per 100,000 populations [US\$ 0.03 per capita]). Lukwago *et al.* (101) reported total annual IDSR costs for Burkina Faso, Eritrea, and Mali at US\$ 690,957, \$476,208, and US\$ 270,360, respectively. The costs for Chad are largely conflated with IDSR but also include laboratory analysis for meningitis—the Lukwago study does not include laboratory or treatment costs. The surveillance costs spent per capita recorded in the present study were similar to Mali and Burkina Faso. In Chad, laboratory analysis was the largest cost driver, amounting to 30% of total costs. This was followed closely by supervision, which was 25% of the costs. This was a similar finding in Niger where laboratory investigation accounted for 51% of costs. However, in most of the other studies, ‘personnel’ was generally the largest cost driver. This is also true for Chad, though in the above analysis surveillance functions and activities include salary costs.

Several studies also reported similar challenges to estimate costs accurately due to missing data and difficulties in allocating shared costs to IDSR specific activities (101, 207). Also, Toscano *et al.* reported the challenge of quantifying specific surveillance costs since they are shared across other programmes and encompass a range of activities (106).

Table 8.32 Comparison of present study results to other CDSS cost evaluations

Study description	Country/countries	Findings
Cost analysis of meningitis surveillance (Present study)	Chad	.03 costs per capita Largest cost driver: laboratory investigation and surveillance
Cost analysis of meningitis surveillance (207)	Niger	.012 per capita Largest drivers: laboratory investigation and personnel costs
Cost analysis of IDSR (105)	Burkina Faso, Eritrea, Mali	Mali: 0.02 per capita Burkina Faso: 0.04 per capita Eritrea: 0.16 per capita Largest cost driver: Personnel
Cost associated with meningococcal disease outbreak (104)	Colombia	Total costs of surveillance: \$3,935 Cost per 100,000 for disease surveillance = 0.04 Largest cost driver: personnel costs
Cost analysis of integrated vaccine preventable disease surveillance (106)	Costa Rica	Total annual cost: US\$ 420, 000 Largest cost drivers: Laboratory and personnel

Of the few studies that assess the cost of CDSS, most do not provide unit cost or cost per unit. The Niger study stratified costs proportions and examined the allocation of spending by surveillance function similar to what we did in Chad, but did not calculate unit costs beyond cost per suspected case and mean cost per case. My analysis provides an interesting insight to the unit costs of surveillance activities. The basis of this information could be used to conduct more ambitious analysis, such as a cost-effectiveness analysis. Moreover, the ability to separate unit costs for each activity is very useful to forecast budgets for disease programmes and can be used to optimise task sharing.

8.4 Contributions and limitations of the cost analysis to CDSS evaluations

This study adds to the existing literature on the costing of disease surveillance, which is limited. Even among these few studies, this study is unique in that it provides unit costs for surveillance activities. This study, together with the Niger study, is expected to contribute to the understanding of the costs of meningitis surveillance in the countries along the African Meningitis Belt. The cost analysis offers a first snapshot of the nature of costs incurred in performing case-based and enhanced meningitis surveillance. It outlines the resources and activities needed at each administrative level and highlights the main cost drivers by surveillance function and activity.

The study sample includes the range of facilities and surveillance offices involved in meningitis surveillance. This range is key to understanding differential costs incurred by different types of facilities. The multiple breakdown of costs across surveillance functions and activities presented with relevant performance results provide insight to how investments in specific activities, for example 'specimen transport', can be increased to improve surveillance system indicators, such as number of '*Percent of probable bacterial meningitis cases with a known outcome recorded*'. Equipping policymakers with crucial financial information can allow for the selection of an appropriate surveillance strategies in terms of economic feasibility, long-term sustainability, and compliance with existing standards. The analysis in this thesis focused on activity-focused costing and stratification, while this did not include a costs per administrative level, the activity costs could be designated to the appropriate level and estimated accordingly, in a later step. Finally, the findings from the Chad and Niger studies will provide a tool to calculate meningitis surveillance costs of other countries through a user-friendly spreadsheet.

Particular risks in both over- and under- estimating have also been highlighted throughout. The risk of under-estimating is due to the lack of data in several of the districts and the risk of over-estimating when using the Moissala and Goundi suspected

case numbers for the national extrapolation—as mentioned their numbers were high because they experienced a meningitis outbreak at the time of the study collection period. With the perceived efficacy of the new conjugate vaccine it is speculated that average number of suspected cases should be less (though they should not be zero for reasons already mentioned). Without the availability of surveillance sensitivity indicators for expected suspected cases, it will be difficult to include predicted cases in a baseline budget.

Some of the cost estimates may not be accurate due to the difficulty in isolating meningitis activities from other IDSR activities. The estimated allocations made to meningitis surveillance that were based on expert's opinions may or may not be accurate or generalizable to other settings. This limitation is primarily a result of a shortcoming that is larger than the study, which is the predominance of disease-specific funding that focusses on narrow objectives instead of how to make improvements across several disease programmes or throughout the system. This also underscores the complexity of this type of cost analysis.

Another limitation was that this study was difficult to compare to existing studies since additional analyses were not undertaken, such as analysis of capital versus recurrent costs analysis. While this was mainly due to the unit-cost focus of this analyses, missing data such as overhead costs also made this difficult. Additionally, though higher level budget analyses are useful, the upgrading activity presented in Chapter 9 also provides broader categories of costs that can provide approximate estimates from actual surveillance activity costs (especially at the sub-national level) and can be used to forecasts future budgets. Finally, in addition to the aforementioned data-quality and availability issues another limitation of the study was that the health facilities were not selected randomly, which may affect the representativeness of their mean costs.

9 Upgraded system costs and components

In addition to the current costs, the study also estimated the costs of upgrading the surveillance system to an 'operational standard'. The operational standard relies heavily on improved relevant skills, established systems and adequate resources to perform optimal meningitis surveillance. In this chapter, several upgrading result-scenarios are presented. First, a breakdown of identified resources that are needed to upgrade the system. This is followed by an incremental costs analysis of total cost to upgrade the system and costs proportions per activity. The third result summarises the three-district pilot plan budget that was developed for Chad.

9.1 Methods

The incremental costs to improve the system were calculated in Chapter 8 and is defined as the additional costs needed to achieve an operational standard of meningitis surveillance throughout Chad. Necessary resources needed to scale up the current surveillance system to an upgraded standard were determined in accordance with technical, national, and international standards. Experts from LSHTM, the Chad Ministry of Health, and WHO staff also reviewed and modified resources to make recommendations Chad-specific.

The following approach was used to create the operational standard:

- 1) **Define the gap** between the current surveillance system and the operational standard by first reviewing performance findings, participant feedback, and national and international performance standards and then determine the activities needed to bring the current system up to the operational standard.
- 2) **Identify the needs at core function level or/and jurisdiction** revealed in the performance assessment and through participant and subject matter expert interviews.
- 3) **Construct a feasible operational standard** for meningitis surveillance in Chad.

- 4) **Summarise the resources needed** for implementing the ideal standard in various scenarios.

9.2 Results

9.2.1 Upgraded system components

Appendix 5 shows the components of the recommended 'operational standard' for meningitis surveillance in Chad by presenting existing activities as well as suggested improved activities for each health level and surveillance function: (a) the current surveillance activities performed, (b) the activities needed to upgrade the system to the operational standard and (c) the inputs needed for each activity.

The upgrading model addresses each administrative level and organizes activities by core function (or support activity). This upgrade approach intends to create a path for comprehensive surveillance system building from foundational capabilities to maintenance of strong levels of functionality. This information is intended to be used to prepare a detailed budget for upgrading activities.

Description of recommended upgrade activities

Training: Training was identified as a crucial need at every administrative level and by each group interviewed. Only 9 health facilities reported having had a training on IDSR. IDSR is a key component of the health system; when it is functional, it can provide the data needed for rational decisions and resource allocation choices. Clear guidelines for meningitis and other priority diseases must be given at this training. The CASE and national level should have funds allocated to plan and execute such trainings. The CASE should coordinate each zonal training (which includes all health facilities in each), and the national level should coordinate the training for the CASE and CdZ. IDSR training should occur periodically. In the upgrading model we recommend an annual training.

The upgrading model introduces another level of actors for meningitis surveillance, namely district hospital staff. This evaluation found that lumbar punctures were not often being performed, and when they were performed only one tube of CSF was sent to the district laboratory instead of two tubes as stated in existing guidance. District hospital staff should receive periodic clinical training on lumbar puncture and correct CSF collection methods.

Additional training needs were identified by the district, regional, and national laboratories and includes quality assurance and control and specific tests and disease investigation techniques for meningitis and other priority diseases. These trainings should occur periodically, but not necessarily annually.

Personnel: The request for at least one additional skilled professional employee at the health facility was noted in most health facilities. This was also noted in 5 of the 7 district health offices and at the regional and national laboratories. This person's work would primarily be to provide administrative support and perform surveillance functions across disease programmes, for example at the health facility level they would review the register, fill out case forms and report to the CdZ. They would also do follow-up, an activity that was missed many times, due to overburdened personnel. An appropriate staff member who works with the surveillance budget or national plan of action should correspond with regional and district leads to formulate the particulars of this resource.

Systemized reporting system: As described in the performance evaluation, several weaknesses were found in the reporting system, primarily at the health facility level. As the main causes for this was lack of paper-based forms as well as a lack of storage facilities for archived information, the upgrading model recommends either purchasing storage structures or transitioning to a full electronic reporting system. An intermediate step of purchasing storage structures, such as desks or filing cabinets

would be useful to organize current forms. It may be more cost effective to begin a Health Management Information System (HMIS) by digitizing the entire process.

At the health facility level, it is recommended that health facility managers have sufficient credit and functional mobile phones in order to report cases on time. This is because nearly all the CdZ reported that RCS submit weekly data via SMS.

At the district and regional levels, laptops and mobile phones are recommended –with sufficient credit for both. Also, since both CdZ's and CASE's reported periodically collecting monthly forms from health facilities, petrol allowances should be included in the budget as well as transport costs (e.g. maintenance of existing vehicle or cost of hiring a vehicle). At these levels some basic data analysis should be performed to review area status.

Electronic reporting capability at the district laboratory level is also recommended; preferably a system that can notify the national laboratory when specimens are sent. This could be as simple as an email. Additionally, at least one laptop, mobile phone, and sufficient monthly credit for each district laboratory is recommended.

At all levels, including district laboratories, epidemiological data should be transmitted by use of duplicate forms, such as carbonless forms and carbon copies.

Patient referral/transport system: The suggestion to implement a patient referral system at all health facilities is an essential component of the recommended district-based surveillance strategy and is supported by the success of a similar system in the Moissala district. This upgrade activity would be put in place at the health facility level. Each suspected meningitis case will be given complementary transport to ensure they reach the district hospital for lumbar puncture and treatment. Contracts with specific clandomen or motorbike companies to ensure appropriate care for patients is a

potential method to secure a transport mechanism. A patient referral form should accompany each patient and a copy should stay at the health facility.

Specimen transport network: The upgrade model corrects some deviations to guidelines with the suggestion of a specimen transport network. This study found the method of sending to district and national laboratories was haphazard due to lack of appropriate shipping materials. The recommended upgrade follows the WHO transport network guidelines, which comprise of sufficient triple packaging and T-I and an established transport method for shipping specimen (208). This transport system could be a dedicated courier service or could be a designated MSP or WHO staff responsibility.

Supervision: While a written supervision framework exists, this study observed that it is not achieved due to lack of adequate resources. The upgrade model reinforces existing activities by identifying inputs at each level to carry out scheduled supervision visits.

Monitoring and evaluation of district data: This upgrading model introduces monitoring and evaluation of district data at the regional (i.e. CASE) level. Measurements of surveillance quality, such as timeliness and completeness of reporting, analysis of data, outbreak response and case fatality rate, are necessary for taking action on the findings. Regular evaluation and feedback of district results will encourage motivation of high surveillance performance. This can be done as part of supervision to the district level or as a separate activity, where all CdZs meet the CASE to review data.

Feedback: Adequate feedback was missing at all levels in different surveillance areas. The upgrade model includes notification of results from the highest level of confirmation (national laboratory) to the primary level of health facility and patient. This should be done in a timely manner. Feedback also includes review of

epidemiological data. Finally, the national level must provide feedback to all levels in a periodic medium such as a monthly bulletin or by posting national summary reports online. This allows for situational awareness by disease for all appropriate health personnel.

Lab reagents and RT-PCR: Laboratory capacity, in terms of staff and equipment for meningitis surveillance has already been established. However, stock-out of reagents and rapid diagnostic kits at the district and regional level prevented necessary meningitis analysis. The upgrade model recommends sufficient supplies and reagents for each test. At the national level, a real-time PCR machine is recommended to replace the current standard PCR machine. This will reduce the number of specimens sent to the Oslo reference laboratory.

9.2.2 Incremental costs to upgrade system

National extrapolation to an operational standard

Due to the additional resources and higher quality of coordination and organization in Moissala and Goundi districts, the most consistent and accurate surveillance data were provided by these sites. It is likely that because both of these districts receive external support their surveillance system is already operating similarly to the recommended upgraded system detailed above. Taking the average estimated costs of these two districts amounts to US\$ 6,934 per 100,000 populations. If Chad were to consider a national operational standard for meningitis surveillance as a hybrid of these two districts' systems, it could extrapolate this value to the whole country. **This raises the annual costs of operating the meningitis surveillance system to US\$ 877,898. This is an increase of 123% compared to the estimated costs in 2012.**

Incremental costs by activity

In order to understand how the incremental costs would be distributed across surveillance activities I used the performance assessment findings of our study sites

and extrapolated them to illustrate the current proportion of sub-national sites (health facilities, district laboratories) achieving the operational standard. This then left the proportion of the other sub-national not achieving the operational standard, which also represents the amount of resources that are needed for the systems. For example, for (IDSR) training, only 48% of health facilities reported having any staff that received training in the previous two years. In order to meet the standard that all health facilities receive training, a 52% investment of resources should be considered.

Table 9.1 further describes the indicators used to estimate the proportion needed to improve the system. Figure 9.1 illustrates the proportion of investment needed to upgrade the meningitis system according to the identified needs outlined in the earlier section.

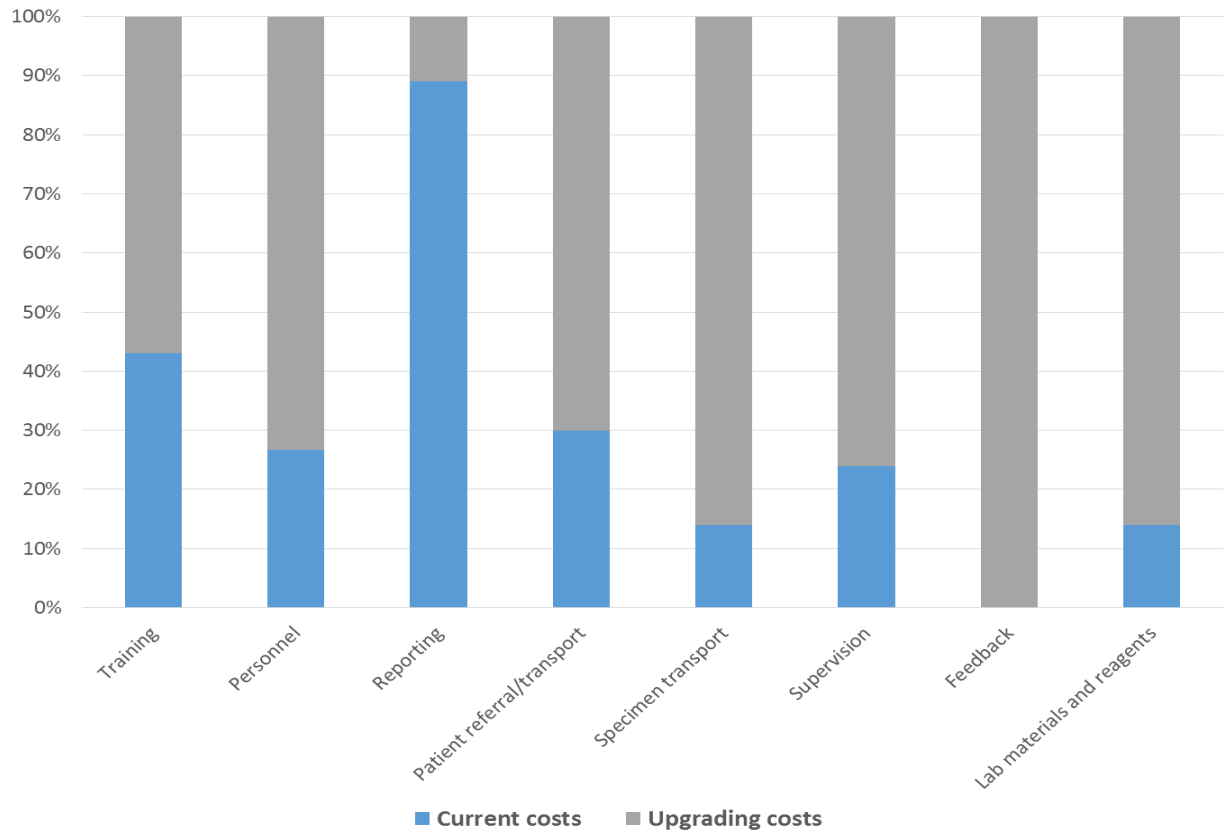
This analysis is consistent with the other results, and shows that in order to upgrade the current system to an operational standard, more than 100% of the current investment is needed for most surveillance activities. Most of the upgrading costs would be attributed to activities associated with case detection and confirmation (i.e. training, personnel, patient referral, specimen transport, and lab materials and reagents).

This analysis provides a visualisation that can help highlight the issues, but does not directly reflect the costs findings and budget needs. For example, Figure 9.1 shows that supervision, which is one of the largest cost drivers at estimated 20% of the current total costs, would require a near 80% increase in resources/investments based on the selected performance indicator. This costs seems inflated, unless a majority of those costs were invested in capital inputs such as motorbikes and vehicles. Alternatively, this high cost estimate may reflect that the indicator used to calculate this proportion is not robust enough to accurately assess supervision activities.

Table 9.1 Description of indicators used to assess proportion needed to upgrade

	Indicator	Target
Training	Proportion of health facilities that received IDSR training in the last two years	100% of health facilities staff trained in IDSR in the last two years
Personnel	Proportion of health facilities that meet standard of health personnel per 1000	100% of health facilities have 2.28 health personnel per 1,000 population
Reporting	Proportion of health facilities that report on time	80% (for the purpose of this exercise, it is increased to 100% since this indicator is already met in Chad)
Patient referral/transport	Proportion of health facilities that have a patient referral/transport network in place	100% of health facilities with a patient referral/transport network in place
Specimen transport	Proportion of district laboratories that have a specimen transport network in place	100% of district laboratories that have a specimen transport network in place
Supervision	Proportion of health facilities that have had supervision in the previous three months	100% of health facilities have supervision in the last three months
Feedback	Proportion of probable cases with result fed-back to RCS	100% of probable cases with result fed-back to RCS
Lab reagents, materials, equipment	Proportion of laboratories with no stock-out of materials or reagents in the previous one month	100% of laboratories do not have stock-out of materials or reagents in the previous one month

Figure 9.1 Proportion of upgrading costs compared to current costs at sub-national level



9.2.3 Pilot plan to optimize meningitis surveillance in Chad

Following the present study, the WHO country office in Chad requested a pilot plan that incorporated our findings and recommendations. The resulting plan was an eight-month, three-district case-based surveillance strategy, and we recommended that it be piloted in Moundou, Moissala, and Goundi districts. This is because of the regional laboratory, which needed support in Moundou, and because Moissala and Goundi were 1) high risk districts for meningitis, 2) were already operating strong surveillance and 3) would eventually transition from external support to government ownership. The plan used components of an existing proposed 18-district plan and suggested that three districts were more manageable. The strategy focused on alleviating the workload

of the *Responsables* at the health facility level by increasing support for integrated activities and by establishing specimen and patient transport systems.

In addition to the aforementioned upgraded activities to address the many weaknesses in the system, the plan provided a detailed budget of all activities, equipment, and training costs. This budget is shown in Table 9.2. The unit costs for each activity were derived from different sources including, the current study findings, the budget estimates from the existing 18-district plan, and estimates from relevant experts and laboratory suppliers. The 2012 incidences of detected cases in Moissala and Goundi, which were 149 and 89 per 100,000 populations, respectively¹, appeared most probable of what other districts would observe if surveillance performance was improved. Hence, the near average number of 100 suspected cases per 100,000 in each district was used to estimate costs of the plan.

The total costs of this eight-month pilot plan was US\$ 220,396. The upfront cost of introducing real-time PCR (RT-PCR) is high and exclusively due to the cost of the equipment, which was estimated at US\$ 60,000² (27% of the upgrading costs). Even with this, the plan may still be underestimated since the costs for RT-PCR per sample is not included since the unit costs were not calculated in the study. The plan also does not give an estimate for lumbar puncture training for district hospital personnel since these sites were not included in the study and data on number of staff were not available. Finally, it was assumed that this pilot plan would be coordinated by a local non-governmental organisation (as was done with the MenAfriCar study), in order to avoid adding additional responsibilities to the national surveillance staff. The costs for this contract is not included in the plan and it was assumed that the MSP in coordination with WHO would fill-in the missing inputs. The pilot plan was provided to the WHO-Chad in April 2014.

¹ These are the values reported by the Chef du Zones of Moissala and Goundi (also seen in Table 7.9)

² As estimated by Thermo Fisher Scientific <https://www.thermofisher.com/uk/en/home.html>

Table 9.2 Budget for eight month 3-district CBS pilot plan

	National	Moundou	Moissala	Goundi	Total (USD)
<i>Training</i>					
Training workshops for RCS	NA	730	1240	NA ^a	1,970
Training at districts hospitals	NA	?	?	?	?
<i>Supervision</i>					
Supervision - CdZ to health facility	NA	10063	13334	8679	32,076
Supervision- CASE	NA	197	197	197	592
Supervision - National to sub-national	2082	NA	NA	NA	2,082
<i>Lumbar puncture and specimen transport</i>					
Lumbar puncture kits	NA	8,271	5,463	3,326	17,060
Patient referral transport	NA	7878	5203	3168	16,248
Specimen transport to regional laboratory	NA		5203	3168	8,370
Specimen transport to national laboratory	NA	7878	5203	3168	16,248
Specimen quality assurance transport	800				800
<i>Communication (IEC)</i>		3456	3312	1152	7,920
<i>Laboratory analysis</i>					
Microscopes (one per lab)	1678	1678	1678	1678	6,712
Cytologie	400	394	260	158	1,212
Pastorex	4,000	3,939	2,601	1,584	12,124
Gram colorisation	1,200	1,182	780	475	3,637
Culture	6,000	5,908	NA	NA	11,908
Determination du serogroupe	8,000	7,878	NA	NA	15,877
Sensibility aux antibiotiques	2,800	2,757	NA	NA	5,557
RT-PCR machine	60,000	NA	NA	NA	60,000
RT-PCR analysis	?	NA	NA	NA	
				Total	220,396

NA = not applicable; ? = No previous data available

9.3 Discussion

The results provided cost estimates to close resource gaps identified in the evaluation. Since the aim of the WPA is to inform programme budgets for better resource allocation, the ideal next steps, would be to use the activity and input unit costs to estimate the costs of each proposed upgrade component. Inputs (e.g. per diem, annual register, accommodation) could then be calculated by cost multipliers (e.g. number of districts, number of Pastorex kits) to formulate district budgets that reflect reality. The WPA template for budget development shown in Appendix 5 details which expenses should be included in such a future budget. In lieu of calculating specific estimates for each proposed activity, the proportional analysis of incremental costs and the national extrapolation of Goundi and Moissala were estimated as proxy estimates that can be used to plan or advocate resources needed for improving the system. This is a less ideal method, but due to data limitations it was adequate to guide stakeholders in thinking about needs and resource re-allocation.

Even with limited data, the results of the Chad evaluation show that a poorly invested system is highly inefficient as noted by the high cost per detected case and potentially more costly in the long run. The sister-study in Niger, used a similar methodology to estimate incremental costs but benefited from a much stronger surveillance system and more available data. In contrast to Chad, Niger spent US\$ 1,951,562 and .12 per capita on meningitis surveillance in 2012—four times that of Chad. They estimated that the costs to upgrade the current system would only be 9% of current costs (207). The other costs of the system include potential harm to the population; the current Chad meningitis surveillance system is missing many cases of meningitis as suggested from the comparison of the number of cases detected in Moissala and Goundi compared to those in the other districts. The potential for harm is also evident in the lack of trained individuals to do lumbar puncture and the inability of some suspected patients to get to the district hospitals.

The 123% increase in spending for meningitis surveillance may appear steep and is potentially an under- or over-estimate due to the data limitations and assumptions already described. However, such a large estimate calls attention to the low level of current investments and the enormity of the task to implement a meningitis surveillance (and IDSR) system that is beneficial for the health workers and the population. The pilot plan detailed above requires that the MSP spend 56% of its current annual meningitis budget on an eight-month plan operated in three districts. With continued support from the WHO and other partners support, this was a suggested starting point to test the return on investment and demonstrate how to strengthen particular districts to an operational standard in a feasible and sustainable way. Our recommendations also urged that particular attention and resources are devoted to supporting district and regional laboratories and ensuring regular delivery of laboratory supplies. Training in performance of lumbar punctures among appropriate clinical personnel was also suggested as a priority.

10 Discussion and conclusion

The essential functions of communicable disease surveillance are not contingent on setting. Whether investigating the remaining polio cases in Pakistan or tracking Middle East Respiratory Syndrome Coronavirus infection around South Korea, public health systems must have the ability to detect and confirm new cases, report and analyse disease data, and respond to health events in a timely manner. This intrinsic structure lends itself to straightforward standard CDSS guidelines. Yet, in countries with underdeveloped health systems, competing factors present challenges to adopting these guidelines and to realising the operational potential of communicable disease surveillance. In such cases, in order to ensure that basic functions are performing as intended, evaluations must consider potentially hidden gaps and hindrances so that recommended corrections are appropriate and feasible. This thesis examined the usefulness of standard evaluation CDSS guidelines in such contexts and documented the outcomes of applying a novel work-process methodological approach to evaluating meningitis surveillance in Chad.

10.1 Summary of thesis findings

In Chapter 3, I presented the results of a systematic review of 20 CDSS evaluations in low- and lower-middle income countries, which found that every study used the WHO or CDC frameworks in some capacity to guide study design and methods.

In Chapter 5, I introduced and described the new WPA approach tailored for CDSS. The chapter also gave an overview of the methods used to evaluate the cost and performance of meningitis surveillance in Chad.

In Chapter 6, I described the PHSS in Chad and the theoretical logic model for the meningitis surveillance system, as informed by meningitis, surveillance, and laboratory

experts. This logic model was used as a reference to compare actual and expected performance. This mapping exercise revealed that the national surveillance programme was only nominally integrated and in reality operated through several parallel and redundant systems.

In Chapter 7, I presented findings from five levels of analysis to assess the performance and operations of the meningitis surveillance and IDSR in Chad. After describing the IDSR structure, the subnational analysis found that performance was weakest for case detection and confirmation functions at the health facility and laboratory levels. Other key findings at the health facility level included the lack of data archival ability and multiple immediate notification, and sample collection forms with differing formats. Another key finding was that poor adherence to CSF specimen handling and shipping procedures resulted in high levels of contaminated samples.

At district- and regional- levels, varying population estimates and lack of demographic and health survey data inhibited the surveillance officers' ability to estimate reliable epidemiological rates and thresholds. Further comparison of district performance by surveillance strategy showed that Moissala and Goundi were the only districts that operated surveillance in close compliance with national and regional SOPs. Both districts received additional funding from non-governmental entities. Their data on resource costs and unit estimates were later used to inform the proposed CDSS operational standard.

In Chapter 8, I calculated the costs for the three surveillance strategies as well as costs per surveillance activity. The main cost driver for meningitis surveillance in Chad was laboratory investigation, which accounted for 30% percent of costs. The national meningitis surveillance system spent an estimated \$0.03 per capita.

Chapter 9 presented the combined cost and performance data used in the meningitis surveillance operational standard recommendation. We found that the incremental cost

for upgrading all of Chad to this standard would require a 123% addition to the programme. Subsequently, upon the request of the *Ministère de la Santé Publique*, a three-district sentinel surveillance pilot study with budget was proposed to demonstrate feasibility and effectiveness of suggested changes to the system before attempting large-scale implementation.

10.2 Empirical validation of the WPA approach

This thesis redesigned a non-public health assessment concept into a CDSS evaluation approach for particular use in low- and lower-middle income countries. To the extent of my knowledge, this was the first time the WPA approach was used in a resource-constrained setting in the evaluation of a CDSS. This section examines the validity of this new approach by reviewing its merit to the present evaluation study in relation to the empirical literature as well as its added benefit to the existing CDSS evaluation frameworks.

To reiterate the operationalisation of the approach: the WPA tools were customised for the Chad evaluation. The tools are the logic model, work-process tree, and performance indicators for the present evaluation. From these activities a “gold-standard” meningitis surveillance system for Chad was composed and approved by stakeholders. For the analysis stage, processes were mapped to the logic model standard, which exposed missing inputs, activities and needs gathered during the study. The resulting table was used to guide selection of the resources needed to upgrade the entire system to a feasible operational standard.

The WPA approach as proposed in this thesis addressed several limitations of other CDSS evaluations. In the literature, either the CDC or WHO frameworks guided all surveillance system evaluations, yet studies varied widely in methods used. The present study tested a more structured and systematic methodology for low-resource settings. Other studies have noted the need for such a structure, recommending the

development of a more systematic or “best practice” approach for assessing performance and identifying systemic challenges that impede surveillance implementation (98, 209). The influence of the WPA structure and rigour to the evaluation findings was demonstrated in several areas identified in the literature as lacking.

10.2.1 Benefit of precise evaluation findings

The systematic literature review provided an in-depth understanding of how IDSR is implemented in resource-constrained settings. Additionally, the background reading on bacterial meningitis gave me a foundational comprehension of clinical and laboratory procedures. This intense focus on formative research in addition to consulting local experts greatly benefitted in the development of a factual surveillance blueprint for the Chad context. Further, the accuracy (i.e. in regards to content and context) of our questions permitted participants to offer specific details about their daily experience performing processes versus merely “testing” the participants on standardized indicators and SOPs. The study deliberately took this approach as other studies noted that some participants feared that answering questions honestly could result in penalisation from Ministry of Health officials (162, 169).

The study also found that reviewing how a system is *supposed* to work provided a level of education to the evaluation participants and stakeholders. It also allowed us to gather more nuanced reasons on why performance was weak or strong. For example, other evaluation studies found that disease detection suffered because health staff were weak in their knowledge on case definitions, or due to a lack of active case search or community involvement in surveillance activities (156, 159, 165). In this study, I found that, in addition to these issues, health facility staff often lacked understanding of the importance of their role within the overall disease monitoring and outbreak prevention strategy. In countries with limited resources, trainings are often infrequent; obtaining this information allows for topics to be customised and optimises training efforts to meet staff needs.

In summary, the study provided the Chadian government and other stakeholders with evaluation results that:

1. Identified the gaps in surveillance functions in each district by comparing current surveillance activities against the evaluation logic model as a consensus standard;
2. Presented district surveillance performance according to costs which, highlighted specific areas of investment needed for overall system improvement; and
3. Provided cost estimates per surveillance function and support activity that can be used in all meningitis belt countries to estimate cost per 100,000 population of upgrading their system.

These types of results are not typically obtained through traditional CDSS evaluation methods. The data collected elucidates the specific needs of the Chadian meningitis and integrated disease surveillance systems, but also provides generalizable data that are useful to the similar environments in that region (e.g. countries within the meningitis belt). The unique benefit of the WPA evaluation design was affirmed by the quality of pertinent information that was accepted by stakeholders to improve meningitis surveillance and CDSS functionality.

10.2.2 Value-added of including cost-analyses in CDSS evaluations

The broader evaluation addressed my PhD aim to understand if combining financial and performance results, using the WPA structure, was useful in providing information to advocate for funding. Few studies have conducted a systematic cost-analysis alongside performance assessment. In this study, from the protocol development to pilot testing, several health economists worked alongside surveillance specialists to design the study. Combining the ingredient approach to the WPA methods revealed complementary granular techniques for identifying resource constituents of the system. Previous evaluation studies with cost assessments generally performed this by extracting and reviewing budgetary data. These studies often had access to old budgets

or historical data on costs, inhibiting an appropriate comparison of the current evaluation (162). Lukwago *et al.* conducted the most thorough cost analysis and “examined” budget allocations to compute per capita input, but did not report on actual programme expenditure (101). Such sweeping budget reviews and unstructured cost assessments are often used to speculate on the adequacy of funding in relation to the efficiency of a system. However, since the methods used were not systematic, decision makers may not have much confidence in such claims about funding sufficiency and may be concerned that additional resources could lead to resource wastage (210). By discounting the cost-consequence element of performance, surveillance programmes miss an opportunity to provide evidence to advocate for system improvement to policy-makers and donors.

The present study demonstrates how to meaningfully consider costs in relation to surveillance operations and performance. The study provided reliable information on average cost per suspected case, average cost per analysed sample, and cost drivers of surveillance expenses. Several studies mentioned the need for cost estimates when considering reinforcing logistics and performance capacity (101, 162, 168). While the existing evaluation standards acknowledge the importance of CDSS costs, they do not provide any meaningful guidance on cost-analysis methods or on how to effectively use cost data (8, 31, 98).

Studies such as this evaluation provide an opportunity to build a repository of cost-estimates specifically for resource-constrained settings. While cost-data tools exist (e.g. WHO CHOICE), accurate estimates of most surveillance costs are currently unavailable (211). Understanding the economic side of surveillance systems can be quite daunting for epidemiologists and programme managers; fortunately, as seen in the present study, health economists with relevant experience can propose useful methods and creative solutions to improve attempts to ascertain the cost-performance dynamic of a given CDSS.

10.2.3 Collection of contextual and non-surveillance-related factors

In our study, contextual factors were not deeply analysed or assessed. However, the deliberate observation, collection, and review of such information provided meaningful insights to help the MSP officials and stakeholders better understand district and health facility performance. These factors helped the study team with this question: *If all surveillance-related factors are the same, how are some districts performing so much better than others?* Understanding the implications of districts supported by government, private, and/or non-government organisations, was useful in considering recommendations for new strategies. Other studies endorsed the need to understand contextual factors. Wuhib *et al.* documented how the dissolution of the former Soviet Union centralised PHSS platform impacted the operations of the Armenian CDSS (162). Studies that did not consider the non-surveillance factors (e.g., social, infrastructural, political) that influence surveillance duties (especially for post-conflict or extremely poor countries) reported vast system issues and hindrances to improving surveillance (118). Evaluating these countries without context is an injudicious technique, which could lead to a distorted comparison of countries from the same part of the world but with vastly different circumstances. This could unintentionally alienate or embarrass local study participants and MoHs. Moreover, the recommendations generated may be ineffective to impact policies or programmes due to the unacknowledged backdrop of socio-political and environmental challenges. Contextual information could serve as preliminary data for future in-depth investigations or underlying assumptions for optimisation models.

10.2.4 Usefulness of the evidence-based recommendations for programme and policy improvement

The inclusion of MSP staff and local stakeholders throughout the process ensured ownership or “buy-in” at the start of the evaluation and also created a direct link between the study and relevant decision makers. The effect of this was clearly seen when the finding of the dubious lumbar puncture policy was revealed in the

dissemination meeting; the ministry of health official granted nurses permission to do lumbar punctures at the meeting. I use this example not to remark on the judiciousness of his reaction, but to illustrate that this type of direct influence on policy is unusual and may have been due to factors unique to Chad; such as the relatively direct access researchers have to the small number of influential health officials. Still, this sequence of events demonstrated the practicality and usefulness of the approach in such settings.

The dissemination meeting was valuable in assessing the merit of our recommendations and served as an opportunity to harmonise practices and train sub-national level staff. Study participants validated the usefulness of the findings by discussing solutions to identified programme weaknesses and system bottlenecks, including the non-distribution of latex tests to the district laboratories. Upon hearing this, the chief laboratory technician immediately retrieved and distributed the tests to the district laboratory leads at the meeting. This suggests, that this level of specificity of evaluation findings could be useful in countries with emerging surveillance programmes and more flexible administrative processes. In contrast, other studies reported more typical evaluation findings that provided policy recommendations, which focused on the attainment of standards, performance indicators, and common top-down changes (19, 101, 153). Mostly, this was because the recommendations aligned with the objectives of the study, which in Sub-Saharan Africa were typically to appraise the implementation of the IDSR strategy. Hence, exact programme improvements were not accentuated in the articles, but may have been conveyed to the MoHs.

The evaluation findings resulting from the WPA approach were sufficiently specific to develop an evidence-based upgraded surveillance strategy for meningitis in Chad. Our results provided both cost and performance information, which was previously unknown to local decision makers and stakeholders. Information generated from similar approaches can be used to request specific resources to optimise parts of surveillance systems.

Further validation of this approach was obtained through ensuring face and content validity of study questionnaires as well as traditional vetting of concepts and methods, including: appraisal by other academics, surveillance practitioners, evaluation experts, and health economists. The approach and study finding have also been presented at conferences, seminars, and reviewed by applied scientists from the WHO. Based on this feedback, the WPA constructs and tools have been refined.

10.3 Strengths and limitations

This was the first study to estimate the costs of meningitis surveillance in the African meningitis belt. The thesis demonstrated the WPA's methodological benefits to low-resource settings; however, the approach has several limitations that should be considered. The primary limitation is that it can be resource and time intensive. In this study, the time spent for the deeper WPA inspection of the system was still insufficient to cover a number of areas with the required depth, as explained in Chapter 7. There is an opportunity to refine the approach for efficiency purposes. The amount of funds needed and expertise required for such a comprehensive evaluation are unlikely to be easily available in low-resource settings, and it is impractical to continually depend on external funding. However, an in-depth evaluation can be conducted periodically or alongside other system planning activities already earmarked in the public health budget.

Alternatively, WPA-type evaluations can be divided into smaller and more focused parts; this can be done by facility type (e.g. health facility or laboratory assessment) or by surveillance function (e.g. case detection assessment). In this way, the system parts can be regularly monitored and reinforced. Local evaluation and health economics expertise is likely to be unavailable; external evaluators should commit to working alongside MoH staff and local NGOs to conduct assessments with an aim to transfer knowledge and increase local evaluation capacity. Several studies have produced richer findings by performing targeted assessments of a small number of surveillance

functions (79, 166) or specific ancillary structures such as logistics and emergency preparedness (165, 168). A precaution of conducting a truncated assessment with fewer study sites is that the precision of data along with the inclusion of contextual information may increase the ability to identify specific health facilities. It may also make it difficult to ensure confidentiality about study findings, especially when needs or complaints are shared. This problem was encountered during our study. To avoid this issue during the dissemination meeting, we were selective about the content of the aggregate data we displayed and chose generic quotes that were not incriminating. Thoughtful consideration around ensuring anonymity in multi-level audiences should be considered with this evaluation approach to ensure that punitive measures are not taken against a health facility or individuals and that shame is not caused. District or regional authorities may need specific health facility information, in such cases positive and negative results should be presented objectively.

The WPA may not be useful for more advanced systems or for systems that have already benefitted from regular evaluations. One example is the Burkina Faso and Mali assessment to increase the country capacity of case based surveillance before the introduction of MenAfriVac® (155). The authors explained that both countries had ‘strong’ existing surveillance infrastructures and in-country expertise. Hence, the study revealed nationwide and higher-level gaps to improve performance and provided progressive recommendations, such as mentorship, training and technology transfer. Additionally, the study relied heavily on existing reliable data an evaluation to only improve achievement of the performance indicators was preferable. In Chad, such infrastructures, strategies, and data did not exist; further, the cost to perform a WPA-type analysis for the entire country would have been infeasible and unrealistic.

Another constraint is that the WPA approach is very dependent on access to local surveillance actors and relevant key partners. In Chad, we had the advantage of building on already established institutional links. Additionally, I was fortunate in knowing several persons in key partner organisations, namely CDC and the Carter

Centre. This will not always be the case in WPA appropriate settings, especially those recovering from or in the midst of political and social instability. In such cases, foreign researchers, in particular, should focus on gathering as much documented information on the country as possible as well as working with larger institutions, such as WHO.

Finally, one modest strength, but a strength nonetheless, is the underlying assumption of non-linearity between evaluation processes, surveillance activities, and resource allocation, which was presented in this thesis. While in some ways the thesis premise mirrors that of the empirical operational literature, which asserts if resource gaps are aptly filled, the CDSS will function optimally, I also acknowledge the importance of the tacit institutional knowledge and contextual factors. For example, the present study identified barriers, such as incomplete adoption of IDSR and a narrow understanding/lack of ownership of CDSS aims. These concerns were anticipated, so our health facility questionnaire included a Likert-type (rating) scale to measure staff perception of CDSS value, work burden, and budget ownership. Unfortunately, the respondents were not familiar with this type of rating exercise and so the answers were not included in the analysis. It is possible that these barriers could have been understood through a deeper exploration of non-linear influences or a robust social-ecological approach for improving CDSS performance in low resource countries. This consideration was beyond the scope of the PhD objectives, but such cross-disciplinary applications have proven beneficial in similar public health research areas (212, 213).

10.4 Research recommendations and policy implications

10.4.1 Rethinking CDSS evaluations in resource-constrained settings

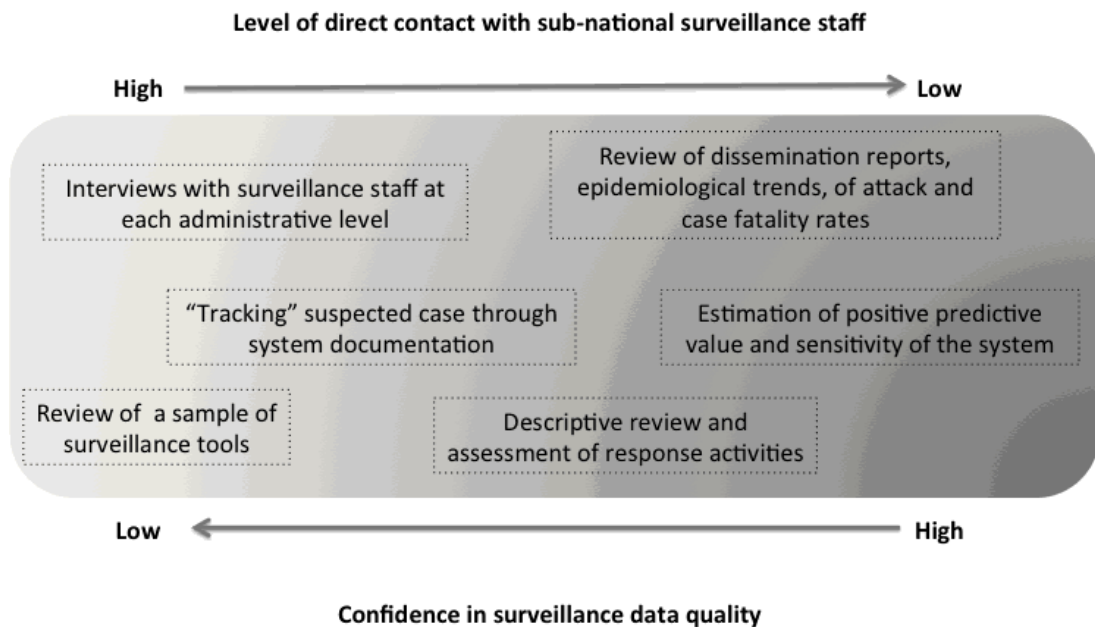
CDSS evaluations are generally undertaken to improve the ability to monitor population health and ensure prompt and effective response system for disease outbreaks and other public health emergencies (214). Evaluation findings have pointed to systemic, targeted, and comprehensive gaps, yet numerous developing countries, mostly in sub-Saharan Africa, have yet to demonstrate significant improvements in CDSS as a result of these assessments. Though there may be several reasons for lack of research uptake, the findings of this thesis indicate that lack of tailoring conventional methods to health system maturity is a possible explanation.

The concept of tailoring evaluations to meet programme needs is inherent within the traditional evaluation frameworks, but within a linear, indicator-driven structure. This thesis contributes a field-validated approach to capturing the unique challenges of evaluating a surveillance system in a developing country. It demonstrated that there are methodological synergies across disciplines, which can expand conventional evaluations. The Chad evaluation case study countered the unstated assumption that what is needed for CDSS evaluations was already captured by the existing frameworks. This PhD demonstrates that to truly understand system complexities at sub-national levels, we need to think towards applying different methods for different settings.

The WPA approach in many ways echoes certain principles of health systems thinking as adapted by the WHO for health systems strengthening (210). Specifically, by designing evaluations (and interventions) that acknowledge and attempt to confront the dynamics between country priorities, donor funding, human capacity, contextual influences, structural elements, and other underlying characteristics of health system. The findings in this thesis suggest that there is an evolutionary pattern towards the use of certain in-depth evaluation methods in relation to the maturity, stability, and functionality of a given CDSS. There are several factors and processes that could be

coupled to certain stages of surveillance system maturity. Figure 10.1 depicts a potential model of such an evaluation gradient. As shown, when a health system is weaker or the data quality produced by that health system merits low confidence from the evaluator and local stakeholders, the type of methods to obtain reliable data for a CDSS evaluation must involve high levels of contact with the sub-national staff. Like the present study, and other studies found in the literature, these methods should include interviews and reviews of actual surveillance forms and tools. The more robust a surveillance system is and the more confidence the evaluator and stakeholders have in the data quality is high, direct with staff is less necessary. In this case, the surveillance outputs can be assessed to calculate quantitative indicators and determine system performance.

Figure 10.1 Potential model of a methods gradient for CDSS evaluation



This concept of a gradient of evaluation methods blurs the hard line between 'tree-by-tree' and 'forest', or details versus context beliefs to gaining knowledge and understanding of surveillance system (210). The WPA, while granular in practice, was

presented as an integrated component of common approaches that increases local participation and builds ownership while ensuring high performance of a national surveillance system. As illustrated in the case study, the meningitis surveillance system could not be disentangled from the needs, goals, and planning of the overall integrated disease surveillance system—nor should it ever be. The weaknesses that were found in the meningitis surveillance system actually represented broad system inadequacies that if strengthened could be leveraged for multiple disease programmes and initiatives (e.g. health facility staff training and transport needs). This view of CDSS evaluation fuses well with the global trend towards holistic management of systems and meaningful consideration of larger system-wide issues and inter-related system components (210, 215, 216)

10.4.2 Toward sustainable and reliable surveillance systems in resource-constrained countries.

Policy implications in Chad

While it was still in progress the present study was presented in the autumn of 2013 at the *11th Annual Inter-Country Meeting on Surveillance and Response of Meningitis, Yellow Fever, Measles, And Cholera Epidemics in Africa*. Several regional and global surveillance practitioners and meningitis epidemiologists and laboratory specialists expressed interest in the study results and universally agreed that the study was indeed novel and necessary, especially in providing the unknown economic costs of meningitis surveillance. Several of the Chad national surveillance office attended this meeting, and their feedback reinforced the Chadian MSP commitment to the study and raised the meningitis surveillance profile Chad. Two years later, the MenAfriNet organisation requested the study results. MenAfriNet is an international consortium recently supported by the Bill & Melinda Gates Foundation, but has been operating in several countries for more than a decade. Its aim is to strengthen the meningitis surveillance network in Africa. Their work, headed by CDC and AMP, has been instrumental in

supporting Burkina Faso, Mali, Niger and Togo by enhancing epidemiology, laboratory, and data management capacity.

I participated in the MenAfriNet mission to evaluate the suitability of adding Chad as one of two additional country sites. The results from our evaluation, particularly the detailed understanding of CBS and ES, the detailed laboratory inventory and associated costs, and the identification of critical gaps, allowed the team to forgo the customary needs assessment and surveillance evaluation. Moreover, our in-country knowledge and relationships expedited the mission activities. By the end of the mission, the consortium decided to include Chad as a MenAfriNet site and expedited its integration. Our suggested three-district sentinel plan was used to guide their decision of district-selection for the first year pilot phase. During this phase, which commences in autumn 2015, activities to enhance case detection, laboratory confirmation, and data management in select districts will be implemented to support meningitis disease burden monitoring. Another aim will be to evaluate the impact of introducing MenAfriVac® and PCV13 into the routine immunisation schedule. MenAfriNet leverages the IDSR platform in order to harmonise meningitis surveillance activities, including specimen transport and data transition—this will greatly influence further policy initiatives and the programme was personally welcomed by the Chadian Minister of Health.

This incredible, but unexpected outcome successfully answered the thesis inquiry and found that robust evidence-based data provides powerful and persuasive advocacy for donor funding. Also, since working in low-income countries is challenging, donors can leverage evaluations, such as ours, to identify and fill crucial surveillance gaps. This real-world outcome underscores the important role of partnerships in sustaining and optimising surveillance (and health) systems in resource-constrained settings. The work of CSSI and MSF-France in collaboration with the Chad MSP provided the foundation for MenAfriNet to build upon. In most cases, institutional knowledge of in-country partner organisations is essential for any incoming intervention or new study. MSF-

France supplied our study with high quality and fluid information, which supplemented our stationary evaluation data. This type of information can allow stakeholders to make informed decisions on where and how to improve the system as well as brainstorm contingency strategies based on local circumstances.

Since the first aim of MenAfriNet is to improve the laboratory capacity and capability, it is my hope that the regional laboratory in Moundou will be reinvigorated, sufficiently equipped, and fully utilised to analyse specimen in the south of the country. This will reduce the burden at the national level and will require less specimen travel time from the district laboratories. Further, Chad has started a path once travelled by countries like Burkina Faso. Over the past 10 years, Burkina Faso has become the sub-Saharan model of successful and capable laboratory services. Their surveillance data is often lauded as high quality, and other health programmes have built on the strong surveillance foundation (217). Burkina Faso also benefits as host of the regional West Africa Field Epidemiology and Laboratory Training Program, another product of deliberate collaborations to improve disease control and response capacity within the region (218). This type of consistent and thoughtful systems strengthening can help Chad transition from its weak system to a higher functioning surveillance system that benefits from a sound understanding of the system attributes and can realistically attempt to achieve regional and global standards. With a new focus on improving quality epidemiological and laboratory data, Chad can become a confident proxy of the veracity of MenAfriVac® effectiveness and the success of future routine immunisation and vaccination campaign efforts. This is a promising venture for both Chad and the region.

Moving forward, I hope this research encourages the MSP and international and local partner agencies to work on filling the gaps identified in the system in a coordinated manner. There were three parallel meningitis surveillance systems identified in the study: Moissala (the MSF-ran district), Goundi (the private-Catholic supported district) and for some time Gonou-Gaya and Guelengdeng (supported by a study team at

LSHTM) all operated independently from the governments purview. The evaluation findings illustrated how multiple data streams make the system inefficient and increases the burden of work for staff. The findings can be used as an opportunity for stakeholders to collaborate in filling the system gaps together and going forward with a unified plan of action.

Global policy implications

"As the importance of health in the global agenda grows, so does the responsibility to measure accurately its complex dimensions and to assess the effects of increasing investments on population health. The present bursts of political and financial will to improve global health has to be matched by an adequate response from the community of experts in constructing a firm foundation of metrics and evaluation."

- Dr Christopher J. L. Murray,

Institute for Health Metrics and Evaluation

The world is not lacking in institutions, policies, and global agenda items to guide and bolster international efforts to detect emerging and re-emerging diseases. The International Health Regulations (2005) are the most regarded and internationally agreed rules specifically aimed at preventing and controlling the international spread of disease (15, 219). Still, many low-income countries continue to be unprepared to successfully prevent and combat disease outbreaks as seen with Ebola in West Africa where, at the time of this thesis, communities were still ravaged by the consequences of poor health-care systems and infrastructure (220). The main affected countries, Guinea, Liberia, and Sierra Leone, have many similarities to Chad. All appear on the *least developed countries* list, have weak public health systems, volatile political pasts, patchy infrastructures, and rank among the lowest in global development (221, 222). Many critics and experts note that the only way to ensure that future re-emerging and

emerging disease can be contained is to realise that the global chain of health systems is only as strong as its weakest links (223).

This recognition and refocus on unique context of such countries is a promising direction toward prevention of future outbreaks and epidemics. There is an opportunity for leading world experts and organisations to examine why existing global policies are not effective in certain settings. I found that examining the effectiveness of globally accepted CDSS evaluation standards revealed that resource-constrained settings have specific considerations that are sometimes missed. I believe that the same logic can be applied to understanding why global public health laws have been inadequate in ensuring safe cross-border health. Global health frameworks should be aimed at understanding and meeting the needs of both local and international contexts. This thesis demonstrates the value of meeting countries where they are and providing a path to effectively scaling up health systems.

10.5 Areas for future research

This was the first study to estimate the costs of meningitis surveillance in the African meningitis belt. Though this study did not aim to quantify the effectiveness of the surveillance strategies, it provides data that programmes can use to inform future cost-effectiveness or fiscal-impact studies. Additionally, current targeted disease strategies could readily integrate a cost-analysis by projecting costs of expected surveillance rates (E.g. number of detected cases by 100,000 population) and laboratory diagnosis indicators to achieve minimum global (or regional) standards of surveillance functions. Pairing these rates with known cost estimates while thoughtfully considering potential cost for sharing resources across disease programmes could directly feed programme budgeting.

Another area for additional research is to further explore the aforementioned values that underlie 'granular-when-necessary', 'evaluation methodology gradient', and

'systems thinking' concepts. These concepts can potentially be incorporated in the design and evaluations of multi-disease and integrated surveillance systems in resource-constrained countries. The present study only evaluated a vertical surveillance system due to the focus and aim of the funders. Future research should aim to bring donors on board with field-practitioner and researcher recommendations to end fragmented funding modalities that drive disease-specific, vertical systems and redirect funding toward ensuring sustainable resources for wider surveillance system strengthening activities.

Finally, sustainable and feasible evaluations must capitalise on the wave of technological advancements to modernise the laborious work of collecting, cataloguing, and assessing population health data. Public health researchers can now transform ubiquitous data into predictive surveillance information that can be used to detect health events earlier, as was demonstrated with Google Flu to track influenza-like illness in the United States (224). Further, computer technology can enhance situational awareness from 'timely; to 'real-time' leading to reduced laboratory confirmation and outbreak response times. Continued research on how to effectively fit these technologies into existing health systems and how to effectively digitise evaluation methods should be prioritised.

10.6 Conclusion

This thesis examined how communicable disease surveillance systems in resource-constrained settings could be strengthened by using a work-process analytic evaluation approach. This new approach acknowledged recommendations made from earlier CDSS evaluations and included a cost analysis of the system. The case study of evaluating meningitis surveillance in Chad described the practical considerations as well as constructive challenges of embracing such an approach in a low income country. The study found that this granular assessment, though painstaking, demonstrated value by yielding comprehensive results and providing a well-grounded understanding of the cost and operations of the system. This evidence was used to

formulate and propose an upgraded strategy to improve monitoring of meningitis and pre-empt challenges that may emerge following the introduction of the new serogroup A meningococcal conjugate vaccine.

By incorporating more of a research design into a programme evaluation, I challenged the conventional methods of assessing a CDSS. I was able to demonstrate that a granular understanding of the Chadian meningitis surveillance system produced evaluation results that were used to change policy, attract donors, and to restructure and optimise meningitis surveillance operations and functionality. This research was instrumental in Chad policymakers rethinking and ultimately modifying certain task-position roles for meningitis diagnosis, particularly for performing lumbar punctures on suspected cases. Furthermore, it directly contributed to the selection of Chad as a MenAfriNet site.

The findings also have relevance for policy makers in other settings. The resulting cost estimations have been shared with the WHO and other countries in the African Meningitis Belt region to assist in the process of tailoring surveillance strategies and estimating resources needed to accommodate the introduction of MenAfriVac[®]. The findings highlight the value in examining how global and regional standards for disease control and response can be re-framed or better targeted to address the unique factors affecting resource-constrained contexts. Additionally, the thesis advocates an evaluation framework that examines how contextual factors can influence which methods are best to evaluate CDSS.

Public health surveillance undergirds all health systems; it is also an essential indicator of the strength of health systems, especially in low-income countries. In these nations, disease surveillance is connected to country autonomy, self-reliance, and even human rights. While progress has been made globally in improving disease surveillance, the least developed countries are sometimes tasked to take on broad strategies and policies that while useful, may also burden more nascent or unsteady systems. My experience

in Chad showed me that that there are mutual growth opportunities for global and local communities to exchange ideas for improving evaluation and programme standards towards sustainable surveillance system strengthening in these settings.

11 Appendix

Appendix 1. Study approvals

REPUBLIQUE DU TCHAD
PRÉSIDENTE DE LA RÉPUBLIQUE
PRIMATURE
MINISTÈRE DE LA SANTÉ PUBLIQUE
SECRETARIAT D'ÉTAT
SECRETARIAT GÉNÉRAL

UNITE-TRAVAIL-PROGRES



N° _____/MSP/SE/SG/2013

1175

AUTORISATION DE RECHERCHE

Nous soussigné **Dr. MATCHOKE GONG ZOUA**, Secrétaire Général Adjoint du Ministère de la Santé Publique, autorise le Centre de Support en Santé Internationale (CSSI), de mener une étude sur le thème : «**Estimation des coûts de surveillance de la méningite au Tchad et au Niger**»

Cette étude s'inscrit dans le cadre des études épidémiologiques sur la méningite menées en collaboration avec London School of Hygiene and Tropical Medicine (LSHTM) de Londres au Royaume-Uni, la Représentation de l'Organisation Mondiale de la Santé (OMS) au Tchad et le Ministère de la Santé Publique (MSP) du Tchad. Cette étude sera conduite au Tchad par les Chercheurs : Ulla Kou Griffiths et Ngozi Erundu.

Le CSSI a déjà organisé en collaboration avec le LSHTM, l'OMS, et le MSP des études épidémiologiques sur le portage sain de Méningocoque au Tchad dans le cadre du Projet MenAfriCar. Toutes les dispositions requises étaient donc prises pour que les populations concernées soient largement informées des objectifs de ces recherches et que rien ne soit entrepris sans leur consentement éclairé. Ainsi aucun membre de la communauté n'était et ne serait contraint à participer à cette recherche. Tout participant sera ainsi libre de se retirer à tout moment de l'étude.

Pour la présente étude, aucune procédure autre que les interviews des intervenants, l'analyse des documents, des comptes et bilans financiers ne sera utilisée.

Toutes les personnes interviewées se verront attribuer un identifiant unique qui sera utilisé pour le stockage des données et leur analyse.

Une fiche sera fournie à chaque personne participant aux interviews détaillant le but de l'enquête et les méthodes de collecte des données.

Hormis ces considérations d'ordre éthique, nous soutenons cette étude qui entre également dans le cadre de la politique national de santé au Tchad et satisfait l'une de priorité du Ministère de la Santé Publique, celui de lutter contre toutes les maladies et de fournir l'accès aux soins à toute la population.

Enfin, les résultats de cette recherche seront mis à la disposition du Ministère de la Santé Publique pour toute fin utile et peuvent être utilisés par les gouvernements Tchadien et Nigérien pour prioriser les activités de surveillance et la sélection de la stratégie la plus adaptée.

Fait à N'Djamena le 14 mars 2013

Dr. MATCHOKE Gong Zoua



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Observational / Interventions Research Ethics Committee

Ulla Griffiths
Lecturer
GHD/ PHP
LSHTM

29 May 2013

Dear Dr. Griffiths,

Study Title: Estimation of the Costs of Meningitis Surveillance
LSHTM ethics ref: 6416

Thank you for your letter of 20 May 2013, responding to the Observational Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
LSHTM ethics application	n/a	
Draft Protocol including Information Sheet & Consent form		20/05/2013

After ethical review

Any subsequent changes to the application must be submitted to the Committee via an E2 amendment form. All studies are also required to notify the ethics committee of any serious adverse events which occur during the project via form E4. At the end of the study, please notify the committee via form E5.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'John Porter'.

Professor John DH Porter
Chair
ethics@lshtm.ac.uk
<http://intra.lshtm.ac.uk/management/committees/ethics/>

Appendix 2. Logic model for meningitis surveillance in Chad

	<i>Detect/ Laboratory confirmation*</i>	<i>Report and analysis **</i>	<i>Investigation/ Response</i>	<i>Supervision and Feedback</i>	<i>Monitoring and Evaluation***</i>
INPUTS					
	<p>Relevant personnel trained on LP technique and transport of CSF and IDSR forms</p> <p><i>Regular training and supervision of provincial and district laboratories, and ensure that reagents and laboratory equipment are available.</i></p>	<p>Trained CdZ on data analysis and IDSR reporting</p>		<p>Transportation to provide supervision includes Motorbikes, bicycles, and/or vehicles</p> <ul style="list-style-type: none"> -Petrol -Supervision schedule <p><i>Patient laboratory confirmed laboratory results</i></p>	<p>Surveillance expertise</p> <p>Support from WHO</p>
ACTIVITIES					
<i>Health Facility</i>	<p>Diagnose suspected case</p> <p>Refer patient to district hospital for LP (CBS) or</p> <p>Conduct LP at health facility (ES)</p> <p>Provide treatment</p>	<p>Notify CdZ /Regularly send line list to CDZ</p>	<p>If there is a case, RCS conducts active surveillance and IEC activities</p>	<p><i>Inform patient of lab results</i></p>	
<i>District</i>	<p>Pick up CSF, send to reference lab with surveillance form</p> <p><i>Perform rapid diagnostic tests</i></p> <p><i>Send CSF to national or regional laboratory</i></p> <p><i>Report results to CdZ</i></p>	<p>Notify CASE</p> <p>Regularly compile and send line list to CASE</p> <p>Aggregate data send to CASE</p> <p>Develop weekly epidemic curve</p>	<p>If there is a case, CdZ supports health facility with active surveillance and IEC activities</p> <p>If there is an outbreak conduct mass immunisation</p>	<p>Weekly surveillance visits to 2 to 3 health facilities</p> <p>Monthly meetings with clinicians at health facilities</p>	

		Inform lab results to reporting clinician at health facility	campaign targeting the entire district		
<i>Region</i>	<i>Perform diagnostic tests (Regional reference laboratory)</i> <i>Send confirmed cases to national laboratory</i>	Regularly report aggregate data to national level Aggregate data send to SSEI	If there is an outbreak RRT must support and evaluate affected district(s) surveillance and laboratory activities.	Weekly surveillance visits to 2 to 3 health facilities	Monitor epidemic trends and thresholds
<i>Central</i>	<i>Perform diagnostic tests</i> <i>Report results to national epidemiologic surveillance team</i> <i>Ship 15% of positive specimen to Oslo, Norway for quality assurance and control (QAQC) and molecular analysis</i>	Regularly report aggregate country data to WHO and country partners Create weekly map showing the alert and epidemic districts Analyse laboratory results by district and for the country	If there is an outbreak RRT must support and evaluate affected district(s) surveillance and laboratory activities.	Biannual QAQC for some labs and regional laboratory Biannual surveillance and laboratory supervision visits <i>Weekly surveillance bulletin</i>	<i>Monitor the circulation, distribution and evolution of Nm serogroups and other pathogens.</i> <i>Monitor the antibiotic resistance profile of Nm.</i> <i>Monitor the circulation, distribution and evolution of Nm strains (by sequence-typing)</i> Evaluate control strategies
OUTPUTS					
	weekly line lists available at district <i>regular feedback on samples in order to minimise contamination and handling/transportation</i> <i>laboratory results fed back in a timely manner</i>	Copies of CBS forms at district and central level	Alert or epidemic districts investigated and documented within 48 hours of reaching threshold Active CBS for all confirmed cases of meningitis		

INTERMEDIATE OUTCOMES					
	<p>80% of specimen sent to lab</p> <p>< 20% of specimen contaminated/ week</p> <p><i>10 to 20% of positive isolates are transported to Oslo, Norway - WHO Collaborating Centres for QAI and genotyping and sequence-typing.</i></p>	80% districts reporting on time	Mass vaccination campaign for all districts which reach epidemic threshold	<p>Continuous supportive supervision</p> <p><i>Feedback timeliness:</i></p> <p><i>Districts: within 48 hours upon reception of the sample(s)</i></p> <p><i>Province/Region: within 5 days upon reception of the sample(s)</i></p> <p><i>National level: within 7 days upon reception of the sample(s)</i></p>	Evaluate the impact of the conjugate meningitis A vaccine on the number of cases and outbreaks, on epidemic patterns and on circulating serogroups
LONG-TERM OUTCOME					
	<p>Prompt detection of meningitis cases from all health facilities</p> <p><i>Rapid laboratory confirmation of causal pathogens to inform epidemic control and response measures</i></p>	<i>Up to date case burden and incidence trends for acute bacterial meningitis</i>	Early response and immediate and appropriate public health control measures implemented for meningitis outbreaks/epidemics	Increased quality of surveillance due to regular supervision	Estimated effectiveness of the meningitis A conjugate vaccine

**Laboratory' activities are written in italics

** 'Analysis' activities are written in italics

*** 'Monitoring' activities are written in italics

Appendix 3. Quality indicators included in the study questionnaires

	Indicator	Numerator	Denominator	Target	Indicator/ Target source(s)	Data Source
1	Percent of suspected meningitis cases that have a lumbar puncture performed	Number of suspected meningitis cases that had a lumbar puncture performed	Number of suspected meningitis cases	90%	IB-VPD, 2012	National, Regional, District
2	Percent of lumbar punctures performed that were recorded	Number of suspected meningitis cases that had a lumbar puncture performed that were recorded in database	Number of suspected meningitis cases	90%	PBM Network - 2009; IB-VPD, 2012	National, Regional, District
3	Percent of specimens of CSF that showed bacterial growth	Number of suspected cases who received a lumbar puncture, that have probable bacterial meningitis	Number of suspected meningitis cases with lumbar punctures performed	20%	PBM Network - 2009; IB-VPD, 2012	National, Regional, District laboratory
4	Percent of probable bacterial meningitis cases with a known outcome recorded	Number of probable bacterial meningitis cases with an outcome recorded	Number of suspected meningitis cases with probable bacterial meningitis	90%	IB-VPD, 2012	National, Regional, District laboratory
5	Percent of suspected pneumococcal meningitis cases identified	Number of suspected pneumococcal meningitis cases identified by national, district or regional laboratory	Number of suspected meningitis cases	NA	Created by research team	National, Regional, District laboratory

6	Percent of CSF samples logged into the laboratory	Number of CSF samples logged into the laboratory	Number of suspected meningitis cases that had a lumbar puncture performed	75%	IB-VPD, 2012	National Laboratory
7	Percent of CSF contamination	Number of CSF samples contaminated	Number of suspected meningitis cases that had a lumbar puncture performed	≤ 5%	IB-VPD, 2012	National Laboratory
8	Percent of CSF specimens forwarded to the reference laboratory for PCR and genotyping	Number of CSF specimens sent to the reference laboratory for PCR and genotyping	Number of suspected meningitis cases that had a lumbar puncture performed	80%	IB-VPD, 2012	National Laboratory
9	Number of months for which reports with results were made	Number of months that a report with aggregated results was made	Number of months in the specified timeline	≥ 8 months	PBM Network - 2009	National Laboratory
10	Percent health facilities that report meningitis data on time to the district (weekly)	Number health facilities that report meningitis data on time to the district (weekly)	Total number of health facilities reporting	80%	IB-VPD, 2012; IDSR-2010	Regional, District
11	Proportion of complete surveillance reports submitted on time to the district	Number of sites that submitted complete surveillance reports on time to the district	Total number of health facilities reporting	80%	IDSR-2010	District, Health facility
12	Proportion of cases reported with case-based forms or line lists	Number of cases reported with case-based forms or line lists	Total number of cases that occurred in the health facility	80%	IDSR-2010	Health facility
13	Proportion of suspected meningitis outbreaks notified to the district level within 2	Number of suspected meningitis outbreaks notified to the district level	Total number of suspected meningitis outbreaks in the health facility	80%	IDSR-2010	District, Health facility

	days of surpassing the alert threshold	within 2 days of surpassing the alert threshold				
14	Proportion of suspected meningitis outbreaks notified to the national level within 2 days of surpassing the alert threshold	Number of suspected meningitis outbreaks notified to the national level within 2 days of surpassing the alert threshold	Total number of suspected meningitis outbreaks in the health facility	80%	IDSR-2010	National, District
16	Number of trained staff in surveillance methods*	Number of trained staff in surveillance methods	Number of staff at the health facility or district office	NA	Created by research team	District, Health facility
17	Percent of staff that know the case definition of meningitis*	Number of staff can state the case definition of meningitis	Number of staff at the health facility or district office	NA	Created by research team	District, Health facility
18	Proportion of investigated outbreaks with lab results	Number of investigated outbreaks with lab results in a given time period	Total number of investigated outbreaks that occurred in a given time period	80%	IDSR-2010	National, Regional, District
19	Proportion of confirmed outbreaks with nationally recommended health response	Number of confirmed outbreaks with a nationally recommended response	Number of confirmed outbreak in the district	80%	IDSR-2010	National, Regional, District
20	Proportion of monthly surveillance reports submitted from the district to the region on time for 3 consecutive months	Number of districts that submitted meningitis surveillance reports on time to the regional level	Total number of districts that report to the regional level	80%	IDSR-2010	National, Regional, District
21	Proportion of monthly surveillance reports submitted from the region to the national	Number of regions that submitted meningitis surveillance reports on time to the national level	Total number of regions that report to the national level	80%	IDSR-2010	National, Regional, District

	level on time for 3 consecutive months					
22	Proportion of districts in which a current line graph of weekly trend analysis of meningitis is available	Number of line graphs available at the district level	Number of districts	80%	IDSR-2010	National, Regional
23	Proportion of epidemics detected at the national level that were missed at the district level	Number of epidemics detected by the regional or national level from analysing district specific data	Total number of epidemics reported by district	0	IDSR-2010	National
24	Proportion of health facilities with available transport for suspected cases to referral hospital*	Number of sample health facilities with available transport for suspected cases to referral hospital	Total number of sample health facilities	NA	Created by research team	Health facility
25	Percent of suspected cases, identified at health facility, to reach referral hospital*	Number of suspected cases, identified at sample health facilities to reach referral hospital	Number of suspected cases identified at sample health facility	NA	Created by research team	Health facility
26	Proportion of health facilities with free meningitis treatment*	Number of sample health facilities with free meningitis treatment available for suspected cases	Number of sample health facilities	NA	Created by research team	Health facility
27	Proportion of health facilities with meningitis treatment for a cost*	Availability of purchasable meningitis treatment at sample health facilities	Number of sample health facilities	NA	Created by research team	Health facility

28	Percent of full time staff at health facility*	Number of full time staff at sample health facilities	Total number of staff at sample health facilities	NA	Created by research team	Health facility
29	Average number of staff at health facilities*	Number of staff at all sample health facilities	Number of sample health facilities	NA	Created by research team	Health facility
30	Average length of employment of pertinent staff at health facility*	Number of days of employment of pertinent staff at each sample health facility	Number of pertinent staff at sample health facilities	NA	Created by research team	Health facility
31	Average length of employment of district surveillance lead*	Number days of employment of sample district surveillance lead	Number of sample district surveillance lead	NA	Created by research team	District

* Denotes supportive indicators created by research team

IB-VPD: Invasive Bacterial Vaccine Preventable Diseases Laboratory Network

IDSR: Integrated disease surveillance and response

PBM: Paediatric bacterial meningitis

NA: Not applicable

Appendix 4. Health facility questionnaire

Résultat de l'interview: Complété

Partiellement complété (indiquer le numéro de la question ainsi que la raison)

QUESTIONNAIRE DESTINE A LA PERSONNE RESPONSABLE DE LA SURVEILLANCE DE LA MENINGITE DANS UN ETABLISSEMENT DE SANTE

Version 08 SEPT 2013

1. Dates des visites des interviews:

Visite 1

Visite 2

Visite 3

2. Nom de l'enquêteur: _____

3. Région: _____

4. District: _____

I. INFORMATIONS GENERALES

5. Nom de l'établissement: _____

6. Type d'établissement (Cochez toutes les cases):

Hôpital régional

Hôpital de district

Mission

Centre de soins

Clinique

Publique

Privé

7. Renseignements sur le répondant (répondant 1 doit être le répondant principal, ajouter des lignes si nécessaire)

	Nom	Poste	Numéro de téléphone	email
1				
2				
3				
4				

8. Ce centre utilise-t-il une surveillance au cas par cas ou une surveillance renforcée pour la méningite bactérienne?
- Au cas par cas
- Renforcée
9. La personne interviewée connaît-elle la différence entre la surveillance au cas par cas et la surveillance renforcée?

Oui Non Ne sait pas

S'il ne la connaît pas, donnez-lui la définition suivante:

La surveillance renforcée est la collecte de données pour les cas suspects de méningite, les données agrégées sont rapportées au niveau du district de manière hebdomadaire et en suivant les lignes directrices de l'IDSR.

La surveillance au cas par cas permet de collecter les informations pour chaque cas suspect de méningite sur un formulaire spécial incluant aussi le prélèvement du liquide cérébro-spinal (LCR) qui est envoyé au laboratoire pour analyse.

10. La définition de cas de méningite est-elle visible/affichée dans l'établissement de santé?
- Oui Non
11. Demander au personnel disponible si ils connaissent et peuvent énoncer la définition d'un cas suspect de méningite bactérienne
- ___ Nombre d'employés interrogés
- ___ Nombre d'employés qui connaissent cette définition

II. CARACTERISTIQUES DE L'ETABLISSEMENT

12. Qui détient les droits de propriété de l'établissement?
- Gouvernement Privé Mission; ajouter le type _____
- ONG; ajoutez le nom _____ Autre, préciser _____
13. L'établissement a-t-il son propre budget?
- Oui Non
- a. Si oui, quel est le budget total de l'établissement pour 2012? _____ CFA
- Si oui, demandez à voir le budget*
14. Quelles sont les sources de financement ou de revenu de l'établissement? *Cocher ci-dessous*
- Transfert budgétaire de collectivités locales (incluant les assemblées de district)
- Budget du gouvernement national
- Honoraires pour le service
- Donateur (spécifier _____)

- ONG (spécifier _____)
- Prime d'assurance
- Autre, spécifier _____

15. L'établissement a-t-il reçu des donations en nature en 2012? Oui Non; Si oui, compléter le tableau suivant

Type de donation	Quantité reçue	Valeur de la donation en CFA	Source
a. Véhicule			
b. Ordinateur			
c. Equipement de chaîne du froid			
d. Frigidaire			
e. Autre (spécifier _____)			
f. Autre (spécifier _____)			

16. Dans quel type de zone l'établissement est-il situé?

- Urbain (>5.000 habitants) Rural (<5.000 habitants)

17. En quelle année l'établissement a-t-il ouvert? _____

18. Quand ont eu lieu les derniers travaux de rénovation de l'établissement? Mois Année

19. Combien de villages sont-ils supervisés par votre établissement? _____

20. Quelle est la distance entre le village le plus éloigné et l'établissement? _____ km

21. Combien de centres plus petits sont-ils soutenus, managés et supervisés par cet établissement?

22. Combien de lits l'établissement compte-t-il? _____

23. Quel est l'état des routes entre l'établissement et les villages?

- Goudronnées Gravelées Ni goudronnées ni gravelées

24. Disponibilité des transports publics (taxi, bus) pour se rendre à l'établissement

- Mauvais Moyen Bon

25. Y-a-t-il eu des inondations qui ont impactées le service en 2012?

- Oui Non

a. Si oui, quel genre d'impact: _____

b. Combien de temps a duré l'interruption du service? _____

26. A quelle heure la prise en charge des patients commence et finit-elle ?

Jour	Début	Fin
Lundi		
Mardi		
Mercredi		
Jeudi		
Vendredi		
Samedi		
Dimanche		

27. Qui est en charge de l'utilisation des véhicules? _____

28. Où gardez-vous les carnets d'utilisation, les registres et les carnets de dépenses?

III. POPULATION

29. Quelle était la population totale de la circonscription en 2012? _____

30. Combien y-a-t-il eu de naissances au sein de cette population en 2012?

31. Combien y-avait-il d'enfants de moins d'un an dans cette circonscription en 2012?

32. Combien y-avait-il d'enfants de moins de cinq ans dans cette circonscription en 2012?

33. Combien y-avait-il de femmes entre 15 et 49 ans dans cette circonscription en 2012?

IV. EMPLOYES DE L'ETABLISSEMENT

34. Quel est le nombre total de personnel soignant travaillant pour l'établissement?

- a. Veuillez lister le personnel soignant dans le tableau ci-dessous (*Pour les grandes structures, lister seulement le personnel impliqué dans la surveillance de la méningite*)

Poste/titre <i>S'il vous plaît indiquer également si à temps plein ou à temps partiel</i>	Description rapide des fonctions et durée du travail au centre de santé	Impliqué dans le traitement de la méningite et/ou de la surveillance? (oui/non)

35. Quel est le nombre total de personnel non soignant travaillant pour l'établissement?

- a. Veuillez lister le personnel non soignant dans le tableau ci-dessous (rajouter des lignes si nécessaire)

Poste <i>S'il vous plaît indiquer également si à temps plein ou à temps partiel</i>	Description rapide des fonctions et durée du travail au centre de santé	Impliqué dans le traitement de la méningite et/ou de la surveillance? (oui/non)

V. PROCEDURES POUR DIAGNOSTIQUER ET CONTRÔLER LA MENINGITE

36. Des ponctions lombaires sont-elles habituellement réalisées sur les patients présentant des signes cliniques de méningite avant de commencer à traiter par antibiotiques ?

Toujours Souvent Parfois Rarement

37. Quel type d'employé réalise les ponctions lombaires?

(poste/titre) _____

38. Combien de ces employés sont actuellement dans

l'établissement? _____

39. Combien de tubes de LCR sont normalement prélevés sur un cas suspect de

méningite? _____

40. Quand les prélèvements de LCR sont-ils livrés au laboratoire, *cochez la réponse appropriée*:

Immédiatement toutes les heures chaque demi-journée une fois par jour
 autre

41. Comment les prélèvements sont-ils manipulés et stockés avant le transport vers le laboratoire?

42. Pour un patient atteint de méningite, estimez le temps qu'il faut, en minutes, pour réaliser les activités suivantes:

	Activité de surveillance de la méningite pour un patient (complétez seulement les activités appropriées)	Minutes
A.	Diagnostic du patient	
B.	Réalisation d'une ponction lombaire	
C.	Envoi des prélèvements au laboratoire	
D.	Test sur les prélèvements de LCR	
E.	Gestion des cas incluant le traitement	
F.	Remplir le formulaire de surveillance et/ou les fiches descriptives	
G.	Déclaration détaillée d'un cas au niveau régional/national	

H.	Correspondance avec des responsables de la surveillance	
I.	Effectuer le ou les visites de suivi	
J.	Activités d'IEC avec la population	
K.	Autre, précisez:	

VI. AMENER LES PATIENTS VERS L'ETABLISSEMENT

43. L'établissement a-t-il une ambulance à disposition? Oui Non

44. Si ce n'est pas le cas, comment transportez-vous les patients vers votre établissement?

45. Quelle distance sépare l'établissement et les villes d'où viennent les patients? *Estimez la distance moyenne en km pour chaque ville concernée*

46. Combien de temps cela prend-il en moyenne? _____ heures

47. Si des taxis ou des bus sont utilisés pour transporter des patients, quel est en moyenne le coût du trajet aller/retour?

Taxi _____ CFA

Bus _____ CFA

48. Combien d'employés de cet établissement réalisent le transfert d'un patient suspecté d'avoir contracté une méningite? _____

49. Reçoivent-ils une rémunération symbolique pour cela? Oui Non

a. Si oui, de quel type? *Précisez le type* _____

b. Si oui, quel est l'équivalent monétaire en CFA? _____

VII. ORIENTATION DES PATIENTS

50. A quelle fréquence l'établissement utilise-t-il des ressources locales (personnel/véhicules) pour transporter vers un hôpital de référence des patients suspectés d'être infectés par une méningite bactérienne? _____ par semaine, mois, année (*encerclez la réponse appropriée*)

51. Donnez des détails

a. Précisez la ou les villes d'où viennent les patients

52. Quelle distance y-a-t-il entre l'établissement et l'hôpital de référence?

a. Pour ceux qui sont amenés directement à l'hôpital de référence sans passer par l'établissement de santé, précisez la ou les villes d'où ils viennent

57. En 2012, en moyenne, combien d'heures par mois un volontaire passe-t-il sur les activités de surveillance suivantes? *Complétez le tableau ci-dessous.*

Activité	Nombre d'heures (en moyenne par mois) pour un volontaire
a. Détection des cas et référence au centre de santé	
b. Mobiliser la communauté et les ménages, et préconiser la vaccination / Activités d'IEC avec la population	
c. Surveillance	
d. Formation sur la surveillance	
e. Tenue de registre pour la surveillance	
f. Autre (préciser):	
g. Temps de travail d'un volontaire (toute activité confondue)	

58. Les volontaires reçoivent-ils une rémunération symbolique? Oui Non

59. Si oui, précisez la nature et la fréquence

Fréquence _____ Type de rémunération _____ Valeur monétaire (CFA) _____

60. Combien donne-t-on aux volontaires pour les Jours d'Immunisation Nationale?

Montant en CFA _____

61. Est-ce que l'introduction de la surveillance au cas par cas nécessite du temps supplémentaire pour les volontaires?

a. Oui Non Pas applicable

b. Si oui, pouvez-vous donner une estimation du % de temps passé en plus : _____%
ou du temps total passé en plus : _____ par mois

X. VIII. FORMATION A LA SURVEILLANCE

62. Les employés impliqués dans la surveillance de la méningite suivent-ils des formations?

Oui _____

Si oui, veuillez préciser:

–

Non _____

Ne sait pas _____

63. Veuillez compléter le tableau ci-dessous qui détaille la formation pour la surveillance. Pour les formations non financées par l'établissement, veuillez indiquer où des frais ont été engagés et gérés.

	Type de formation	En 2012, combien d'employés ont reçu une formation dans le domaine suivant?	Où la formation a-t-elle eu lieu?	Quel mode de transport était utilisé pour se rendre à la formation?	Nombre de sessions de formation en 2012	L'une de ces formations était-elle tenue pour la première fois ? Oui=1, Non=2	Quelle était la durée moyenne de la formation (en jours)?	Quelle était l'allocation journalière pour la formation? <i>Mettre '0' si pas de frais</i>	Qui a organisé la formation?
A.	Formation introduisant l'IDSR								
B.	Formation de rappel de l'IDSR								
C.	Autre: <i>précisez</i> _____								
D.	Autre: <i>précisez</i> _____								
E.	Formation à l'introduction de la surveillance au cas par cas								
F.	Autre formation relative à l'introduction de la surveillance au cas par cas <i>Précisez:</i> _____								
G.	Autre formation relative à l'introduction de la surveillance au cas par cas <i>Précisez:</i> _____								

XI. SUPERVISION

64. De janvier à décembre 2012, l'établissement a-t-il eu des visites de contrôle pour la surveillance?

Oui Non Ne sait pas

Si oui, veuillez répondre aux questions suivantes:

a. Qui a mené la visite de contrôle? _____

b. A qui cette visite de contrôle était destinée (quels employés)?

Personnel soignant: Oui ___ Non ___ Ne sait pas ___

Technicien de laboratoire: Oui ___ Non ___ Ne sait pas ___

Autres: Oui ___ Non ___ Ne sait pas ___

c. Veuillez indiquer le mois et l'année des deux dernières visites de contrôle venant d'un échelon national? _____ (mois/année) _____ (mois/année)
_____ (mois/année) _____ (mois/année)

65. A quelle fréquence des visites de contrôle d'autres établissements sont effectuées par les employés de cet établissement?

_____ par semaine, mois, année (*entourer la réponse appropriée*)

66. Quel véhicule est utilisé pour les visites de contrôle? *Préciser le type de véhicule* _____

67. Normalement, quel est le temps de déplacement moyen pour effectuer les visites de contrôle? _____ heures

a. Quel est le temps pendant la saison des pluies? _____ heures

68. Si un taxi ou un bus est utilisé pour effectuer ces visites, quel est le coût d'un voyage aller-retour ?

Taxi _____ CFA

Bus _____ CFA

69. Combien de personnes se déplacent-elles pour ces visites? _____

70. Reçoivent-elles une rémunération symbolique pour ces visites? Oui Non

a. Si oui, sous quelle forme? *Préciser* _____

b. Si oui, quelle est la valeur monétaire en CFA? _____

71. Quelle est la proportion de temps consacrée à la surveillance de la méningite pendant ces visites? _____

XII. REUNIONS CONSACRES A LA SURVEILLANCE

72. A quelle fréquence les employés de cet établissement assistent-ils aux réunions consacrés à la surveillance (présentation de rapports mensuels, compte rendu, gestion des épidémies,...)? _____ par semaine, mois, année (*entourer la réponse appropriée*)
- a. Combien de personnes dans cette structure sont concernées en moyenne par ces réunions ? _____
73. Quel véhicule est utilisé pour assister à ces réunions? *Préciser le type de véhicule* _____
74. Où ces réunions ont-ils lieu (en 2012)? *Préciser* _____
75. Quelle distance sépare l'établissement de l'endroit où ont lieu les réunions ? _____ km
76. Combien de temps cela prend-il pour se rendre au lieu des réunions (*temps de voyage seulement*)? _____ heures
77. Si un taxi ou un bus est utilisé pour se rendre à ces réunions, quel est le coût d'un voyage aller-retour ?
- Taxi _____ CFA
- Bus _____ CFA
78. Y-a-t-il des indemnités financières pour ces réunions?
- Oui Non Seulement la nuit
- a. Si oui, quel est le montant des indemnités par trajet? _____ CFA
- b. Si les indemnités concernent seulement la nuit, combien de fois des indemnités ont-elles été versées en 2012? _____
- c. Montant des indemnités de nuit? _____ CFA
79. Combien de personne (en moyenne) se rendent à ses réunions? _____
80. Combien de jours durent ces réunions ? _____

XIII. SYSTEME D'INFORMATION

81. Qui est responsable de la mise à jour et de la gestion des formulaires de déclaration de cas/des formulaires d'enquête/du registre des cas ?

82. Décrivez le processus de saisie des données:

83. A qui l'établissement envoie-t-il les données sur la surveillance? (Cochez toutes les réponses qui s'appliquent)

District ____ Regionale ____ Ministère de la Santé ____

OMS ____ Autre (Préciser) _____

84. A quelle fréquence les données sur la surveillance sont-elles envoyées aux autorités sanitaires ou à l'OMS? (Cochez toutes les réponses qui s'appliquent)

	<i>Hebdomadaire</i>	<i>Mensuel</i>	<i>Trimestriel</i>	<i>≥ 6 mois</i>	<i>Autre</i>
<i>a. Téléphone</i>					
<i>b. Fax</i>					
<i>c. Mail</i>					
<i>d. Ordinateur avec internet</i>					
<i>e. Autre</i>					

85. Avez-vous des retours au niveau national sur les données que vous fournissez, par exemple sur la qualité des données, etc.?

Oui Non Ne sait pas

86. Les carnets et registres sont-ils vérifiés pour détecter des cas suspects de méningite?

Oui Non

87. Y-a-t-il des problèmes rencontrés pour faire le lien entre les données cliniques et les données de laboratoire? Oui Non

88. Si oui, précisez le type de problème:

XIV. SURVEILLANCE ACTIVE DES CAS DE MENINGITE

89. Cet établissement mène-t-il une surveillance active des cas pour la méningite bactérienne ?

Oui Non

Si oui, répondez aux questions suivantes:

90. Veuillez décrire le processus de surveillance active des cas effectivement mise en œuvre dans votre localité:

91. Combien de voyages sont-ils été effectués pour la surveillance active des cas en 2012?

92. Combien de fois ces voyages concernent-ils une surveillance active des cas de méningite bactérienne? _____ par semaine, mois, année (*entourer la réponse appropriée*)

93. Quel type de véhicule(s) est utilisé? Préciser le type de véhicule _____

94. Combien de temps prend habituellement

- a. un trajet aller-retour _____ heures
- b. une mission (hors trajet) _____ heures ou jour (*entourer la réponse appropriée*)

95. Si un taxi ou un bus est utilisé, quel est le coût d'un voyage aller-retour ?

Taxi _____ CFA

Bus _____ CFA

96. Y-a-t-il des indemnités financières versées?

Oui Non Seulement la nuit

- a. Si oui, quel est le montant des indemnités par trajet? _____ CFA
- b. Si les indemnités sont seulement pour la nuit, combien de fois des indemnités ont été versées en 2012? _____
- c. Montant des indemnités de nuit? _____ CFA

97. Y-a-t-il d'autres coûts liés à la surveillance active de la méningite bactérienne?(*Si oui, demandez-leur de les lister ainsi que les ressources nécessaires pour chaque activité*) Oui Non
-

XV. A COMPLETER PAR LES ETABLISSEMENTS QUI SUIVENT LA SURVEILLANCE AU CAS PAR CAS

98. Pour les activités suivantes (sensibilisation, vaccination, supervision, réunions), veuillez estimer le nombre de déplacements supplémentaires depuis l'introduction du vaccin MenAfrVac (donner une période _____):
- A. Nombre de déplacements supplémentaires pour la sensibilisation _____
Temps consacré à ces déplacements (trajets + temps sur place) : _____ heure ou jours
(entourer la réponse appropriée)
- B. Nombre de déplacements supplémentaires pour la vaccination _____
Temps consacré à ces déplacements (trajets + temps sur place) : _____ heure ou jours
(entourer la réponse appropriée)
- C. Nombre de déplacements supplémentaires pour la supervision _____
Temps consacré à ces déplacements (trajets + temps sur place) : _____ heure ou jours
(entourer la réponse appropriée)
- D. Nombre de déplacements supplémentaires pour les réunions d'immunisation

Temps consacré à ces déplacements (trajets + temps sur place) : _____ heure ou jours
(entourer la réponse appropriée)
- E. Autre déplacements supplémentaires, préciser _____
Temps consacré à ces déplacements (trajets + temps sur place) : _____ heure ou jours
(entourer la réponse appropriée)
99. L'établissement a-t-il acheté ou obtenu des véhicules supplémentaires du fait de l'introduction de la surveillance au cas par cas? Oui Non

100. Quelles sont les sources principales de financement de la surveillance au cas par cas?

Activité de surveillance au cas par cas	Source de financement
a. Formation	
b. Mobilisation sociale ou communautaire	
c. Surveillance spécifique	
d. Autre (préciser)	
e. Autre (préciser)	
f. Autre (préciser)	

XVI. NOMBRE DE CAS DE MENINGITE ENREGISTRE

101. Veuillez noter le nombre total de personnes suspectées d'avoir été infectées par une méningite bactérienne entre janvier et décembre 2012

		Jan	Fev	Mars	Avril	Mai	Juin	Juillet	Août	Sep	Oct	Nov	Dec
A.	Nombre de cas suspects vu (admis par) l'établissement												
B.	Nombre de cas suspects renvoyés vers un hôpital												
C.	Nombre de cas suspects ayant subi une ponction lombaire / prélèvement de LCR												
D.	Nombre de cas suspects ayant subi une ponction lombaire avec une probable méningite bactérienne												
E.	Nombre de cas suspects ayant fait l'objet d'une investigation du cas												
F.	Nombre de foyers en 2012												
G.	Nombre de foyers avec des annonces en ligne documentées												
Nombre de cas suspects ayant subi une ponction lombaire avec confirmation par un laboratoire de:													
H.	• Méningite												
I.	• Grippe												
J.	• Pneumonie												

Evaluation des registres de l'établissement

Dans les derniers 28 jours, combien a-t-on diagnostiqué de personnes atteintes de méningite? _____

102. Pendant 12 Mars- 8 Avril 2012, combien a-t-on diagnostiqué de personnes atteintes de méningite(méningite bactérienne aigue, méningite à pneumocoque, méningite à méningocoque et tout autre type de méningite) *Suivre les dossiers de ces personnes en incluant les carnets de prélèvements effectués ou le carnet de référencement du patient, les registres du laboratoire ainsi que les données sur la surveillance. Veuillez lister par type de méningite.*

103. Pendant 12 Mars-8 Avril 2013, combien a-t-on diagnostiqué de personnes atteintes de méningite?
Suivre les dossiers de ces personnes en incluant les carnets de prélèvements effectués ou le carnet de référencement du patient, les registres du laboratoire ainsi que les données sur la surveillance. Veuillez lister par type de méningite.

104. Dans tous les cas de méningite diagnostiqués dans le registre de l'hôpital, combien ont été enregistrés sur des formulaires de surveillance individuels:

- a. Pendant 12 Mars- 8 Avril 2012 _____
- b. Pendant 12 Mars- 8 Avril 2013 _____
- c. Si inexistant, expliquez pourquoi:

105. Quel est le total des autres maladies qui ont été diagnostiquées dans cet établissement en 2012? Veuillez compléter le tableau ci-dessous et lister chaque maladie ainsi que leur nombre

<i>Maladie</i>	<i>Nombre de cas total diagnostiqué par l'établissement</i>
<i>a.</i>	
<i>b.</i>	
<i>c.</i>	
<i>d.</i>	
<i>e.</i>	
<i>f.</i>	

XVII. QUESTIONS QUALITATIVES

	Tout à fait d'accord	Neutre	Pas du tout d'accord	NA
Budget				
106.Nous préparons notre budget annuel pour la surveillance de la méningite et les activités de l'IDSR				
107.Nous avons le contrôle de notre budget pour l'IDSR				
108.Les fonds que nous recevons chaque année correspondent à nos propositions budgétaires				
109.Les fonds arrivent en temps et en heure				
110.Notre travail n'est jamais gêné par le manque de fonds				
111.Nous connaissons nos dépenses pour la surveillance				
112.Nous recevons toutes les fournitures dont nous avons besoin en temps et en heure				
Logistiques pour le transport en laboratoire				
113.Le système logistique d'envoi de prélèvement vers un laboratoire est efficace				
114.L'année dernière, nous n'avons pas eu de rupture de stock				
115.Au cours de l'année passée, nous avons eu un système de transport fiable pour transporter les prélèvements vers un laboratoire				
116.Nous comprenons le processus pour emballer et envoyer les LCR vers un laboratoire				
117.Nous avons des fonds suffisants pour envoyer les LCR vers un laboratoire				
Ressources Humaines				
118.Nous avons assez d'employés pour mener des activités de surveillance de manière efficace				
119.Nous n'avons pas beaucoup de rotation de personnel (c'est-à-dire des employés qui partent et d'autres qui arrivent)				
120.Nos employés ont une bonne connaissance et sont formés à la surveillance				
121.Nos employés sont motivés				
122.Nos employés reçoivent une supervision et des remarques utiles				
Rapport				
123.Durant l'année écoulée, nous avons remis en temps et en heure tous nos rapports au district				
124.Nous recevons des retours sur nos rapports dans des temps acceptables				

-FIN DU QUESTIONNAIRE DESTINE AUX ETABLISSEMENTS DE SANTE-

Appendix 5. Recommended upgraded meningitis surveillance activities for Chad

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
Health facility				
Support Activity: Training	Health workers identify cases who meet case definition for meningitis and record in register	Annual IDSR Training for Health facility	Per Diem	Cost of training for one staff per health facility per year
			Transport Accommodation	
Detection and Confirmation		Additional employee to support IDSR activities	Personnel time/ salary	Salary for additional employee
Reporting and Analysis	Weekly and monthly report to CDZ as part of IDSR zero-reporting	Archive all paper-based forms	Annual register	Cost of annual register
			Storage furniture (not needed if move to electronic system)	Cost of storage furniture
Detection and Confirmation		Suspected cases are referred to health facility	Personnel time Mobile phone + credit	Cost of mobile phone and credit
			Patient Transport fee (to motorbike taxi)	Plus PT fee
			Patient transport referral form	

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
Detection and Confirmation	Weekly IEC activities as part of IDSR		Personnel time	
Investigation		Weekly active surveillance during Meningitis season	Personnel time	Personnel time for 7 (Dec to June) months
			Transport	Transport costs for 7 months
Response	Conduct Vaccination Campaign		Personnel time	
			Transport	Transport costs
			Materials (e.g. cold box)	Materials
District Hospital				
Support Activity: Training		Annual IDSR and lumbar puncture training for Clinicians	Cost of training at each district hospital	
Detection and Confirmation	Lumbar puncture performed on suspected case		Lumbar puncture kit	Plus cost of lumbar puncture kit
			Personnel time	
Detection and Confirmation	Send 1 Tube of CSF to district laboratory	Send two tubes of CSF to district laboratory	Tube	Plus 1 tube (up to sufficiency)
			TI	Plus cost of sufficient TI
Reporting and Analysis		Complete case-based form and send to district laboratory	Case-based form	Plus cost of copies?
District Laboratory				
Support Activity:		Biannual training (or on-	Personnel time	Cost of outside

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
Training		site instruction) on QA/QC and methods		consultant, if necessary
				Training materials
Detection and Confirmation	Perform gram stain and cell count		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform rapid latex test	Sufficient amount of Latex tests	Personnel time	Plus cost of sufficient latex tests
			Lab supplies and reagents	
Feedback	Report results back to hospital/CDZ			
		Package CSF for transfer to National or Regional reference laboratory within 48 hours upon reception of sample	Personnel time	
			T-I	Plus cost of sufficient TI
			Triple packaging box	Plus cost of sufficient Triple packaging
			Cryotubes	Plus cost of sufficient Cryotubes
			Case-based form	
District Health Office (CDZ)				
Support Function: Training		Annual IDSR Training (1 day for CASEs and CDZs)	Per Diem	Cost of training for all CDZs

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
			Transport	
			Accommodation	
Detection and Confirmation		Additional employee to support IDSR activities	Personnel time/ salary	Salary for additional employee
Detection and Confirmation		Send prepared CSF to National or Regional lab using established specimen transport network within 48 hours upon reception of sample	Funding for specimen transfer (e.g. by official courier)	
			Personnel time	
Feedback	Notify patient and health facility of result within 48 hours		Mobile phone + credit	Cost of mobile phone and credit
			Personnel time	
Support Activity: Supervision	Weekly supervision visits		Motorbike	Cost of motor bike
			Monthly petrol allowance	Sufficient petrol allowance
				Sufficient motorbike maintenance
			Personnel time	
Reporting and Analysis	Analyse district data	Electronic analysis of data	Laptop	Cost of laptop for each CDZ
			Personnel time	

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
Reporting and Analysis	Report weekly and monthly to Regional level	Mobile phone + credit	Personnel time	
			Internet modem	Cost of modem
			Monthly internet credit	Cost of monthly internet credit
Response	Conduct Vaccination Campaign		Personnel time	
			Transport	Transport costs
			Materials (e.g. cold box)	Materials
Regional Health Office (CASE)				
Support Activity: Training		Annual IDSR Training (1 day for CASEs and CDZs)	Per Diem	Cost of training for all CASEs
			Transport	
			Accommodation	
Reporting and Analysis	Analyse regional data	Electronic analysis of data	Personnel time	
			Laptop	Cost of laptop for each CASE
Reporting and Analysis	Report weekly and monthly to National level		Personnel time	
			Mobile phone + credit	Cost of mobile phone and credit
			Internet modem	Cost of modem
			Monthly internet credit	Cost of monthly internet credit

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
Support Activity: Supervision	Weekly supervision visits		Monthly petrol allowance Vehicle	Sufficient petrol allowance Sufficient vehicle maintenance
Support Activity: Coordination		Organize annual training for health facilities and district hospital	Personnel time Venue costs Materials Food	All costs for training except per diem, accommodation, and transport
Response	Conduct Vaccination Campaign		Personnel time Transport Materials (e.g. cold box)	Transport costs Materials
National Surveillance Office (SSEI)				
Support Activity: Training		Annual training with partners and national counterparts on IDSR		
Support Activity: Coordination		Organize training for CASEs and CDZs	Personnel time Venue costs Materials Food	All costs for training except per diem, accommodation, and transport
Support Activity:	Two field visits with		Personnel time (Per diem?)	

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
Supervision	laboratory cadre		Two Vehicles	Cost of additional vehicle
			Accommodation	
			Petrol	
			Materials (Education, lab, other)	
Reporting and Analysis	Weekly data analysis		Personnel time	
			Software	
			Hardware (laptop and desktop for relevant Personnel)	
Feedback	Weekly and Monthly feedback of results	Develop and distribute monthly national bulletin with IDSR results	Personnel time	
			Printing	Cost for printing x each health facility
			Courier fees	Cost of shipping to each CdZ (i.e. to each district)
Response	Support Vaccination Campaign		Personnel time	
			Transport to field	Transport costs
			Regional Laboratory	
		Biannual training (or on-site instruction) on QA/QC and methods	Personnel time	Cost for outside consultant, if necessary
				Cost of training materials
Detection and Confirmation	Perform gram stain and cell count		Personnel time	

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform rapid latex test		Personnel time	
			Lab supplies and reagents	
Detection and Confirmation	Perform culture test		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform Serogrouping		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform Antibiotic sensitivity		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Feedback		Report results to district and national laboratory within five days of sample receipt in the system		
Reporting and Analysis	Weekly reporting of cases to CdZ		Case-based surveillance forms	
			Mobile phone and credit	
Detection and Confirmation	Send positive isolates to national laboratory for		Personnel time	

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
	confirmation		T-I	
			Triple packaging box	
			Cryotubes	
			Case-based form	
National Laboratory				
Detection and Confirmation	Perform gram stain and cell count		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform rapid latex test		Personnel time	
			Lab supplies and reagents	
Detection and Confirmation	Perform culture test		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform Serogrouping		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform Antibiotic sensitivity		Personnel time	
			Lab equipment	
			Lab supplies and reagents	
Detection and Confirmation	Perform PCR	Perform real-time PCR	Real time PCR machine	Cost of real-time PCR machine

<i>Level/ Function</i>	<i>Current Activity</i>	<i>Activities to upgrade system</i>	<i>Inputs needed for upgrade</i>	<i>Expenses to include in budget</i>
			Lab supplies and reagents and reagents	Cost of real-time PCR reagents
Detection and Confirmation	Send 80% of positive isolates to WHO Collaborating Centers		Triple packaging box	
			Cryotubes	
			Case-based form	
Detection and Confirmation	Report weekly to National Surveillance Office	Electronic aggregation and reporting (presentation)	Personnel time	
			Laptop	Laptop
			Software	Software
			Internet modem	Internet modem
			Credit for monthly internet	Credit for monthly internet
Support Activity: Supervision	Two field visits per year with surveillance cadre		Personnel time (per diem?)	
			Accommodation	
			Materials (Education, lab, other)	

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