

Verbal Autopsies, Mobile Data Collection for Monitoring and Warning Causes of Deaths

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Abstract — These paper summarizes the work performed to endow the doctors, the technicians of laboratory and the agents of collection of verbal autopsies on the ground, of a mobile system which will facilitate the data-gathering. The system will automate the collection, the sending and the insertion of the data in a data base centralized. The stakes to aim in the realization of such a project are varied. The developed system mainly will allow the reduction in displacements and the optimization of the times carried out by the agents. The reduction of the processing time necessary for the manipulation of data will be also a considerable asset, because it will allow the medical organizations and the ministry for health to supervise and manage with promptitude the causes related to certain deaths. To lead to the results which we obtained, we interviewed the actors and future users to identify and analyze the real needs. After having made an adequate modeling we developed the three blocks of the system: the mobile application which will be exploited in the mobile telephones of the agents, the data base which will store all the collected autopsies and the Web platform for the monitoring and the administration.

Keywords – *Verbal Autopsy; Neonatal; Mortality, Mobile System.*

I. INTRODUCTION

Telecommunications is defined as all procedures for transmitting and receiving information remotely. Since its introduction in the late nineteenth century, this sector was in constant and diversified evolution: Chappe telegraph, telegraph wire, submarine cable, wireless telegraphy, telephone, radio, television, satellite use, etc... This, by the progress made sector-specific, either because of the use of other technological advances. Mentioned, it is argued that advances in telecommunications have largely accompanied all scientific and technological achievements since the end of the first industrial revolution. But over the past ten years, two dominant trends in this sector are outlined, and then are being profiled to win. On the one hand, there is a convergence of application domains between which the sector was segmented (transport text, voice, and image) and the development of interoperability between technical transmission and reception, fixed and mobile. This means that at a horizon of a decade, each of us will live in a network of communicating objects whose offer of service will apply to most areas of our daily life, housing situation in a situation like nomadic.

Moreover, in conjunction with the computer, telecommunications is no longer just an accompanying factor of economic progress, but a driving force behind this progress. Already exist today; it will probably be decisive in the next twenty years. This is probably carrying considerable changes that are impossible to ignore in the health sector. Following the work done by various researchers in medicine and World Health Organization (WHO) for an international statistical classification of diseases and related problems; for revised estimates of causes of maternal mortality, for levels, causes and factors of maternal mortality in rural Senegal, Verbal Autopsy (VA) which is a medical technique designed for reliable determination of the cause of death by interviewing the entourage of the deceased, cannot be ignored by the innovations of ICT. When conducted rigorously using a standardized questionnaire, VA can establish the most probable diagnosis. Data obtained by VA can be suitable for demographic or epidemiologic purposes. The VA technique depends on the exact purpose for which the data will be used [1].

The current paper reports the work performed to endow the doctors, the technicians of laboratory and the agents of collection of VA on the ground, of a mobile system which will facilitate the data-gathering. The system will automate the collection, the sending and the insertion of the data in a data base centralized; it is organized as follows: Section II describes analytical framework and VA specifications. Section III presents the design approach of the information system for the mobile processing of data. Section IV outlines some discussion about our results and some challenges of VA. Section V concludes the paper and lays out our future work.

A. Context and motivations

1) The penetration of Mobile telephony

The United Nations Conference on Trade and Development (UNCTAD) Information Economy Report 2009 presents Africa as the fastest growing mobile market in the world (UNCTAD 2010). The number of mobile subscribers worldwide are expected to grow to 5.5 billion by the end of 2013 and 70% of them will be in developing countries. Mobile phones are

contributing to unprecedented social and economic development on the continent with pioneering initiatives led by international agencies, Non-Governmental Organizations (NGO) and the private sector in agriculture, health, education, banking, citizen media, disaster and humanitarian relief [2]. There is a widespread agreement that Information and Communications Technology (ICT) services, especially mobile ones, have the potential to play a major role in furthering social and rural development in developing economies such as Africa.

2) The Millennium Development Goals

In order to achieve the Millennium Development Goals (MDGs), including [3]:

- Number 4: reduce child mortality,
- Number 5: improve maternal health.

These are to:

- Take advantage of ICT including the strong mobile network coverage in Senegal,
- Propose a solution with VA forms embedded directly into mobile phones.

3) The scope of Verbal Autopsy

Known since the 17th century but formalized 50 years ago in first observatories of population (1), the VA is generally used in two circumstances: demographic surveillance and epidemiological investigation. In recent years, VA have been used more widely to provide information on cause of death in areas where civil registration and death certification systems are weak, and where most people die at home without having had contact with the health system. This type of interview is often the only way to find out about the cause of death. VA has been used for a variety of purposes, all of which require arriving at a diagnosis for the cause of death:

- To provide data on mortality by cause.
- To evaluate health interventions aimed at reducing mortality from specific causes of death, when these interventions are being introduced into a limited geographic area on a trial basis.
- To identify ways to reduce unnecessary deaths. For example, combining a VA questionnaire with a household questionnaire asking about steps taken by the family and by the health services during the illness preceding death can make it possible to identify problems relating both to health-seeking behavior and health service provision.
- To facilitate research into factors associated with mortality from specific causes of death.

The three international standard VA questionnaires are intended to serve the needs of multiple users and producers of mortality information, including researchers, policy-makers and those carrying out monitoring and evaluation activities. Because VA can not ascertain all causes of death. Furthermore, as many validation studies have shown, VA does not perform equally well for all causes that it can ascertain [4][5]. Taking these limitations into account, the standard questionnaires were developed in such a way as to:

- Permit certification and coding procedures of International Classification of Diseases (ICD-10)
- Ascertain all causes of death that may be attributed with reasonable accuracy from a well administered VA interview.

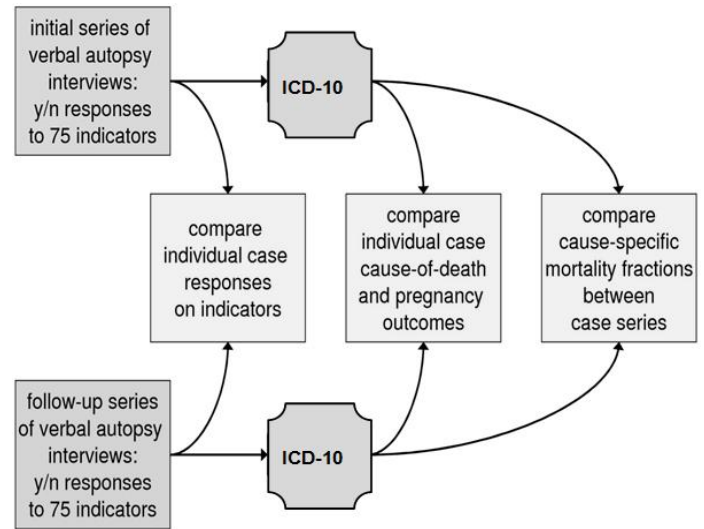


Figure 1. International Classification of Diseases (ICD-10).

The international standard VA questionnaires should address the major causes of death in most populations where the use of VA is a necessary means to obtain cause-of-death information. Figure 2. show an example of hierarchical assignment of neonatal causes of death provided by WHO [6].

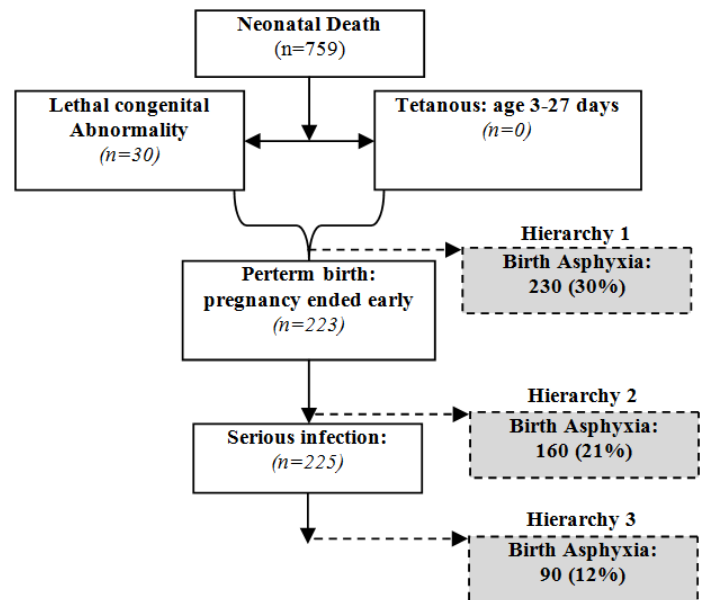


Figure 2. Hierarchical assignment of neonatal causes of death.

B. Circumstances

1) The situation

The organizational structure of the national health care system in Senegal is divided in three levels: Regional Hospitals; District Health Centers which includes medical units and equipment, and is supervised by a medical doctor who has overall responsibility of the management of the center; Health Posts which are located in rural regions and depend on district health centres. Health posts have about health workers but no medical doctor working. The number of health posts per health centre is depending on the size of the district and its population density. The main duties carried out in health posts are consultancy and treatment of patients, rapid HIV and malaria tests, assistance in birth giving, vaccination, monitoring of children's and babies health, distribution of medicaments and quick clinical tests (malaria and HIV) [6].

The main goal of the Network of Laboratories is to improve people's health in these countries. Three areas of activities are covered by this network: training of laboratory technicians/health workers and medical biologists, VA and epidemiological surveillance of specific diseases.

Different activities are performed in regional and district laboratories, particularly the following ones: biological testing prescribed by doctors, and collecting and reporting VA and epidemiological information. The reporting of VA information must be sent to the Network of laboratories (NL) and would be focused on neonatal deaths, infant deaths and adult deaths. More precisely, peripheral laboratories have to fill in and send two forms or documents: one form is used to collect information about verbal reason or diseases of death that are prioritized (e.g. cholera) on a weekly basis. This form comprises different data: the ID of the laboratory, diseases that have been detected, identity of the patient, date of the swab and interview, date of reception in the laboratory, quality of the swab, if possible pathogen that have detected, date of delivery of the result, date in which the document has been sent to the Network of Laboratories. The second form is used to collect information about all diseases that are closely watched the reason of the death, including prioritized ones. This form must be sent on a monthly basis. This form comprises the following data: type of form, the ID of the laboratory and the person who filled out the form, type and number of diseases that have been detected, nature of the swab, whether the swab has been collected by National Laboratory, pathogenic agents that have been detected.

laboratories are very important for the Network of laboratories because it is used to produce country's health indicators (statistics about death, diseases and illness) which are reported to international governmental agencies, particularly the World Health Organization. The production of these indicators is crucial for the country because the obtaining of funds is mainly based on these data.

2) Needs and expectations

Only few district laboratories report VA information. Regional laboratories are the main laboratories that send the VA forms. It seems that the main reason why some district laboratories do not report epidemiological information is that because these laboratories do not have computers and an internet access.

He explained that two issues would be worth to explore in the context of this project:

1. Improving and facilitating the reporting of VA information, especially from "silent" laboratories that is laboratories which do not report deaths being kept under watch to the networks of laboratories.

2. Assisting laboratory technicians in accomplishing their tasks (for example, in performing biological tests), and facilitating the learning of existing or new technical procedures. The goal is then to ensure a better and quicker transmission of epidemiological data from district laboratories to the Network Laboratories.

Because VA is a technique used to determine the cause of death by asking caregivers, friends or family members about signs and symptoms exhibited by the deceased in the period before death. It is firstly recommended to use standardized questionnaire that collects details on signs, symptoms, complaints and any medical history or events. At secondly to undertake four standard steps to identify the underlying cause of death. In order to collect reliable and useful statistical information, each step must be performed in a standard fashion.

The following sections provide the necessary detail on each of the four steps [7].

- Step 1: Identify the cause of death
- Step 2: Certify the death
- Step 3: Code the causes of death
- Step 4: Select the underlying cause of death

II. ANALYTICAL APPROACH

A. Case studies

Laboratories technicians use a mobile phone to transmit epidemiological data to the Network Laboratory. In district laboratories, the head doctor of the health center is informed about data transmitted to the Network Laboratories, by receiving a SMS on his/her mobile phone. Two types of interfaces will be tested: voice and widget (GUI: Graphical User Interface). The voice interface is based on an Interactive Voice Response system (IVR), which is an automated telecommunications system allowing a person to interact with a computer to achieve defined results, without human intervention. System inputs will use DTMF (Dual-Tone Multi-Frequency, which is a mechanism for navigating voice user interfaces using the phone's numeric

FICHE DE COLLECTE DE DONNEES DE LABORATOIRE POUR LA SURVEILLANCE DES MALADIES PRIORITAIRES										
Laboratoire : _____		District : _____		Région : _____						
Mois : _____		Année : _____		Date d'envoi : _____						
Numéro d'identification PPM-XXXX-YYYY-AAAA (sans format au PPM-XXXX- YYYYY-AAAA) ODD - District YY - Année NNN - Numéro d'ordre dans l'année	Malade : - Choléra - Diarrhée - Sanguinolente - (Shigella) - Mémorable - Autre	Numéro d'identification du labo	Nom du Patient	Date du prélèvement	Date de réception au labo	État du produit pathologique 1 = Bon 2 = Mauvais	Agent pathogène isolé - Vibrio cholerae 01 - Sérotype/désignation type 1 - Autre légionelle - Vibrio parahaemolyticus - Autre pathogène - Pas d'isolement de pathogène	Autres résultats	Date d'envoi des Résultats au District ou au Réseau National	Date d'envoi au Réseau National de Laboratoires

Figure 3. Form sent monthly.

These forms are received by Network of Laboratories which is in charge of collecting VA data sent by regional and district laboratories. These data are aggregated and treated. A quarterly bulletin containing a synthesis of VA reported by the laboratories (regional and districts) is sent to all of them every 3 months. This bulletin also includes educational information called information of the month. VA data sent by the

keypad) and outputs will use Text to Speech Synthesis (TTS). The GUI will collect the data from the user and send it to the server via SMS. The idea is to compare which mobile interface (i.e. voice, GUI) is the most effective in terms of accuracy, speed and user experience. Data collected via mobile phones will be stored on a central server platform. A web interface will allow the Network of Laboratories to view the data transmitted by laboratory technicians.

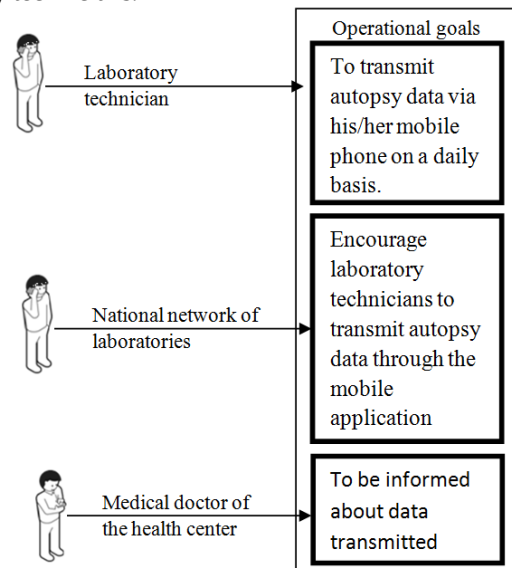


Figure 4. Actors and operational goals.

A.1) Widget scenario:

Karim, laboratory agent is going to use the m-autopsy (widget) system in order to transmit VA data to the the Network Laboratorie.

Steps	Actions
1:	Karim open the m-autopsy application on her mobile phone by clicking on a widget
2:	The system welcomes him and prompts him to select neonatal, infant or adult deaths
3:	The system prompts him to enter or select the reason/disease (a list of diseases is presented, including the item 'other') that has been identified as the cause of the death. If the user selects 'other', he will be prompted to enter the reason/disease by using the keyboard.
5:	The system prompts him to enter the identification of the patient: 'type patient ID'
6:	The system prompts him to enter the name of the patient: 'type the name of the patient'
7:	The system prompts him to enter the date of the swab and interviews: 'enter the date of swab and interviews'
8:	The system prompts him to enter the date of reception of swab and interviews in the laboratory: "Enter the date of reception of the swab and interviews"
9:	The system prompts her to enter the quality of the swab: "Enter the quality of the swab. choice 1 if swab is good, or 0 if swab is bad"

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10:	The system asks him whether he wants to report another case: "press "1" to report another case, press "0" to finish"
11:	The system thanks her for reporting epidemiological data to the Network Lab
12:	The system displays the following message: "Your message has been sent successfully!"

Table 1. Widget (GUI) scenario

A.2) Voice scenario:

Karim, laboratory agent is going to use the m-autopsy (vocal) system in order to transmit VA data to the the Network Laboratorie.

Steps	Actions
1:	Karim dials a phone-number to report VA data
2:	The system welcomes him and prompts him to select: press "1" for neonatal, "2" for infant or "3" adult deaths
3:	The system prompts him to enter the verbal reason/disease that has been (a list of diseases is presented, including the item 'other') that has been identified as the cause of the death. If the user selects 'other', he will be prompted to enter the disease by using the keyboard. The user will use DTMF to select the disease: "select the reason or disease. Press 1 for cholera, Press 2 for malaria, etc." If the user selects "other", she will be prompted to enter the disease by recording a voice message.
4:	The system prompts him to enter the name of the patient by recording a voice message: "say the name of the patient after the beep and then press #".
5:	The system prompts him to enter the identification of the patient by recording a voice message: "say the ID of the patient after the beep and then press #".
6:	The system prompts him to enter the date of the swab and interviews: 'enter the date of swab and interviews'
7:	The system prompts him to enter the date of reception of swab and interviews in the laboratory: "Enter the date of reception of the swab and interviews"
8:	The system prompts him to enter the quality of the swab: "Enter the quality of the swab. Choice 1 if swab is good, or 0 if swab is bad"
9:	The system asks him to enter any other result: "if you want to report any other result press #, if not please wait"
10:	The system asks him if she has sent the result to the district: "did you send the result to the district?" If you did so, enter the date, if not press *
11:	System's action "The data will be transmitted. You will receive an automatically generated delivery status notification [by SMS and/or email]. If you want to report another case of cholera press #, if not press *"
12:	back to the main menu -> step 2
The voices system shall allow the Network Laboratories to view collected data on a web interfaces. Wireframes of these interfaces are shown in the appendices.	

Table 2. Voice (IVR) scenario

B. Interaction and communication structures

The following figure describes the flow of information among the actors involved in the VA use cases:

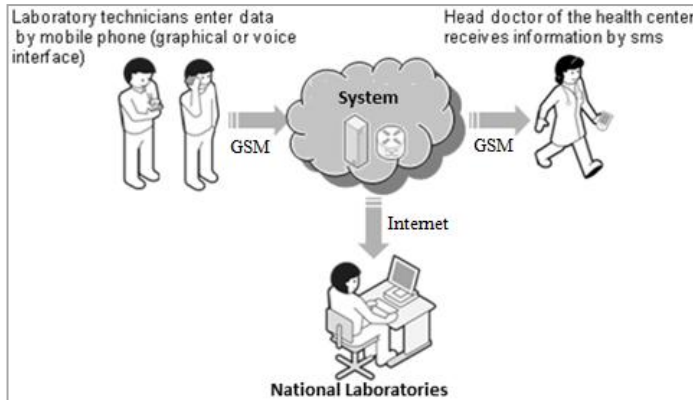


Figure 5. Flow of information among the actors involved in the VA.

The Laboratory agent enter data by mobile phone while using the graphical application call (widget), Head doctor of National Laboratories can receives information by SMS. L'administrateur de la plateforme (serveur de collecte de données) accèdera aux informations collectées et stockées dans la base de données, un interface web y est développée et, permet de visionner les statistiques des données remontées.

The scenario described above is modeled with unified modeling language (UML) in Figure 6.

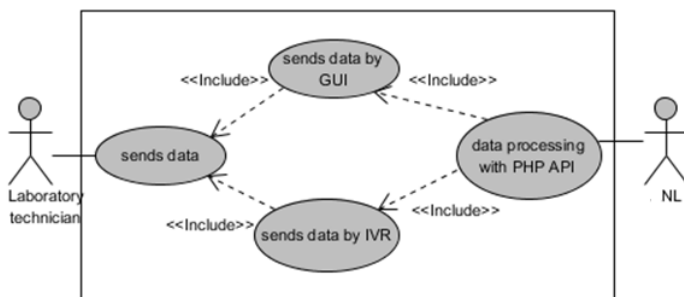


Figure 6. UML case diagram for the VA use case [8]

B.1) Technology infrastructure

This section describes the software and hardware components needed for implementing the VA system and using the applications.

VOICES System

- Based on Emerginov platform, hosting: PHP, Apache Web server, database MySQL, PBX platform (Asterisk), voice xml, IVR, TTS in french language, Kannel SMS gateway.

IVR case

- Mobile phone or landline phone
- Software installed on the mobile phone: None
- Bearers: GSM or PSTN

GUI case Native Application

- Smartphone or feature phone
- Software: OS Android and Java for Smart phone, JavaVM (MIDP 2.0, CDLC 1.1) [9] and Java ME for feature phone [10][11]

- Bearers: GSM (SMS)

Web site for the NL

- Personal Computer
- Software: OS (Linux, Mac OS or Windows), Web browser
- Bearers: Internet

B.2) Cost considerations, feasibility and sustainability

Technically speaking, there is no major obstacle or barrier hampering the feasibility of the system. One important requirement regarding the technical aspects is that the software components system shall be easy to install in different physical platforms. As for cost considerations and sustainability issues, the major issue that we are considering is how the cost of the system (exploitation costs, operational costs, communication costs, etc.) and its usage by end-users (laboratory technicians and the NL) will be met after the end of the project; in other words what kind of socio-economic model (in terms of business model, partnership, kind of partners, etc.) should be implemented for funding mobile health in order to ensure long-term sustainability.

B.3) Privacy and security issue

The VA use case involves the usage of sensitive medical data, including identity information (name of the patients). This document addresses the security and privacy issues raised by this use case. It describes how the security and confidentiality of these data will be protected and examines the security weaknesses of the system, at different levels: data entry, data transmission, data storage, and data access.

Data entry: configuration of mobile for the security of data

- Dedicated Subscriber Identity Module (SIM) card will be used by the RNLs Technicians in order to access Health application

- Data shall not be stored locally in the phone SIM card nor in any memory card incorporated into the phone

- In the graphical and voice interface scenarios, the access to the application will protected by a password.

Data transmission: GSM network, support for data transmission GSM incorporates certain security features. It uses integrated cryptographic mechanisms that prevent unauthorized use of the network as it maintains the identity and authentication key of the subscriber on the SIM card, and over-the-air interfacing through ciphering of the user and signaling data. Subscriber's Identity (IMSI) is further protected by a temporary

number, so called the Temporary Mobile Subscriber Identity (TMSI) number.

There are four basic security services provided by GSM:

- Anonymity: TMSI assignment;
Protects against someone tracking the location of the user or identifying calls made to or from the user by eavesdropping on the radio path [12][13];
- Authentication:
Network operator can verify the identity of the subscriber making it infeasible to clone someone else’s mobile phone
- Confidentiality:

Encryption of user voice and signaling data over the radio link protects voice, data and sensitive signaling information (e.g. dialed digits) against eavesdropping on the radio path

- Subscriber Identity
SIM and Mobile Equipment Identity (IMEI) number.
- Data storage:** Security of data on servers
Data access: The access to epidemiological data will be protected by password and login. Only the RNL will have access to these data.

III. EXPERIMENTAL RESULTS

A. Tests and results

After the development of different applications of VA system, we present in this section some results:

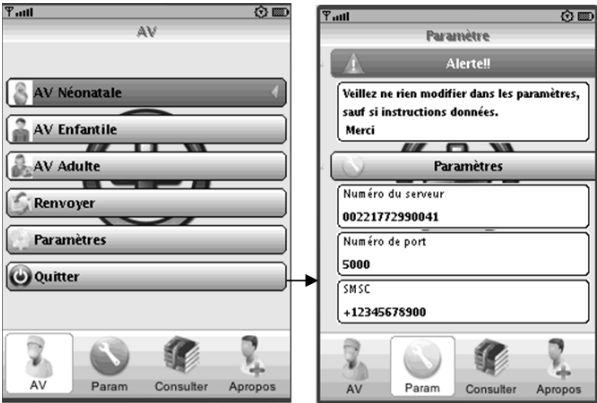


Figure 7. GUI application (widget).

The results of the first realized tests with certain agents of laboratory of district can be viewed on the web server in the form of a histogram, of pie chart or of bend (Figure 8.)

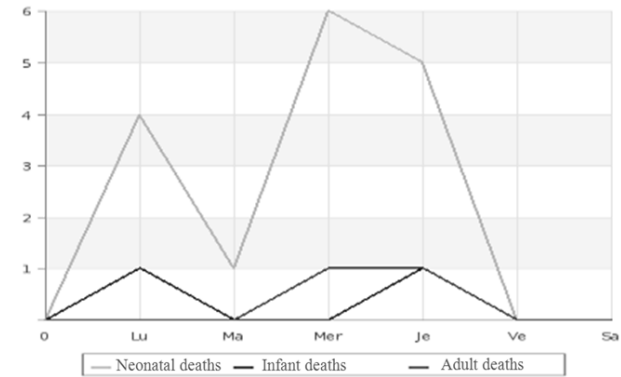


Figure 8. GUI application (widget).

The same results can be observed under cartographic form, the results are colored according to thresholds of alarms predefine

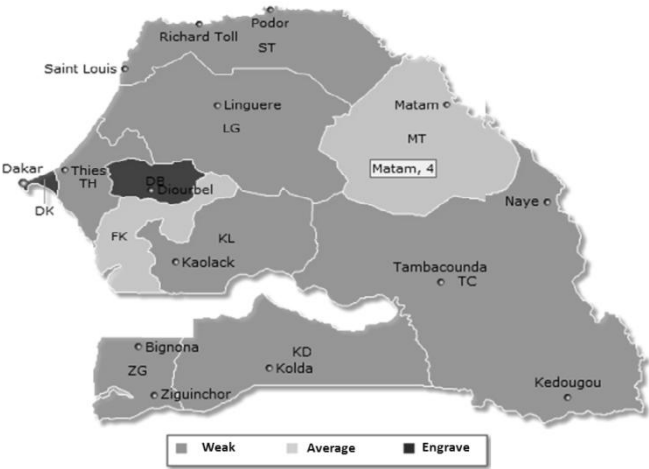


Figure 8. GUI application (widget).

IV. DISCUSSION AND SOME CHALLENGES OF VERBAL AUTOPSY

VA are of optimum value when they are applied to all deaths in a population, which is crucial in situations where only a fraction of deaths are registered or occur in hospitals. However, there are limits to the use of VA.

First, they require skilled field-based personnel to record evidence as well as office-based staff to assess cause of death, and to code and to analyze data. Second, the list of causes of death that can be assessed by VA is only a small sample of the list of causes used on medical certificates. Third, the quality of the assessment depends on sensitivity and specificity of each diagnosis. While they work well for some diseases of high public health importance (such as measles, whooping cough, tetanus, cholera, and dysentery) as well as for accident and violence, the use of VA is more problematic with diseases that have less specific symptoms, but which are equally important (such as HIV/AIDS in children, malaria in adults, and cancers). Fourth, the coding of verbal autopsy causes has never been made systematic, although it could be made so with the

inclusion of rules for assessing "underlying", "immediate" and "contributing" causes.

V. CONCLUSION

Verbal autopsy methodologies are still evolving; many areas of active and important research in verbal autopsy methods remain. These include topics such as further optimization of questionnaires and statistical methods for assigning causes of death from verbal autopsy that however – and in order to ensure that data on cause-specific mortality derived from VA in coming years have the greatest possible benefits to those producing them as well as to those using them for comparative purposes – it is urged that these new standard resources become the foundation for efforts in VA data collection wherever possible.

VA allows identification of major health problems, comparisons of local and national differences in mortality ratios, the monitoring of trends over time, and the evaluation of interventions and health programs. However, the usefulness of VA depends on quality and standardization. If poorly conducted, they can produce misleading results. The issues of quality assurance and systematic coding are the main hurdles to overcome before their universal use can be recommended. We hope that the mobile systems that we developed for data collection will help understand and correctly interpret verbal autopsies statistics.

There are many possibilities for future development of the system. That is why we believe that the work produced will open doors to a large development of mobile application for VA in Senegal to overcome lack of internet access and computers in district laboratories.

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