Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 3, Issue. 8, August 2014, pg.679 – 693

RESEARCH ARTICLE

An Implementation of Early Warning of Floods along Zambezi Basin Through the Use of Context-Awareness

Munyaradzi Magomelo[1], Hilton Chikwiriro[2], Clive Gurure[3]

[123]Computer Science Department & Bindura University of Science Education, Zimbabwe

[1] mmagomelo@buse.ac.zw; [2] hchikwiriro@buse.ac.zw; [3] clivethescott@gmail.com

Abstract— The ever-growing research area of early warning in floods is a broad field that has received much attention from researchers. This is because early warning has proven to be effective in reducing deaths, injuries and property damage due to floods if done appropriately. In this research, firstly, the researcher performed an in-depth study and analysis of existing flood warning systems with the aim of evaluating what has been done and identifying weaknesses that exist if any. Also, improvements over the more traditional early warning flood systems were evaluated with the aim of justifying the applicability of each in the studied research implementation area. Secondly, the researcher used an experimental research design that included surveys as a method to infer conclusions from the sample population, which included the influential flood warning people selected in the implementation area. The context-aware model was then designed and implemented using a number of open source tools using an agile software methodology strategy in the research implementation area and various qualitative and quantitative result data obtained. These results were then analyzed and the researcher concluded that context awareness did manage to improve early warning of floods.

Keywords— Context, Context-awareness, Early Warning System

I. INTRODUCTION

The flexibility of decision making through the use of contextual information has been recognized and applied in many aspects of computer science and other fields such as information retrieval, mobile computing and data mining. Contextual information provides vital information that can be used to determine the situation that the person or device being monitored is in, and make further deductions about what action to take given different scenarios. The dynamic nature of contextual information makes it ideal for use within situations of danger such as floods, in which the person's context can be used to make timely decisions.

II. BACKGROUND OF THE STUDY

Countries have long been concerned about the huge impacts that natural disasters have on society in developed and especially in developing countries. Throughout history, disasters have destroyed lives and livelihoods, killing people and damaging homes and businesses. It is estimated that disasters in the past 35 years have taken an estimated 2.5 million lives and cost more than US$1.5 billion, mainly in developing countries [40]. The extent of damage caused by a natural disaster is related to its severity and the level to which people in the disaster area are able to prepare for it.

When these disasters occur, adequate warnings are usually not available or not received in time for the relevant people to take appropriate action in the danger zone. Effective early warning systems for natural hazards not only save lives; they also protect the livelihoods of communities and national development gains. In most communities that are afflicted with natural disasters such as floods, landslides and earthquakes, disaster early warning systems today are either not available or extremely ineffective. In most situations

Early warning describes the provision of information on an emerging dangerous situation where that information can enable action in advance, to reduce the risks or damage involved. The United Nations describes the term Early Warning as: "The provision of timely and effective information, through identifying institutions, that allow individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response" [20].

These early disaster warning systems are a combination of computer systems, tools and processes that are capable of notifying people when a disaster is imminently approaching so that these people can take the appropriate action.

Warning services lie at the heart of early disaster warning systems in that they disseminate information to the relevant people so that the people can prepare for the coming disaster. However, in most situations, the method of notification is ineffective in that the relevant people are notified of an imminent disaster late or do not receive a notification at all.

Early warning systems have limitations in terms of saving lives if they are not combined with the knowledge of the context of the disaster area. To be effective, early warning systems must be easily understood and trusted by the communities that they serve. Warnings are of very little value if they fail to prioritise or reach the people that are most at risk, who need to be trained to respond appropriately to an approaching hazard.

III. PROBLEM STATEMENT

The current method of flood warning in the Zambezi area is outdated in that it uses information dissemination methods such as sirens, alarms and door to door warning for sending out imminent flood warnings. With the advent of modern communication technologies, this has proved to be ineffective due to a number of reasons.

In a traditional warning system, where sirens/alarms are used, some people often do not get notified when a disaster is approaching. The alarm/siren that is raised may not be heard by some people if they are in noisy conditions. Sometimes people can be in the range of the disaster but fail to get the message because they will be far away from where the siren is rang. Also, some people who are deaf or have other hearing impairments will not be able to hear the alarm raised. No matter what technology is used to generate a disaster warning and how the warning is transmitted from the originating centre to local officials, the warning is useless unless it reaches the individuals who need to take action [10].

In the event of an approaching disaster notification, people either do not get information on time or do not receive adequate information that helps them to make informed decisions on the appropriate action to take, A siren usually initiates an evacuation procedure, which may be a problem because it does not take into account things such as whether it is really an evacuation needed, or just staying indoors is needed, which direction to go, what supplies to take and how long before the disaster strikes.

The aim of an early warning system is to empower individuals, groups of people or businesses to respond timely and in an appropriate manner to hazards. This timely intervention will possibly reduce the risk of injury, death, loss of valuable property or its damage. Warnings must get the message across and stimulate those at risk to take action [15].

Early warnings are broadcast to all the people in an area, even those that are outside the danger area. This leads to high costs, in the case of SMS or call based systems as these systems must send notifications to all the people that are known to the system. This may also lead to panic, because when a siren is rung, all the people that hear the siren may evacuate an area even though they are not being affected by the coming disaster.

All of the above mentioned problems have resulted in deaths, injuries and information reaching the wrong people for which it was originally intended. Hence, despite disasters being detected correctly, they have not always been disseminated to the relevant people ahead of time which has caused many problems, some of which are listed above.

IV. RESEARCH OBJECTIVES

- To perform an analysis of the approaches that are being used in improving early warning systems for developing countries
- To design and implement an early disaster warning system for developing countries that uses context awareness.
- To assess the effectiveness of the using context awareness in the early flood warning system

V. RESEARCH QUESTIONS

- Can context awareness be applied in early flood warning systems for developing countries?
- Can context awareness improve the effectiveness of early flood warning systems in developing countries?

VI. JUSTIFICATION OF THE RESEARCH

An early warning system that uses context is important in that it, allows information to be disseminated appropriately, efficiently and to be received by only those people for which the information is intended. This kind of information when received in the right manner, can be used to avert or prepare for disasters, which goes a long way in ensuring that injuries and deaths are minimized.

Also, the use of an early warning system will lead to a reduction in operating costs as compared to traditional warning systems that broadcast messages in bulk. By using context, such a system restricts the warning of disasters to only the people that are in that are being affected by it. This makes it a relatively cheaper method of information dissemination compared to traditional early warning systems that make use of other forms of telecommunication such as SMS.

The method of early warning using context is effective in that automatic warnings are sent out without need for much user intervention. This is in contrast to traditional forms of warning which are not automated and were they might be delays between detection of an imminent disaster and information dissemination to all affected people.

VII. SCOPE OF THE RESEARCH

The research was limited to application of context in the generation and dissemination of warnings about floods in the Zambezi water basin. It did not major on the complex process of detection, monitoring, or prediction of water floods.

Also, this research focused on how a flood, identified before its occurrence by some means, can have its effect reduced by provision of information to the affected individuals within the context only and how using such a model is of particular benefit.

VIII. RELATED WORK

A. Early Warning Systems

Early warning is used to mean the provision of information on an imminent and potentially dangerous circumstance, where that information can enable action in advance to reduce the risks involved. In the UN-ISDR terminology, the early warning system is the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by hazards to take necessary preparedness measures and act appropriately in sufficient time to reduce the possibility of those people coming to harm or losing valuable property [40].

The aim of any early warning systems is to provide warning to people of an impending natural hazard, so that those who are vulnerable are aware of the potential impact of the natural processes. This will assist them in responding appropriately and will minimize damage [34]. Empowering individuals and communities exposed to hazards helps them to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property and the environment.

Early warning is one of many important tools that can be used to prepare for flood hazards and similar threats. This early preparation is of major benefit as it can assist communities in preparing for the flood. [22] notes that in developing nations, injuries, loss of livelihoods and deaths have been reduced because of the application and gradual improvement of early warning systems. He also further concludes that the advances in forecasting techniques, newer methods of disaster detection and the eventual dissemination of information are other major contributors to reducing the impacts of floods and other natural disasters.

Although floods cannot be prevented, they have usually taken a larger toll because affected communities are vulnerable and often unprepared. People receive warnings about imminent floods too late for them to take any preventative action. Early warning systems have been proved beyond doubt to save lives and reduce economic losses at all levels [22].

Early warnings help to prevent injuries, deaths and damage to property in many ways. For example, people avoid road travel when floods are anticipated, they can move property out of flood zones and implement relevant mitigation actions. Early asset protection can also be helpful. Preparing a house before a hurricane (for example, by covering windows) can reduce damage by up to 50% [11].

In their study [8] it is highlighted that in the residential sector, one-third of the damage concerns the non-fixed contents, i.e. the house contents that could be saved, thanks to an early warning, by being moved out of vulnerable places (for example, moved to the second floor). For any early warnings system to work, the warning generated by the system must be able to reach all those at risk particularly the vulnerable members of a community. Clear messages that contain simple, useful and understandable instructions are crucial in enabling proper understanding of warnings and responses in order to safeguard lives and livelihood.

B. Context Awareness

1) ***Context:*** In one of the first pieces of literature that starts using the term 'context-aware,' [9], refer to context as location, identities of nearby people and objects, and changes to those objects. In a similar definition, [33] extended this definition of to include things such as the time of day, season, temperature. [28] defined context as the user's location, environment, identity and time. [3] describe context as the being a user's emotional state, focus of attention, location and orientation, objects, date and time or people in the user's environment.

Although concrete, such definitions that attempt to define context by example are intrinsically difficult to apply to real life scenarios. When we wish to determine whether a specific type of information that is not listed in the definition is context-based or not, there is no information provided in the definition that makes it clear on how to use the definition to solve the problem. Other authors' definitions have conveniently provided synonyms for context; for example, referring to context as the environment or situation. Also, some authors consider context to be the observed user's environment, while others consider it to be more of the application's environment.

[33] defined context to be the elements of the user's environment that the user's computer knows about. [3] Identify location, identity, time, and activity as the primary attributes that are utilized when attempting to characterize the situation of a particular entity using context. In these context types, we can obtain information such as where, who, when and what, but they also act as pointers that we can make use of when obtaining other sources of contextual information. Say, given a particular person's identity, we are able to obtain related information such as addresses, phone numbers, birthdate, email addresses list of associates, relationships to other individuals in the environment.

2) ***Context Awareness:*** Any system that is capable of manipulating contextual information in its decision making is described as being context-aware.

3) ***Context Aware Computing:*** Context awareness in computing is software or hardware that examines and reacts to an individual's changing context. The main ideas that inspire the field of context-aware computing originate from the broader computer science field known as ubiquitous computing. Context-awareness means that one is able to make use of context information. A system is context-aware if it can extract, interpret and use context information and adapt its functionality to the current context of use [21].

Context-aware computing is a relatively new mobile computing paradigm that enables applications such as those running on mobile devices to be able to discover and take advantage of contextual information and use it in decision making. This contextual information consists of things such as user location, time of day, nearby people and devices, and user activity. [10] Identifies three categories of features that a context-aware application can support:

- Presentation of information and services to a user;
- Automatic execution of a service for a user; and
- Tagging of context to information to support later retrieval

The presentation of information and services to the user is the part of the system that the user has access to and interacts with. In similar fashion to ubiquitous computing, there is often a background activity that happens automatically without the user's intervention. The contextual information obtained is cached to make future retrievals easier and make inferences from the observed data.

4) ***Ubiquitous Computing:*** Context awareness is part of larger computer science field known as ubiquitous computing. Ubiquitous computing (also abbreviated as "ubicomp") is the new paradigm of computing in which the computer completely permeates the life of the user. It is also known as pervasive computing, ambient intelligence [38], or every ware [4]. It is based on the principle that computing is made to appear everywhere and anywhere and is meant to help the user while remaining invisible and unobtrusive.

The need for perceptual information about the operating environment distinguishes ubiquitous computing from traditional computing. Sensors and sensing systems help to provide these pervasive or ubiquitous systems with information such as the locations of people and devices. The system can then use this information to interact more naturally with users, moving beyond the desktop legacy of isolated interaction [16].

Most computing systems and devices today cannot sense their environments and therefore cannot make timely, context-sensitive decisions. Pervasive/ubiquitous computing on the other hand, however, requires systems and devices that perceive context. For example, mobile computing addresses location- and mobility-management issues but in a reactive context—responding to discrete events whereas pervasive computing is more complex because it is proactive [16].

Implementing perception introduces significant complications such as location monitoring, real-time data processing, and merging data from multiple and possibly disagreeing sensors. The information that defines context awareness must be correct; otherwise, it can confuse or intrude on the user experience.

5) ***Flood Warning Systems:*** Flood Early Warning Systems can help to reduce casualties and damages caused by floods. If vulnerable people in a flood-prone area are warned ahead of time they can leave the danger zone and go to a safer place to avoid drowning. They can also transport moveable items that are susceptible to water damage to higher grounds. However, while Early warning systems are widely recognized as worthwhile and necessary investments, in most cases, early warning systems do not exist, are ineffective, or break down at critical points [41] – risking devastation, death, and destitution.

Flood warning systems are increasingly being used to avert disasters due to floods. For example when Mozambique experienced flooding in 2000s, the death toll from the Mozambique floods was not large compared with other recent disasters, but the press coverage was intense and dramatic rescue footage was captured and broadcast around the world [17]. Five years later, serious floods again hit Mozambique. Yet the 2007 and 2008 floods hardly registered with the global media; there were no dramatic helicopter rescues and the final death toll was less than 30 in 2007 and six in 2008. This was attributed mostly, to the fact that effective early warning system that had been established and were linked to early action at community level. Despite such progress, we are still far from being able to distribute timely and effective warnings to affected populations, especially in less developed countries. This is because, even existing national early warning systems in developed countries – which mainly use broadcast dissemination – are often ineffective when it comes to targeted warnings for specific areas or user groups [39].

Climatic variability is a major problem for southern African societies and economies, where the majority of the population is still largely rural and directly and indirectly dependent on rain-fed agriculture. For example, in the cyclone Eline-induced floods of February 2000 in the Zambezi Basin alone, which left 700 people dead, over 500 000 people homeless and over US$1billion of infrastructural damage [30]. They further identified this flood disaster as being the worst in many years and highlighted the significance of flood disaster management at community level. The flood was declared a national disaster, breaking all records and killing several people. The death toll was increased by survivors who were left to suffer lack of food and clean water and malaria outbreak stemming from mosquitoes swarming and breeding in the floodwaters [32].

The effectiveness of the flood mitigation system then was tested in terms of how they were able to communicate in time to the vulnerable communities on how to adopt disaster mitigation measures before the onset of floods. While analyses of the risks and vulnerabilities of communities hit by floods have been conducted elsewhere, many questions have been raised in terms of what could have been done to minimize the high flood impact on communities' livelihoods. For example, how early were the warning systems? Were the early warning systems the same as forecasts? What information was encompassed in the early warning systems information? Were the early warning systems accepted or ignored by the local communities and if ignored what.

[24] describes the concept of a total flood warning system as consisting of 4 main parts:

- Knowledge of the risks faced;
- Technical monitoring and warning service;
- The dissemination of warnings to those at risk
- Public awareness and preparedness to act.

Handmer further noted that: "A total flood warning system integrates flood prediction, the assessment of likely flood effects, the dissemination of warning information, the response of agencies and the public in the threatened community, and review and improvement. The components must operate together for sound flood warning performance to be achieved". It is clear from Handmer's description that any flood warning system should have, at its core, a proper warning dissemination system that target to those that are at risk.

The United Nations also supports this view, emphasizing that early warning systems must be community-centered [42]. [24] further explains that to achieve all the four elements that he pointed out, there is need for cooperation, shared responsibility and thinking about the problem as well as involvement of the communities at risk among all stakeholders concerned. The four elements are so crucial that any failure in one of them elements can mean failure of the whole early warning system. For flood warning systems, the priorities should be 'early' and 'warn' so that if alerted to an upcoming crisis situation, the chances of preventing the situation from escalating into a serious crisis are highly increased [1].

C. Current Flood Warning System

The current setup being used in the Zambezi water basin makes use of two sources of information for flood detection. These are the hydrological tower and indigenous knowledge

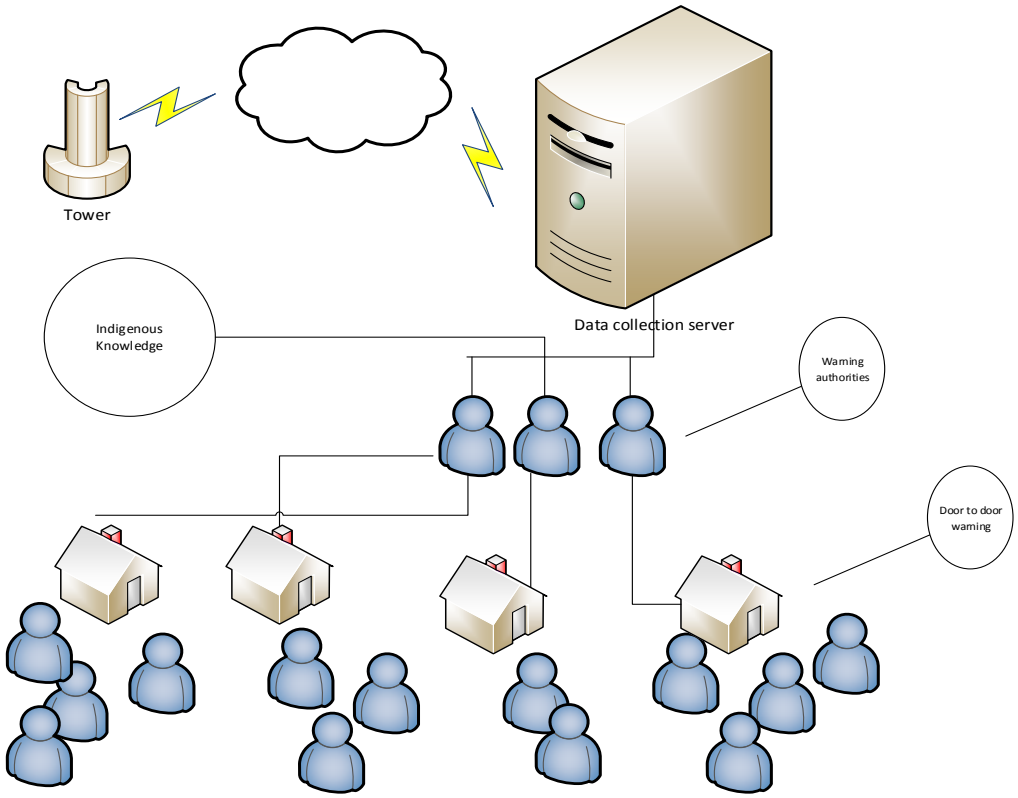

Figure 1: Overview of current system

[41] defines key players in disaster warning including local governments, national governments, regional institutions, the private sector and the media. These key players/authorities as indicated in the figure above are the first to receive warnings of impending floods

1) ***Use of Hydrological Tower:*** The hydrological tower is a sensor that is immersed in the Zambezi River that senses the level of water. It sends its readings to a data collection server in South Africa that processes and store the readings from the tower. In the event that a flood is likely, the authorities in South Africa warn the Zimbabwean authorities responsible for floods, who in turn are responsible for warning each of the vulnerable communities.

2) ***Use of Indigenous Knowledge:*** Indigenous knowledge systems (IKS) are bodies of knowledge of the indigenous people living in a particular geographical area. IKS can also be described as local knowledge that is unique to a given culture or society. Usually these people would have stayed in that area for a very long time, and through this, have gained experience generally based on accumulations of empirical observation and interaction with the environment.

In many cases, traditional knowledge is largely un-documented and has been passed on through generations from person to person through oral means. Traditional knowledge is expressed through stories, legends, folklore, rituals, songs, and even laws.

Like other communities that live in flood prone areas, the people in the Zambezi basin make use of early warning indicators and partially-developed structures through which the wisdom of the community is applied to

deal with disasters. The local people have their own ways of predicting bad weather conditions and rainfall by observing the physical environment. It is reported that droughts and floods have been forecast by the observation of the current weather patterns and the positions of celestial bodies such as the moon, clouds, wind. The behavior of birds and animals are also indicators of the nature of forthcoming rainfall and the probability of droughts. Often, the people anticipate flood by observing and interpreting local, environmental signals- through things like listening to the sound of the river, observing the dead bodies of animals and snakes floating in the water, smelling the foul smell of the river and the muddy taste of water.

The main IKS in use for detecting a potential flood in the flood region are:

1. Behavior of animals e.g. flight of birds such hungwe.
2. Through a close observation on the environmental conditions such as a smelling river, the local people are able to anticipate the impending flood.

These IKS are occasionally used to warn people that a flood is likely to happen, directly without involving the South African authorities.

D. Other Flood Warning Systems

Various authors have approached the field of improving the warning of natural disasters with the aim of reducing the effect of the disasters. In most of these other researches, the researchers have utilized one or more aspects of Information Communication Technologies (ICTs). As described by [13], the use of ICTs has been useful in reducing the impact of disasters such as floods. Various ICT-based devices are now available that can collect data from various sources and predict about future disasters.

[13] described an early disaster warning system where data is collected from several sources, compiled, stored in some database and a warning sent to a subscriber through the use of mainly SMS and e-mail. [31] described an early alert system named LFEWS (Local Flood Early Warning System) which was made up of several components such as rain and river level gauges, an operations center where data are initially received, further analyzed and decisions about a warning are taken. The system also provides information about evacuation routes and emergency rescue response units. [25] proposed another early flood warning system which made use of artificial neural network for that were used for prediction of future disasters. In that system, people are warned through SMS and the web. [35] proposed an early flood warning system for Egypt consisting of several parts, which are automatically activated and linked together. Their system makes use of a warning module called FloodWorks that sends alerts via email or SMS or the web.

E. Problems in Flood Warning

In most flood warning systems, problems have arisen in the effective dissemination of identified warnings to people at risk. Most failures in early warning systems typically occur in the communication and preparedness elements.

Although several attempts, aimed at implementing better alerting mechanisms for the public have been made (e.g., improvement Cell Broadcast-Alerting in the Netherlands [37], SATWAS in Germany [12], MyRescue in Japan [19], among others) the use of contextual information has been under-estimated. Extensive use of available information and communication technologies have offered new potentials as well as new challenges to effective warning. New channels of warning can now be used, such as digital broadcast technologies (Digital Radio and TV), mobile network technologies (GSM, UMTS, TETRA), fixed networks (Internet, Telephone, Cable TV), Satellite Technologies and others (pager and proprietary radio-based solution).

First, as stated by the United Nations, warning messages are often not sufficiently targeted to the users and therefore inefficient [42]. Most of the observed early warning systems that are in use lack knowledge of context, which is rapidly changing over time [39]. Second, a problem may arise with the possible - and in the case of disasters most likely - failure of common communication infrastructures such as door to door warnings [6].

In terms of sustainability, it should be stated that a major part of the afore-mentioned new communication channels comply with the integration of private stakeholders. This fact makes public-private partnership models inevitable and can be strongly beneficial for the sustainability of early warning systems, especially in terms of long-term operational and maintenance costs that are often underestimated in this area.

In terms of cost-effectiveness, the necessary infrastructure should be interoperable with existing warning systems and the synergy of using the same dissemination infrastructure among many early warning systems can be exploited. A major milestone towards this direction has been reached through the development of the Common Alerting Protocol (CAP) [2] which offers a sound basis for interoperability and is now adopted by several early warning systems.

IX. RESEARCH METHODOLOGY

The research has made use of a number of methods of obtaining data. Data was collected using different methods that included quantitative methods such as questionnaires and reporting tools from the system, and qualitative methods such as interviews and observations.

A. Research Design

1) ***Literature Survey*****:** The researcher looked at the current systems that are being used in flood warning in disaster-prone areas. This involved looking into different literature that was related to the subject matter and getting insight into how each of these systems already in use, are working. For each system, the following attributes were analyzed:

- Overall structure
- Warning mechanism
- Improvements of more traditional methods

2) ***Questionnaire Survey*****:** The design of the research was such that in the identified research area, a population of 50 individuals were given questionnaires of which only 31 did manage to respond. The sample included all those people in the population, who were responsible for manually disseminating warning messages to the community. The reasons for selecting this target group were because firstly these are the people who are fully aware of what the current system of warning works like. Selection of a sample of people in the flood are may increase bias because it might be the case that some of them do not even know about the current flood system. Secondly, as flood warning is a sensitive matter, keeping the research confined to well-known individuals will reduce the risk of panic in the area. The questionnaire supplied consisted of 10 questions that were logically ordered and consisted of many closed and some open questions. Some of the questions that were open-ended were categorized to quantify the results.

Multiple variables were measured to verify existing theories or hypotheses and also to question them. The obtained data was used to generate new hypotheses based on the results of data collected based on variables. However, as statistics and numbers do not depict an accurate picture pertaining to understanding meanings, the findings from the questionnaires were supplemented with beliefs and experience about the research area. Questionnaires were selected because they were a quick way of obtaining and concluding about things such as the effectiveness of the system based on user opinion.

3) ***Interview Survey*****:** The interviews were administered to fifteen participants. This enabled the researcher to understand meanings, look at, describe and understand experience, ideas, beliefs and values. It looked at those qualitative aspects that could not be quantified.

Open questions such as ‘what do you think about the using such a new feature?’ would elicit an almost endless number of responses. This, although cumbersome gave a very good idea of the variety of ideas and feelings people have, and it enabled respondents to think and talk for longer and so show their feelings and views more fully. However, it was very difficult to quantify these results and the comments made by the participants were categorized after having received them, picking out particular comments if they seemed to fit the purpose of the research.

4) ***Combining Questionnaire and Interview Surveys*****:** This approach helped the researcher to 'triangulate' i.e. to back up one set of findings from one method of data collection underpinned by one methodology, with another very different method underpinned by another methodology. The questionnaire (quantitative) was used to gather statistical data about responses, and then this was backed up in more depth by interviewing (qualitative) members of the questionnaire sample.

5) ***Reporting Tools and System Data Analysis:*** Data was also collected from the statistics obtained from the data in the database of the system. This data contained information from the day to day running of the system. The researcher worked with the same target group as used in the questionnaire and interview.

The reason for having these observations this was to accurately quantify the results provided by the interview and questionnaire and validate the results using more conventional computer science-based techniques. The variables that were measured were in line with the research objective and included warning delivery times, context detection and utilization.

B. Context-aware System Design

1) ***Programming Language*****:** This system was developed using the JAVA programming language and the Android framework. The JAVA language was used to develop the server-side part of the application while the

Android framework was used to develop the client-side part of the application. The Android framework is the leading API that supports development of applications that run on mobile devices with the Android operating system. It is simple to use, and applications built using it can run on most Android devices without need for reconfiguration on each new device. The JAVA programming language is an open source object oriented programming language that is easy to use and has a great support community.

2) ***Software Development Methodology*:** The system was created using an agile methodology. This ensured that the time between the start of the design of the system and delivery was short to enable any corrections to be made early. Also it enabled changes that needed to be made to be done so quickly and put into effect immediately. The diagram below represents an overview of the system.

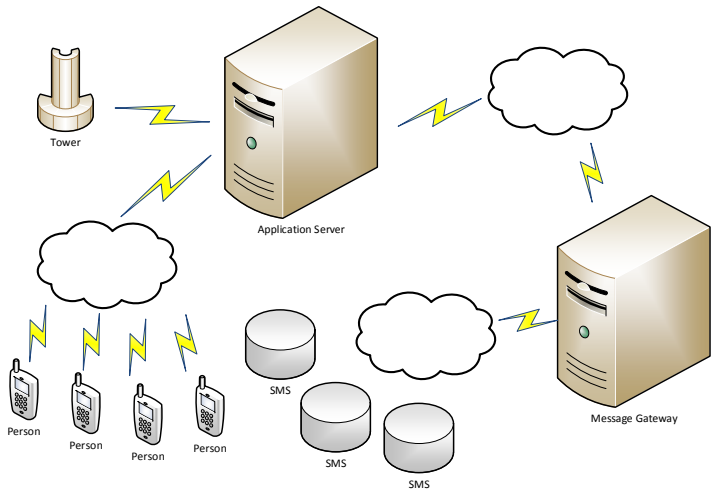

Figure 2: System overview

As indicated in Figure 2: System **overview**, the system consists of two applications working in tandem with each other. One application is the client system which runs on the mobile device and the other is the server application that runs on a server or other PC. The client application is an Android service that runs in the background and basically does two things:

1. Determines the GPS coordinates of the phone at the current moment (longitude and latitude)
2. Sends the GPS coordinate determined above as well as the phone number of the line in the phone at that moment.

At the server application the request (GPS coordinate + phone number), sent by the client is received and the status of the person identified by the phone number sent by the client is updated accordingly. When a potential flood is detected by the tower, it sends a signal to the application server. The application server, will then use its records of people presumed to be in a certain area, to determine which people to send messages to. Once this list is determined, this list along with the message to be sent, is forwarded to the messaging gateway. The gateway will then perform the task of sending the SMS messages to the relevant people and sending back the message delivery statuses.

3) ***Other Design Tools*:** The researcher also made use of the following tools:

- Netbeans IDE
- Intelli-J IDE
- JAX-RS Java API for XML-Based REST-ful web service
- Maven Build System
- Ant Build System
- JPA API and the Hibernate persistence framework
- Spring framework and Wicket frameworks
- Google Play Services Location API
- Android framework API level 10
- MySQL database

X. RESULTS

A. Summary of Interview Responses

Interviews were carried out with the main warning authorities that first receive information pertaining to floods. Questions were asked along the following themes:

1) ***Receiving Warnings via Mobile Device:*** A question asked was to get the opinion of the respondents regarding receiving warnings about disasters on their mobile phone as opposed to the currently used methods. The responses received were grouped into two major groups: those who were generally in favour of receiving warnings directly and those who were against the idea. This was based on analysing the general idea of the response and trying to quantify it to lie in one of the two groups. It was noted that the majority of respondents were in favour of receiving their warnings via mobile devices

2) ***System Effectiveness:*** The question asked was whether respondents felt that it would be more effective to use the context awareness-enabled system as opposed to continued use of the current system. Again, the responses were grouped and the researcher noted that there was a slightly higher number of people who indicated that the context-aware approach has been more effective than the currently used method. A majority of the reasons were based on the fact that nowadays people carry their mobile devices around so it would be logical to warn them directly instead of trusting other people to transmit that knowledge.

3) ***Context-Aware System Implementation:*** The question referred to whether people would want the context aware system to be implemented in the flood region or instead continue using the current system. Of the responses received, there was divided opinion on which system should be used. Some of the participants had concerns over the introduction of a new system and preferred to continue using the old system as it has proven to be occasionally reliable but working.

B. Summary of Questionnaire Survey Responses

A total of 50 questionnaires were distributed and 31 were answered, giving a response rate of 62 percent. The questionnaire consisted of sections to address themes on the number of the participants who possessed mobile phones and would carry them around frequently. Another theme was on the compatibility of the mobile phones with the proposed context-aware system.

1) People in Possession of Mobile Phones:

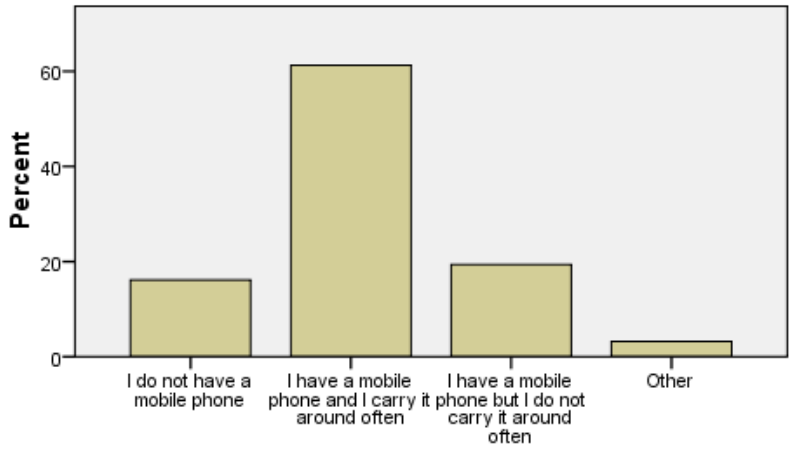

Figure 3: Mobile phone availability distribution

It was noted that of the 31 people who responded, the majority of them had mobile phones. A total 80.64% indicated that they were in possession of a mobile device. Of this 80.64%, 61.29% indicated that they carry their mobile phones often while 19.35% stated that they do not. A small percentage (16.13%) did not have mobile phones at all whilst 3.23% indicated reasons other than those previously stated. It should be noted that the higher percentage of people had mobile phones and carried them around often.

2) ***People with mobile phones that can be used with context awareness:*** The respondents were asked to state the current mobile phone they use. The descriptions obtained from the respondents were grouped according to the operating system that they use.

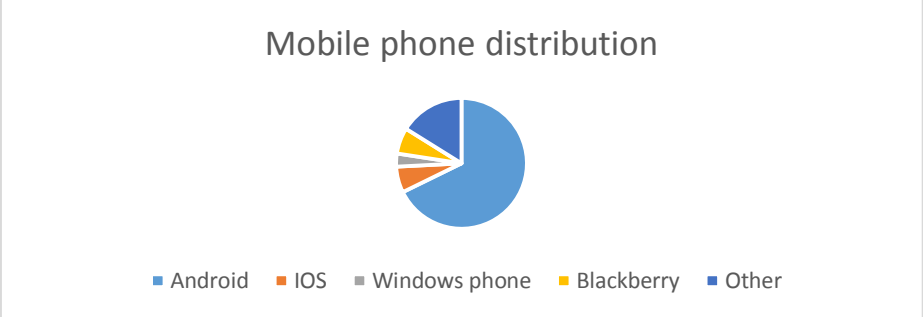

Figure 4: People in possession of appropriate mobile devices

It was noted that the majority of the people in the area have mobile phones that run on the Android operating system. This was essential because it showed the feasibility of implementing a context-aware application in the area that is based on the Android mobile operating system.

3) ***Amount of time spent with mobile device:*** This was done to establish whether a person spends most of their time with their mobile device so as to know whether warnings sent out to people can be seen immediately. Most of the participants who possessed mobile phones indicated that they carry their mobile phones around. This is important because for the person to see a flood warning, he/she must most of the time be in possession of their mobile device.

4) Distribution of people spending most of their time in flood region

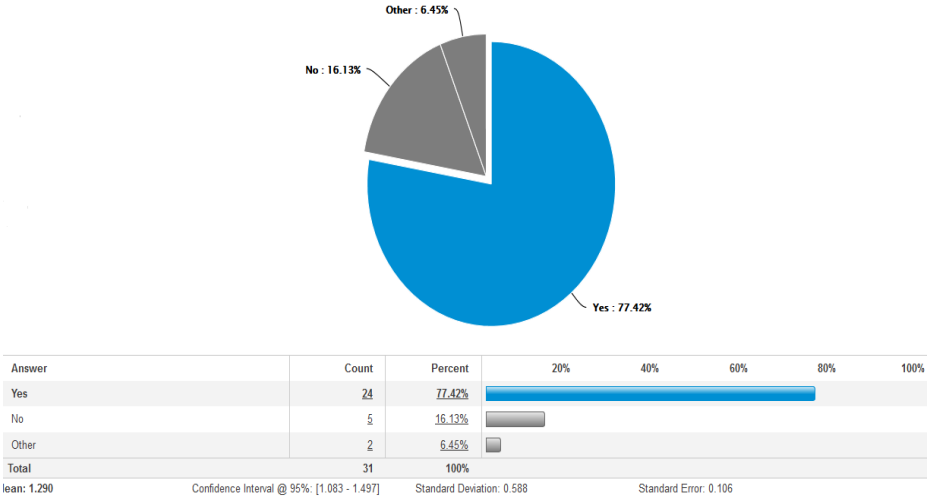

Figure 5: Time spent in flood region

This was necessary for the purposes of identifying if context awareness could be used to identify if the respondents were in the area. The majority of the people stated that they spend most of their time in the flood region so context awareness can be applied.

5) Average time of receiving warning in current and developed system: This was split into two: the time that warnings took to get to the people in the flood region using the current system and the time that warnings took using the context-aware system.

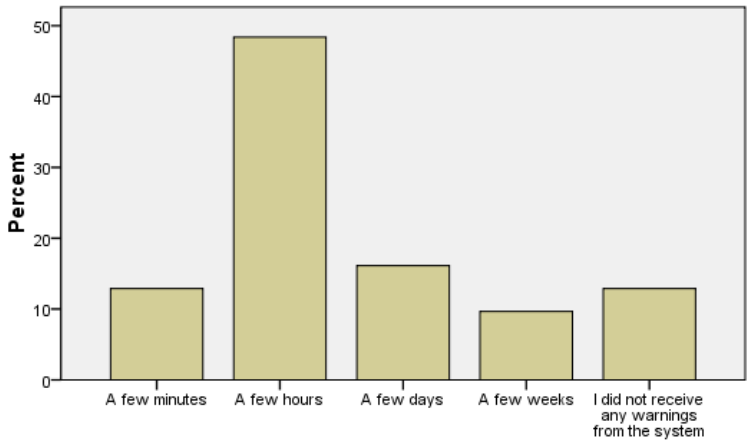

Figure 6: Amount of time to receive warning in current system

Amount of time to receive warning in context-aware system is as shown in the figure below.

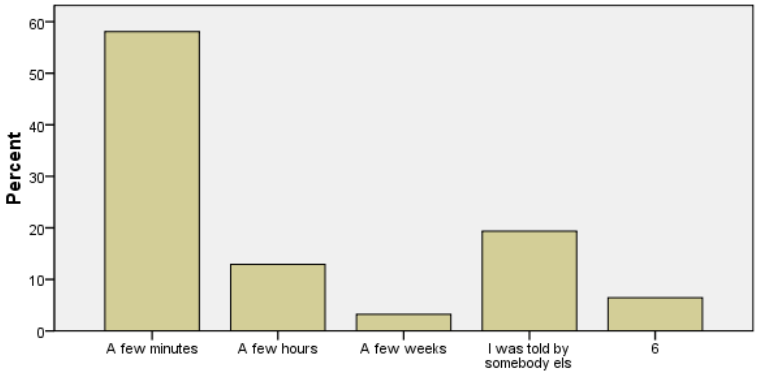

Figure 7: Average warning delivery time in context-aware system

It was noted that comparatively, the context-aware system enabled warnings to get to the intended people faster than the current system.

6) ***Warning arrival method:*** This question was aimed at identifying whether respondents preferred to have warnings sent to them individually or for them to be sent through other people.

Table I: Preference to Receiving Warnings Directly as Opposed to the Current System

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I prefer to receive warnings directly	22	71.0	71.0	71.0
	I prefer to receive warnings through door to door dissemination	9	29.0	29.0	100.0
	Total	31	100.0	100.0	

The results indicated that the majority of the participants wanted to have their warnings sent to them directly. This indicated that most people were happy with having a system that disseminates warnings about floods directly them as opposed to the current system, where warnings are distributed by other people on a door to door basis.

7) ***Overall system effectiveness:*** The researcher posed the question of whether the research participants thought that the context-system was more effective in flood warning that the current system. The data obtained is as shown below.

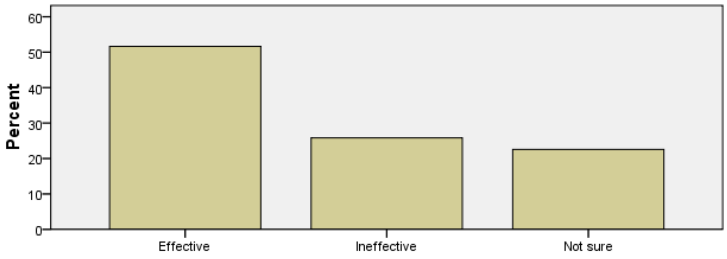

Figure 8: Overall context-aware system effectiveness

The data observed showed that more people were of the view that the proposed system was more effective than the current system. Of the reasons stated, these were more to do with the direct warning dissemination to the mobile device that they thought was more convenient and reliable than the door to door method.

C. System data observations

***1) Warning Message Dissemination Summary*:** Table II below displays the statistics obtained after running a series of 20 tests in disseminating warnings to the target group. In each test, a single warning message was simultaneously broadcasted to each of the recipients.

Table II: Warning Dissemination Statistics

Batch No	Messages Sent	Messages Received	Messages Read	Messages Failed
Batch 1	31	31	28	0
Batch 2	31	30	25	1
Batch 3	31	31	22	0
Batch 4	31	29	21	2
Batch 5	31	31	30	0
Batch 6	31	28	31	3
Batch 7	31	31	27	0
Batch 8	31	30	30	1
Batch 9	31	31	29	0
Batch 10	31	31	30	0
Batch 11	31	30	30	1
Batch 12	31	31	31	0
Batch 13	31	29	31	2
Batch 14	31	30	20	1
Batch 15	31	31	31	0
Batch 16	31	31	29	0
Batch 17	31	29	31	2
Batch 18	31	30	31	1
Batch 19	31	31	30	0
Batch 20	31	31	31	0
Total	**620**	**606**	**568**	**14**

Overally, the results show that of all the warning that were disseminated, a majority of them, managed to reach the intended population (Messages Received). Of the warnings that were successfully received, the majority of them were actually read by the group. There was a small number of the disseminated warnings that did not manage to reach the intended recepients. The major cause of this was because of some people switching off their mobile phones, mobile carrier network inconsistencies amongst many other.

2) Average message delivery time

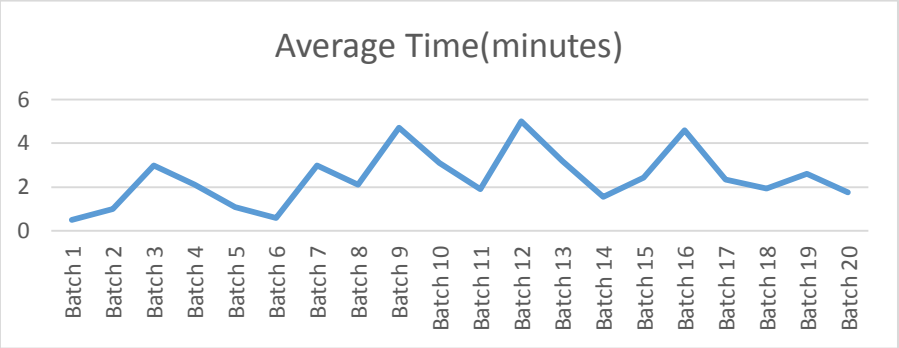

Figure 9: Average message delivery time

This result shows that warnings sent by the context-aware system were received in an average of 2-4mins which was quicker than the previous system.

XI. CONCLUSION

From the data obtained in this research, it was sufficient enough for the researcher to conclude that the context-aware system was a better way of disseminating warnings about floods to potential flood victims that the system that is in current use. The context-aware system could identify which people were in a region and could provide indicators of problems when the system failed to warn individuals. This was often useful in identifying people who could for some reason not receive flood warnings. Also, of the people in the flood region about which data was collected, most of them preferred that the context-aware flood warnings system be implemented. This was mainly due to the fact that warnings would then be disseminated directly instead of having multiple channels through which warnings had to go through to eventually arrive to the intended persons.

REFERENCES

[1] A. Alusa, *Paper presented on Global Climate Observing System.* Addis Ababa, Ethiopia, 2006.
[2] A. Bottorell, *The Common Alerting Protocol: An Open Standard for Alerting, Warning and Notification.* 2006.
[3] A. Drey & G. Abowd, *Towards a better understanding of context and context awareness. Proceedings of the first International workshop on managing interactions in smart environments*. 1999.
[4] A. Greenfield, In: *Everyware: the dawning age of ubiquitous computing*. s.l.:New Riders, p. 11–12, 2006.
[5] A. K. Day, *Understanding and Using Context,* s.l.: Computer Sciences Commons, 2001.
[6] A. Townsend & M. Moss, *Telecommunications Infrastructure in Disasters: Preparing Cities for Crisis Communications,* New York: Graduate School of Public Service, New York University, 2005.
[7] Anon., *Hyogo framework for action for action 2005-15:building the resilience of nations and communities to disasters*, 2005.
[8] B. Merz, H. Kreibich, A. Thieken, & R. Schmidtke, Estimation uncertainty of direct monetary flood damage to buildings. *Natural Hazards And Earth System Sciences*, pp. 153-163, 2004.
[9] B. Schilit, & M. Theimer, Disseminating Active Map Information to Mobile Hosts.. *Network, IEEE,* 8(5), pp. 22-32, 1994.
[10] B. Wallrich, *Disaster Warnings: The Problem of the Last Step Reaching the Hardest-to-Reach With Critical Information,* s.l.: s.n. 2005.
[11] B. Williams, *Floyd and mitigation policy,* s.l.: Berry A. Williams and Associates, Inc, 2002.
[12] BBK, Opportunities for Public Safety in Germany. *German Federal Agency for Public Safety and Disaster Preparedness*, May 2005..
[13] C. Wattegama, ICT for Disaster Management. *Asia-Pacific Development Information Programme*, 2007.
[14] D. M. Wahab, Integrated Data Communications and Processing For Early Warning System. *The Euro-SouthEast Asia Cooperation Forum on ICT Research*, October 2008.
[15] D. Rogers, & V. Tsirkunov, *Costs and benefits of early warning systems*, s.l.: s.n. 2010.
[16] D. Saha, & A. Mukherjee, Pervasive Computing: A Paradigm for the 21st Century. In: *Pervasive Computing: A Paradigm for the 21st Century*. s.l.:IEEE Computer Society, pp. 25-30, 2003.
[17] F. Christie & J. Hanlon, *Mozambique & the Great Flood of 2000.* illustrated ed. s.l.:International African Institute, 2001.
[18] G. Chen & D. Kotz, *A Survey of Context-Aware Mobile Computing Research*, s.l.: s.n.
[19] G. O. Japan, *Japan's Natural Disaster Early Warning Systems and International Cooperative,* Tokyo : Early Warning Sub-Committee of the Inter-Ministerial Committee on International Cooperation for Disaster Reduction, 2006.
[20] GDACS, 2008. *Global disaster alert and coordination system.* [Online] Available at: http://www.gdacs.org
[21] H. Byun, & K. Chervest, Utilizing context history to provide dynamic adaptations. *Applied Artificial Intelligence*, p. 533–548, 2004.
[22] I. F. Crescent, *Focus on early warning, early action,* s.l.: World Disasters Report, 2009.
[23] J. Gleneesha, *Context-Aware Security*, s.l.: s.n.
[24] J. Handmer, Are Flood Warnings Futile? Risk Communication in Emergencies. *The Australasian Journal of Disaster and Trauma Studies,* Volume 2, 2000.
[25] J. Windarto, Flood Early Warning System Developed at Garang River Semarang using Information Technology based on SMS and Web. *International Journal Of Geomatics and Geosciences*, 2010.

[26] M. Ulrich, & A. Voisard, Increasing the Effectiveness of Early Warning via Context-aware Alerting. *Increasing the effectiveness of Early Warnin*, 2007.
[27] M. Weiser, The Computer for the 21st Century. pp. 19-25, 1991.
[28] N. Ryan, J. Pascoe & D. Morse, Enhanced Reality Fieldwork: the Context-Aware Archaeological Assistant. *Computer Applications in Archaeolog*, 1998.
[29] N. Waidyanatha, Towards a typology of integrated functional early warning systems. *Towards a typology of integrated functional early warning systems*, Volume 1, pp. 31-51, 2010.
[30] N. Wamukonya, & H. Rukato, Climate Change Implications for Southern Africa, 2001.
[31] O. Neussner, A. Molen, & T. Fischer, Using Geoinformation Technology for the Establishment of a Local Flood Early Warning System. *econd International Conference of Geoinformation Technology for Natural Disaster Management and Rehabilitation*, 1-2 December 2008.
[32] O. Shumba, *An assessment of NGO Disaster Mitigation and Preparedness*, Harare: SAFIRE, 2000
[33] P. Brown, J. Bovey, & X. Chen, Context-Aware Applications: From the Laboratory to the Marketplace. *IEEE Personal Communications*, pp. 58-64, 1997.
[34] P. Gwimbi, The effectiveness of early warning systems for the reduction of flood disasters: some experiences from cyclone induced floods in Zimbabwe. *Journal of Sustainable Development in Africa*, 9(4), 2007.
[35] P. Vanderkimpen, et al., *FlaFloM-an early warning system for flash floods in Egypt*, s.l.: s.n, 2012.
[36] R. J. Weiss, Ubiquitous Computing. *Ubiquitous Computing*, 2001.
[37] S. Sillem, & E. Wiersma, *Comparing Cell Broadcast and Text Messaging for Citizen Warning*. Newark, New Jersey, 2006.
[38] U. Hansmann, *Pervasive Computing: The Mobile World.* s.l.:Springer, 2003.
[39] U. Meissen, & A. Voisard, Increasing the effectiveness of Early Warning. *Increasing the Effectiveness of Early Warning via Context-aware Alerting*, 2008.
[40] U.N.I.S.D.R, *Global assessment report on disaster risk reduction*, s.l.: United Nations International Strategy for Disaster Reduction, 2009.
[41] UNISDR, Terminology on Disaster risk reduction. *Terminology on Disaster risk reduction*. 2009.
[42] United Nations, *Global Survey of Early Warning Systems An assessment of capacities, gaps and opportunities toward building a comprehensive global early warning system for all natural hazards*, s.l.: United Nations, 2006.
[43] Y. Nanita , *Disaster Management, Developing Country Communities & Climate Change:The Role of ICTs.*, 2011.

