

**A VISUAL ANALYTIC TOOL FOR ASSESSMENT OF URBAN AIR  
QUALITY IN DEVELOPING COUNTRIES (NAIROBI, KENYA)**

**By**

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**Master of Science in Data Analytics**

**KCA UNIVERSITY**

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**FACULTY OF COMPUTING & INFORMATION MANAGEMENT**

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**RESEARCH PROJECT**

**ON**

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QUALITY IN DEVELOPING COUNTRIES (NAIROBI, KENYA)**

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**FRED L. AMBUTSI**

**A RESEARCH PROJECT SUBMITTED IN PARTIAL  
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OF MASTER OF SCIENCE IN INFORMATION SYSTEMS  
MANAGEMENT IN THE FACULTY OF COMPUTING AND  
INFORMATION MANAGEMENT AT KCA UNIVERSITY**

**OCTOBER, 2016**

**DECLARATION**

I Fred Lisalitsa Ambutsi, the undersigned, hereby declare that this research proposal is my original work and that it has not been presented to any other University, college or institution for higher learning other than KCA University.

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Fred Lisalitsa Ambutsi, Date  
Student No: 14/04632

This project has been presented for examination with my approval as the appointed supervisor.

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Faculty of Computing & Information Management KCA University

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Dean,  
Faculty of Computing & Information Management KCA University

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# **A VISUAL ANALYTIC TOOL FOR ASSESSMENT OF URBAN AIR QUALITY IN DEVELOPING COUNTRIES (NAIROBI, KENYA)**

## **ABSTRACT**

Air pollution is considered very crucial in people's health and comfort and is brought by fine particles in the air. The fine particles in the air are directly associated with many health issues to mankind including eye diseases, respiratory and heart problems as well as environmental degradation. In order to control air pollution, access to information about pollution in the air is very important. Mobile applications are best suited to disseminate this information because of their wide use. Aim of the study therefore was to develop a visual analytic tool that can provide timely information about air pollution at different locations. The study was guided by the following objectives: to investigate how a mobile phone based application may be used to assess air quality to create awareness to members of public; to design and develop mobile based visual analytic tool for assessment of urban air quality and test the visual analytic tool. After requirement analysis, the study found out that mobile phones are best suited to disseminate information effectively to a large population. The study employed Unified Data modelling language and adopted evolutionary prototyping approach because it results in the gradual development of systems. The presented system consists of stationary sensor devices measuring pollutants in the air. Periodically, the measurements are uploaded directly to a server, processed and then are made available for all registered users using smart phones through the developed visual analytic tool. The study recommends that the tool be adopted for use and there is need to intensively create awareness on dangers of air pollution to members of public.

Keywords: Mobile application, Air pollution, Visual Analytics, assessment.

## **DEDICATION**

I dedicate this project to my beloved wife Edith and my son Macdonald

## **ACKNOWLEDGMENT**

I would like to take this opportunity to express my sincere gratitude to all who gave their support throughout the process of developing this project. I would also like to thank my beloved lovely wife Edith Lisalitsa and my son Macdonald Lisalitsa for giving me humble time to concentrate in preparing this project. I would also wish to thank my classmates especially David and Lillian, for their support. Special thanks, goes to my supervisors Dr Okeyo and Dr Mwangi H for their underlying support, patience, intellectual support and guidance.

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## **ABBREVIATIONS.**

HCI	-	Human Computer Interface
ICT	-	Information and Communication Technologies
IS	-	Information systems
RFID	-	Radio-frequency identification
SMS	-	Short Messaging service
M-Apps	-	Mobile applications
GPS	-	Global Positioning satellite system
COPD	-	chronic obstructive pulmonary disease
GSM	-	Global System for Mobile
UMTS	-	Universal Mobile Telecommunications System
GPRS	-	General packet radio service
XML	-	Extensible Markup Language
WML	-	Wireless Markup Languag
WLAN	-	wireless local area networks
HTML	-	HyperText Markup Language
WAP	-	Wireless Application Protocol
PM	-	Particulate Matter

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# **CHAPTER ONE**

## **BACKGROUND INFORMATION**

### **1.1 Introduction**

Air pollution is a mixture of solid particles and gases in the air. It is a contamination of the air, whether it indoors or even outside the building. Any changes of air in the atmosphere physically, biological or chemical can be referred to as pollution. Air pollution is also caused by harmful gases, dust or smoke in the atmosphere which makes it difficult for plants and animals to survive

Air pollution can be categorized as either visible air pollution or invisible air pollution. Air pollution can also be thought to be any substance that has the possibility to hinder the well being of living being in the atmosphere. All living things survive because of a combination of gases referred to as atmosphere; any change caused by the increase or decrease of the percentage of these gases can be harmful for continued existence (Conserve Energy Future, 2015).

#### **1.1.1 Air pollution in cities in developing countries (Nairobi)**

Nairobi is one of the world cities facing problems of air pollution which has serious health impacts to its population.

Kinney, et al (2012) suggest that people who spend substantial time on or near roadways particularly motorists, pedestrians, traffic police and those engaged in the many informal businesses located along roadways are of particular concern regarding potential human health

impacts. Those who live and work downtown in buildings adjacent to busy roads may also be exposed to high PM<sub>2.5</sub> concentrations. Results from the vertical dispersion site showed that PM<sub>2.5</sub> concentrations did decrease significantly with height. However, concentrations on the 3<sup>rd</sup> floor rooftop were still double the WHO 24-hour guideline. This suggests that residents of buildings adjacent to heavy traffic roadways in Nairobi, even if they live on upper level floors, may still be exposed to dangerously high particulate matter levels

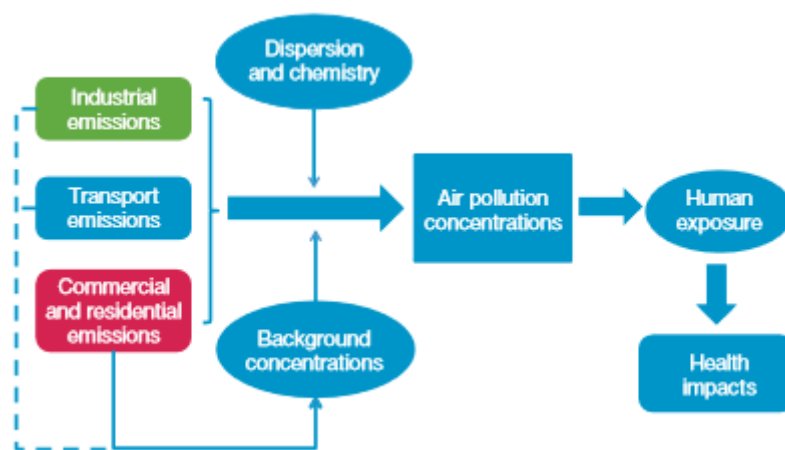
### **1.1.2 Effects associated with air pollution.**

Transport is important in today's life. The freedom to travel either for short and long distances allows personal development and facilitates professional activities. Transport also, increases the options for holidays and leisure, and allows better understanding between people. Regrettably, these positive aspects are directly associated with the alteration to the environment and human health caused by transport, especially road transport. (Michal Krzyzanowski, 2005).

Exposure to air pollutants has been associated to a wide range of health conditions. These effects may vary from mild allergy to lung cancer, or even death. These health conditions are normally assessed through clinical outcomes such as doctor visits, respiratory symptoms, asthma attacks, medication use, school absence, emergency room visits, hospital admissions, chronic diseases and possibly premature death. Each individual reaction to air pollutants normally depends on many factors such as type of air pollutant one is exposed to, genetics, individual health, degree (quantity and duration) of exposure, behavioral and socio-economic position (Sadeq, 2012)

Research done by many scholars indicates that in a few years to come, most of people in the world will be living in towns and that air pollution will be the biggest environmental risk factor and a leading environmental cause of cancer. In 2012 alone, air led to 7 million

premature deaths all over the world. In addition, air pollution is also a leading course of development of cardiovascular illnesses such as heart diseases and hypertension. There is an increase of cases of cancer in Kenya and alot of people suffering from or having a person close to us suffering from a chronic respiratory illness such as asthma, we investigate for reasons why these diseases seem to be getting too common may be the answers may lie in the air we breathe.(Muindi, 2015)



**Figure 1: The relationship between emissions, concentrations and impacts on health**  
(Guy Hitchcock etl, 2014)

### 1.1.3. Use of mobile phones

The number of mobile devices has been increasing drastically. This rapid increase is associated with the increase in number of services available through these devices (especially monetary services), has been changing the way people access information. If the increase continues with the same speed, it is almost certainly true that in the near future, the most

common method of accessing to information is through the use these devices, even by people non computer users.

People frequently make use of visual tools such as maps, graphics and diagrams, to better understand and rapidly resolve certain problems. The continuous advances in the computational power and graphics processing have made it possible to include an extensive array of visualization. Visual analytics is increasing being applied in many fields in an attempt to assist mankind in solving many issues affecting them.

Mobile devices in market today may be more powerful than the computers we owned in 1995 due to technological advancement, but they remain quite inhibited compared to the desktop or laptop computers. The speed of the processor not also affects access speed of the browser but also speed at which the content may be accessed from a given net work. Mobile devices such as mobile phones are also commonly used in contexts where bandwidth may be poor or prone to unexpected latency. Mobile applications therefore should be lightweight and not to impose extra latency through pointlessly heavy mark-up, use of gratuitous and unnecessary effects, or poor data management, A better way to decide an appropriate size for a mobile application is to consider time taken by users while waiting for a page to load.(Microsoft, 2012)

Visual analytics is the science of analytical reasoning using data sets collecting for a period of time. Visual analytics technology has been extended beyond the traditional desktop paradigm to provide to interactive visualizations in other platforms such mobile phones technology (etal, 2005). Integration of mobile technology in health care industry has the potential of increasing the quality of life. Mobile phones are tools that are not utilized to their full capacity; they have ability to offer a wide range of benefits through unobtrusive nonstop

monitoring, becoming the best means of providing users with personalized advices for a healthier lifestyle.(Giuseppe Lo Re, n.d).

Almost all mobile devices today came with a built-in GPS device. This make it possible for the mobile device to automatically obtain the user's position, immediately presenting to the user a map using services such as Google map, together with local points of interest, without the need for any further action. For that reason the user is allowed to perform many tasks, including finding relevant locations in the neighbourhood, such as nearest ATM machine, a gas station, the or calculating the shortest way to a certain place (de Matos, Afonso, & Carmo)

## **1.2 Problem definition**

Air pollution is becoming a health hazard to mankind especially those living in urban areas. Pollution from motor vehicles is a major contributor to air pollution in Nairobi. Motor vehicle emissions include a range of pollutants, including particulate matter (PM), carbon monoxide, sulphur oxides, nitrogen oxides and a wide range of volatile organic compounds, which react with sunlight to form ozone (Kinney et. al., 2011). Air quality studies have indicated that vehicular exhaust is the main source of existence of fine particles in the air due to strong correlation that exist between motor vehicles and the fine particles. Health effects caused by these air pollutants range from subtle biochemical & physiological changes to difficulty in breathing, wheezing, coughing & aggravation of existing respiratory & cardiac conditions (Kinney, et al., 2012).

The fine particles in the air are directly associated with respiratory and eye diseases such as lung cancer, asthma, and conjunctivitis, especially in the elderly and young who are more susceptible. Air pollution is well known to be a key contributor to effects such as acidic rain,

which has been accountable for much damage to soil, vegetation, fish resources, and often very far from the emission sources.(Tibajuka, 2007) These conditions can result in increased use of medicaments, increased frequency of doctor visits, loss of man-hours, more hospital admissions & premature death Available data show that leading cause of death is Respiratory Ailments. In 2000, Respiratory Disease &Malaria accounted for over 50 % of all deaths in city (Nairobi City County JICA Study Team, 2013). This calls for urgent measures in order to reduce human suffering and better the lives of residents. This can be achieved through the use of ICT tools.

ICT use has greatly helped mankind in tackling modern day challenges of life. When it is applied in a cost-effective, user-friendly and realistic problem-solving manner, it significantly reduces human suffering (Anderson, 2007). Utilization visual Analytics has the potential to transform many of our daily work processes and make them both more efficient and effective. If applied effectively; information visualization technology can help users to obtain and maintain an overview in various situations easily. It is noticeable that automated analysis often speeds up analysis tasks considerably whereas the visual representation is then used to efficiently communicate the outcome to the user or to disseminate research results to a wider audience (Keim, Mansmann, & Thomas, 2009)

This project therefore seeks to design and developed a visual analytic tool for Assessment of Urban Air Quality. If the implemented it be used will increase awareness on the effects of air pollution to the residents of Nairobi. This awareness will be provided through use of visual analytics techniques that will enable policy makers develop policies and laws that will go a long way improving life expectancy of people living in Nairobi.

## **1.3 Aims and objective of the study**

### **1.3.1 Purpose of Research**

The aim of the study is to design and developed a visual analytic tool for Assessment of Urban Air Quality. The researcher hopes that this tool will be able disseminate information to residents to create awareness on levels of air pollution so that they can make informed decisions and petition authorities on the same.

### **1.3.2 Specific Objectives**

The study was guided by the following objectives:

- 1) To investigate how a mobile phone based visual analytic tool may be used to assess air quality to create awareness to members of public
- 2) To design and develop mobile based a visual analytic tool for assessment of air quality in cities in developing countries.
- 3) Test the mobile based visual analytic tool for assessment of air quality.

## **1.4 The significance of the study**

This research work is aimed at helping residents of cities in the developing countries have easy, effective and timely access to information related to Air pollution. The researcher hopes that once accepted and implemented it will improve the lives of Nairobi residents. Members of will be able to get alerts of amounts and analytics of air pollution in their mobile phone. This will enable them make informed choices hence reduce the effects of air pollution. This research work will also serve as a wakeup call to policies makers in the environment management to embrace use mobile technology in disseminating information on air pollution.

## **1.5 Assumptions of the study.**

The study makes the following assumptions:

1. That member of public working and living in cities in developing world lack information on the amount and effects of air pollution to their lives.
2. That lack of information on amounts and effects of air pollution to members of public living and working in cities in developing countries is the cause of high rates Air pollution related diseases to the population the city.

## **1.6 Scope of the system**

The system will only cover assessment of dust Air pollution only in Nairobi

## **1.7 Definition of terms**

**Visual Analytics:** the science of analytical reasoning using data sets collecting for a period of time.

**Air pollution:** The condition in which air is contaminated by foreign substances, or the substances themselves

**Mobile device:** Is a generic term used to refer to a variety of devices that allow people to access data and information from where ever they are. This includes cell phones and portable devices.

**Assessment:** the collection of relevant information that may be relied on for making decisions

**PM<sub>2.5</sub>:** Can be defined as fine particles found in the air, examples include dirt, dust, soot, liquid droplets and smoke,. Particles can be suspended in the air for long periods of time. Some particles are large or dark enough to be seen as soot or smoke. Others are so small that individually they can only be detected with an electron microscope.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

This chapter focuses on literature review relating to mobile applications and visualizations. The state of the art relating to visualizations on mobile phones is discussed in details. The state of practice and technological advancements is also discussed and lastly a critique of the related works is highlighted.

#### **2.2 State of the Art.**

Studies relating to mobile application and visualization have been carried out extensively by many researchers. This is because use of mobile phones is becoming necessary in all sphere of life.

##### **2.2.1 Mobile Applications**

Mobile application development is the set of processes and procedures involved in writing software for small, wireless computing devices such as smartphones or tablets. The mobile applications market is currently undergoing rapid expansion, as mobile platforms continue to improve in performance, and as the users' need for a wide variety of mobile applications increases. The latest mobile platforms allow for extensive utilization of network resources, and thus offer a strong alternative to workstations and associated software. Mobile applications are becoming inevitable in people's day-to-day activities. It has become part of daily living for several people, something one cannot do without in all facets of economic growth of any country. This is evident in the convenience and ease of service delivery

customers are provided with. Some examples of successful implementation of mobile communications in businesses are: in banking (mobile banking), education (eLearning), payment of utility bills (e-Billing) etc(Adeyanju, 2012)

### **2.2.2 Data visualization**

Data visualization has become one of the most common modes of information communication because it allows the data or/and analysis of large amount of data to be presented in a good looking and easily understandable way. The use of graphs, charts, maps and other visualization tools has been shown as one of the most effective ways to communicate information as it enables the target audience to “read” the information at a glance.

Most data visualization software programmes are designed with their target audience in mind which means that they usually offer all the tools needed by the specific type of users. Data visualization software designers typically also pay a great deal attention to ease of usability, printing and extra features which facilitate data management, mining, processing and analysis as well as save a great deal of time for the mentioned processes. However, the difference between one software programme to another can be significant even if both are designed for the same target users. For that reason data visualization software should be chosen very carefully.

Data visualizations can help shrink the feedback loops required to ask big questions of complex data and reduce the chance of miscommunication. They can also provide additional ways to answer questions without the need to strictly rely on the vagaries of language or the occasionally impenetrable stories told by numbers. Visualizations offer a way to extend and enhance our innate powers of perception and cognition and get a “grand view” of the world

around us. Different types of visualizations can reveal distinct aspects of the world that otherwise would be invisible to us. Although the terminology is not always entirely clear-cut, here's one way to think about two broad categories of technology-enhanced vision: data visualizations provide concrete visual representations of the nonphysical and the abstract such as a statistical trend; scientific visualizations allow people to see hidden physical forms and processes, such as a positron emission tomography (PET) scan that shows the level of metabolic activity in various regions of the brain when performing certain tasks.(Ware, 2004 )

The modes of information communication evolve constantly in order to improve its efficiency, clarity and aesthetic appeal. Generally, there are no wrong ways to communicate information but the traditional textual forms are slowly giving their way to data visualization. Whether the latter is really the best way to communicate information or not depends on several factors including the type of data you want to present and the target audience to which you are communicating information.

If you are having difficulties deciding between communications of data in the “raw” form or using visualization methods such as graphs, dials, charts, etc. instead, the following overview of advantages of data visualization may help:

Clarity. It is a lot easier to understand a dial or graph than numbers. The viewer understands what you are trying to say at a first sight. Saving time. Since a “picture is worth a million words”, using data visualization helps the audience quickly absorb and interpret the presented data. As a result, data visualization enables you to present a considerably larger amount of data in comparison to the textual format which often requires repetition in order to help the audience understand the information. Less confusion. It is not difficult to get confused when dealing with lots of numbers as you actually need to memorize them to be able to understand

the communicated information. Using visual presentation of numbers, however, dramatically reduces confusion because the audience does not need to process the numbers to be able to see where you are going. Aesthetic appeal: Visualizations look better and attract more attention than the textual format. They are also more likely to keep the audience interested in your presentation.

Although data visualizations are easier to understand and look more attractive to the audience, it is crucial to achieve a perfect balance between visual appeal and functionality. Data visualization is in the first place used to improve efficiency of the communicated information. A beautiful presentation which, however, fails to emphasize relevant data or is not clear enough is of little value. For that reason it is highly important to make sure that the presented data are clear and understandable, and only then focus on aesthetically appealing and attention drawing design. Just as important is to support the communicated information with additional materials such as official statistic data, facts, examples, etc. if you want the audience to accept your view/interpretation.

In the end, it is necessary to mention that the use of data visualization does not necessarily exclude the textual format or vice versa. If you are dealing with numbers, you cannot avoid them completely no matter how sophisticated visualizations you use. Nevertheless, it is a lot easier to make a point and help the audience understand the importance of the communicated information if you also use visual presentation along the numbers.(nd, 2012)

## **Types of visualization**

It's important to point out that not all data visualization is created equal. Just as we have paints and pencils and chalk and film to help us capture the world in different ways, with

different emphases and for different purposes, there are multiple ways in which to depict the same dataset.

Or, to put it another way, think of visualization as a new set of languages you can use to communicate. Just as French and Russian and Japanese are all ways of encoding ideas so that those ideas can be transported from one person's mind to another, and decoded again — and just as certain languages are more conducive to certain ideas — so the various kinds of data visualization are a kind of *bidirectional encoding* that lets ideas and information be transported from the database into your brain.

An important distinction lies between visualization for *exploring* and visualization for *explaining*. A third category, *visual art*, comprises images that encode data but cannot easily be decoded back to the original meaning by a viewer. This kind of visualization can be beautiful, but it is not helpful in making decisions.

Visualization for exploring can be imprecise. It's useful when you're not exactly sure what the data has to tell you and you're trying to get a sense of the relationships and patterns contained within it for the first time. It may take a while to figure out how to approach or clean the data, and which dimensions to include. Therefore, visualization for exploring is best done in such a way that it can be iterated quickly and experimented upon, so that you can find the signal within the noise. Software and automation are your friends here.

Visualization for explaining is best when it is cleanest. Here, the ability to pare down the information to its simplest form — to strip away the noise entirely — will increase the efficiency with which a decision maker can understand it. This is the approach to take once you understand what the data is telling you, and you want to communicate that to someone else. This is the kind of visualization you *should* be finding in those presentations and sales

reports. Visualization for explaining also includes infographics and other categories of hand-drawn or custom-made images. Automated tools can be used, but one size does not fit all.

### **2.2.3 Visual Analytics**

Visual Analytics can be defined as a science of analytical reasoning supported by interactive visual interfaces. Currently data is produced, collected and stored at a faster rate than the ability to analyze it. A very large number of automatic data analysis methods have been developed over the last decades alone, though, the complex nature of these problems makes it necessary to include human intelligence at an early stage in the data analysis process. Visual Analytics methods enable decision makers with the ability to combine their human creativity, and background knowledge with the huge storage and processing capacities of today's computers to gain insight into complex problems. Visual Analytics can be viewed as an fundamental approach for combining visualization, human factors, and data analysis. Using visual interfaces, humans may be able to directly interact with today's computer data analysis capabilities, allowing the decision makers to make well-informed decisions in complex situations. Visual analytics relates to the areas of Information Visualization in the context of data visualization and Computer Graphics, and in the context of data analysis, it gains from methodologies developed in areas such as data management, data mining information retrieval, & knowledge representation.(Cook & Thomas, 2016)

### **2.2.4 Visualization on Mobile Devices**

The use mobile devices for visualization have provided a ubiquitous environment for faster access to information and effective decision making. These visualizations are essential in satisfying the knowledge requirements of key players in areas as diverse as medical services, scientific discovery, and business. Other areas include education, law enforcement, protective services, and homeland security (Kim, Jang, Mellema, Ebert, & Collins, n.d)

Visualization allow developers to build mobile applications that are more useful, productive and intuitive thus becoming one of the most important component of this applications. Technically developing visualizations on mobile devices will become easier because continuously improvements such as new, possibly standard software Application programming interfaces and more powerful devices. These improvements will make it easier to create and experiment with mobile visualizations but may not change most of the limitations of mobile devices. Increasing the currently limited set of mobile visualization techniques will make it more convenient for users to get timely and accurate information from and take decisions with mobile devices (Chittaro, 2006).

If not well carefully considered any non-trivial mobile visualization can rapidly end up with too much to visualize in a too little display area due to the limited screen space provided. Scrolling and zooming navigation techniques may used to allow users to move among parts of the visualization in an attempt to face this problem. Unfortunately, this insufficiently alleviates the problem, because it makes it cognitively complex to navigate the visualization, and also forces users to lose the global context when examining the details of the visualization.(Microsoft, 2012)

### **Challenges of visual analytics on mobile phones**

The creation of visual analytics for mobile environments has several challenges. Some of these challenges are common to general research in ubiquitous computing. For example, the support of interactive graphics with region picking, hyperlinks and mouse-over events is an important issue for the design of interfaces for ubiquitous computing devices. Connectivity and bandwidth is also a critical challenge as visual analytic applications can involve large (up to hundreds of terabytes) data sets and require extensive computational needs. Finally, the issues of screen size, resolution, and color depth as well as different and sometimes limiting

input devices pose challenges just as they do for any complex interactive application some of the challenges more specific to visual analytics include the following.

**User Information needs:** There is a wide variety of information needs dependent on the type of user and the task to be performed. This requires a careful scoping of the problem space being addressed and a realization of whether and how the results apply to other situations

**Multiple Situational Environments:** Users do not have the luxury of using applications only in controlled environments such as a parked car. Interfaces need to support a range of techniques to accomplish the same task in less favourable contexts (e.g. while walking, in dark environments). Selection of the appropriate interaction technique depends on the needed level of control and situational capability of the user to use the interface.

**Adapting Existing Techniques:** Established visual analytics techniques have been developed for desktop systems. Adapting these for use on ubiquitous devices represents a potentially large set of unexplored challenges. (Sanfilippo Antonio, nd)

## **2.3 State of Practice**

### **2.3.1 Introduction**

Traditionally, air pollution situation is monitored by conventional air pollution monitoring systems with stationary monitors. These monitoring stations are highly reliable, accurate and able to measure a wide range of pollutants by using the conventional analytical instruments, such as gas chromatograph-mass spectrometers. The drawbacks of the conventional monitoring instruments are their large size, heavy weight and extraordinary expensiveness. These lead to sparse deployment of the monitoring stations. In order to be effective, the locations of the monitoring stations need careful placement because the air pollution situation

in urban areas is highly related to human activities (e.g., construction activities) and location-dependent (e.g., the traffic choke-points have much worse air quality than average). Changes in urban arrangement, activities or regulation may affect both the species and the concentrations of air pollutants, which require relocating stations or adding new stations. These requirements are typically hard or even impossible to fulfil due to the cost inefficiency in acquisition and maintenance of the monitoring stations. Moreover, the conventional monitoring instruments involve long-term time-consuming average models. The air pollution situation is updated hourly or even daily. Hence, the air pollution maps built by the conventional air pollution monitoring systems are with extremely low spatial and temporal resolutions.(Amorin, Cameiro, & Cardeal, 2008)

In order to increase the spatio-temporal resolution of the air pollution information, researchers are pushing the air pollution monitoring systems to the limit by combining the low-cost portable ambient sensors and the Wireless Sensor Network (WSN) into one system which is known as The Next Generation Air Pollution Monitoring System (TNGAPMS). By utilizing the low-cost portable ambient sensors and the WSN, the air pollution information can be updated in minutes or even seconds. Also, the low-cost portable sensors enable the mobility and the feasibility in large-scale deployment of the sensor nodes. The spatial and temporal resolutions of the pollution information are significantly increased in TNGAPMS. TNGAPMS fills the gap between the conventional monitoring systems and the air quality models because the air pollution information at locations without monitoring stations is accomplished by air quality models or estimations. TNGAPMS also helps researchers understand the distribution of the air pollutants more efficiently and accurately to improve the air quality models. The public users can even measure their personal exposures to pollutants using wearable sensor nodes( United States Environmental Protection Agency, n.d.)

### **2.3.2 WSN Based Air Pollution Monitoring Systems**

According to (Ying, 2015) the existing works are classified into three categories based on the carriers of the sensor nodes, namely Static Sensor Network (SSN. Sensor nodes are usually mounted on the streetlight or traffic light poles, or carefully selected locations.), Community Sensor Network (CSN. Sensor nodes are carried by the public communities, usually by volunteers or people who are keen on air quality.), and Vehicle Sensor Network (VSN. Sensor nodes are carried by the public transportations or specially equipped cars.). (Mendez D e.t.l ., 2011)

#### **2.3.2.1. Static Sensor Network (SSN)**

In SSN systems, the sensor nodes are typically mounted on the streetlight or traffic light poles, or walls. By utilizing the low-cost ambient sensors, the number of sensor nodes in SSN systems is much larger than that in the conventional monitoring systems. Air pollution information with high spatio-temporal resolution is achievable in SSN systems. Authorized air pollution information is available to the public through web pages, Web Apps, mobile Apps, *etc.* Examples in this category include:

Kadri, Yaacoub, Mushtaha, & Abu-Dayya,(2013) proposed, implemented and tested. an outdoor ambient real-time air quality monitoring system. In this system, the concentration of O<sub>3</sub>, NO<sub>2</sub>, CO and H<sub>2</sub>S are sensed and transmitted back to the backend server through the GPRS wireless communication link every minute. Authorized air pollution information is available to the public through the customized Web and mobile Apps. A solar panel was utilized to solve the power constraint issue of the sensor nodes (stationary).

In an innovative system named Wireless Sensor Network Air Pollution Monitoring System (WAPMS) was proposed and simulated to monitor the outdoor air pollution situations in

Mauritius. This system comprises of an array of sensor nodes and a communication system that gathers the air pollution data to the server. The air pollution data are acquired and passed to the cluster heads by the sensor nodes autonomously. The cluster heads then forward the data to the server. In order to minimize the power consumption in the WSN, a novel data aggregation algorithm named Recursive Converging Quartiles (RCQ) was proposed and implemented. Moreover, a hierarchical routing protocol was utilized to maximize the sensor nodes' energy efficiency (Khedo, Perseedoss, & Mungur, 2010).

In, an outdoor WSN based air quality monitoring system (WSNAQMS) for industrial and urban areas was proposed. The sensor node consists of a set of gas sensors (O<sub>3</sub>, CO and NO<sub>2</sub>) and a ZigBee wireless communication link based on the Libelium's gas sensing capable mote. Data are uploaded to the central server through the ZigBee communication link. Authorized air pollution information is available to the public through Email, SMS and customized Web App. This framework is claimed to be simple and reusable in other applications. Also the failure sensor nodes can be identified efficiently and the energy consumption of each sensor node is minimized. Moreover, a simple Clustering Protocol of Air Sensor (CPAS) network was proposed, which proved to be efficient (in simulation) in terms of network energy consumption, network lifetime, and the data communication rate. The QoSs of the network such as delay, accuracy and reliability (fault tolerance) were also considered (Mansour, Nasser, Karim, & Ali, 2014).

### **2.3.2.2 Community Sensor Network (CSN)**

In CSN (or Participatory Sensing) systems, the sensor nodes are typically carried by the users. By utilizing the low-cost portable ambient sensors and the ubiquitous smart phones, users are able to acquire, analyze and share the local air pollution information. Authorized air

pollution information is available to the public through web pages, Web Apps, mobile Apps, *etc.* Example of the Community Sensor Network (CSN) system architecture and prototype.

A low-power and low-cost mobile sensing system for outdoor participatory air pollution monitoring called GasMobile by King's College London, (2016). was introduced. The sensor node composes of a small-size, low-cost O<sub>3</sub> sensor and an off-the-shelf smart phone. The sensor communicates with the smart phone through the USB port. Data (tagged with location information from the build-in GPS module) are uploaded to the server through the cellular network. Authorized information is available to the public through the customized Web and mobile Apps. Two methods were proposed and implemented to improve the data quality of the sensor. An outdoor air quality sensing system (P-Sense) based on the participatory sensing technology was presented. Each sensor node consists of a set of sensors (CO<sub>2</sub>, CO, VOCs, H<sub>2</sub>, temperature and relative humidity) and a Bluetooth link. Data are acquired by the sensors and transmitted to the smart phone through the Bluetooth link. The smart phone then uploaded the data to the server through the cellular network. Authorized air pollution information is available to the public through the customized Web and mobile Apps. Several research issues that need to be addressed before practical deployment of the P-sense system were also pointed out.

Honicky et.al,(2008) introduced a hardware and software platform for outdoor participatory air quality monitoring, called N-SMART. By attaching sensors (CO, NO<sub>x</sub>, temperature and Bluetooth) to a GPS-enabled cellphone, the raw air pollution data, which help understand the impacts of air pollution on both individuals and communities, are gathered. The sensor node communicates with the cellphone through the Bluetooth wireless link. Note that, this paper didn't focus on the implementation but the design of the sensing platform. Several research

challenges like unpredictable user behaviors and movements, and user privacy problems were discussed in this paper

### **2.3.2.3. Vehicle Sensor Network (VSN)**

In VSN systems, the sensor nodes are typically carried by the public transportations like buses or taxis. By utilizing the low-cost portable ambient sensors and the mobility of vehicles, one sensor node is able to achieve sufficient large geographic coverage. Authorized air pollution information is available to the public through web pages, Web Apps, mobile Apps, *etc.*

Example of systems developed using this vehicle sensor Network include Mobile Air Quality Monitoring Network (MAQUMON) by Völgyesi, Nádas, Koutsoukos, & Lédeczi, (2008). This system is composed by a number of car-mounted sensor nodes measuring the concentrations of O<sub>3</sub>, CO and NO<sub>2</sub>. Each sensor node utilizes a GPS module for acquiring time and location information and a Bluetooth link for communicating with the laptop inside car. Collected data are then uploaded to the server through the laptop's Wi-Fi link. Authorized air pollution information is accessible through the sensor node's LCD display or the Sensor Map Web App.

A mobile sensor node prototype that can be mounted on vehicle was introduced and tested. Each sensor node consists of a set of sensors (CO, PM, NO, NO<sub>2</sub> and VOCs) for detecting the pollutants' concentrations, a GPS module for collecting the location information, and a GPRS or Wi-Fi module for communicating with the server. Analyzed data are available to the public through a Web App. This paper claimed that the proposed system demonstrated higher spatial coverage at the expense of lower temporal resolution compared with the SSN systems((Wong, Chua, & Li, 2009).

## **2.4 Technological advancements in visualization on mobile phones**

### **2.4.1 Mobile application technologies**

According to Gwaro (2013) mobile technologies can be generally classified as follows

**Communication technologies:** This includes technologies such as like Bluetooth and WIFI that have enabled communication through a wireless network. The global system for mobile communications (GSM), general packet radio services (GPRS) and universal mobile telecommunications system (UMTS) have been used in communication through the mobile networks.

**Development platforms technologies:** there are four mobile application platforms; Java ME, .NET CF, Adobe Flash Lite and Android. If the four critical application development requirements that is portability, Functionality, development speed and performance are considered then, Java ME is the winner in runtime support followed by Flash Lite. In terms of functionality, Java ME serves the implementation of multimedia-rich full-fledged applications while .NET and android applications use powerful APIs. Flashlight is the most suitable for graphics-heavy applications.

**Middleware technologies:** WAP and iMode are the two examples of mobile middleware protocols, built on top of the TCP and IP, used in mobile application development. WAP (Wireless application protocol) is a protected specification supported by all mobile operating systems that enables users to receive information immediately through their handheld devices and. The i-mode uses a subset of HTML to make content creation very easy and provides a simple conversion of existing websites and uses packet transmissions to offer continuous access (Hu, 2009).

**Presentation technologies:** A multitude of diverse mobile can easily combine voice and data processing as well as communication capabilities. Content delivery i.e voice is made possible

through the use of standards such as XML, WML and various kinds of HTML. XML technologies also offer convenient user interfaces.

### **Tracking and positioning technologies:**

Tracking with the end goal of finding allocation of a gadget is not one, single innovation but a blending of a few advances that might be consolidated to create systems position of a mobile phone. Current technologies being used to create location-tracking and location-based systems include:

#### **Geographic Information Systems (GIS)**

For large-scale location-tracking frameworks, it is important to capture and store geographic data. Geographic information systems can capture, store, analyze and report geographic information. The real power of GIS lies in their ability to combine and analyse georeferenced data from a range of sources (Huisman & deBy, 2009)

#### **Global Positioning System (GPS)**

Worldwide Positioning System tracking is a technique for finding out precisely where something is. A GPS tracking framework, for instance, may be set in a vehicle, on a mobile phone, or on unique GPS gadgets, which can either be a fixed or portable unit. GPS lives up to expectations by giving data on accurate location. It can similarly track the movement of a vehicle or individual. In this way, for instance, a GPS tracking framework might be utilized by an organization to screen the route and advancement of a conveyance truck, or by parents to monitor the whereabouts of their youngster (U.S. Air Force, 2014)

#### **Radio Frequency Identification (RFID)**

Radio frequency identification (RFID) is a technology used to track and trace and identify a person/object using radio frequency transmission. An RFID system includes tags, readers, and an

application system. Information is exchanged wirelessly between a tagged object and a reader when they are tuned to the same radio frequency.

### **Wireless Local Area Network (WLAN)**

These are system of gadgets that associate by means of radio frequency, for example, 802.11b. These gadgets transmit information through radio waves within a range of between 70 to 300 feet. Any location-based service or tracking framework makes use of the fact that framework entails that a node or tag placed on the object, animal or person can be used to find the exact location at any one time.. For example, the GPS receiver in a mobile phone or an RFID tag on a asset can be used to track those devices with a detection system such as GPS satellites or RFID receivers (Alberta Education, 2007).

### **2.4.2 Mobile application development**

Software development for mobile platforms comes with unique features and constraints that apply to most of the lifecycle stages. The development environment and the technologies that support the software are different compared to “traditional” settings. The most important distinguishing characteristics are identified in. Environment particularities include: a high level of competitiveness; necessarily short time-to-delivery; and added difficulty in identifying stakeholders and their requirements. Development teams must face the challenge of a dynamic environment, with frequent modifications in customer needs and expectations. Technological constraints apply to mobile platforms in the form of limited physical resources and rapidly changing specifications.

There is also a great variety of devices, each with particular hardware characteristics, firmware and operating systems. Another view of the constraints associated with mobile applications is presented in. The author mentions two types of constraints, evolving and inherent. Evolving constraints, such as bandwidth, coverage and security, currently apply to

the mobile technology, but are likely to be addressed and possibly resolved in the near future. On the other hand, inherent constraints such as limited screen real estate, reduced data entry capability (due to a limited keypad for example), memory capacity, processing power and limited power reserve, are permanent, at least relative to desktop environments. Various approaches must be used in order to lower the impact of inherent constraints. M-apps are software designed to take advantage of mobile technology and can be developed for technology besides mobile phones. But mobile phones have many key advantages: affordability, wide ownership, voice communications, and instant and convenient service delivery. As a result, there has been a global explosion in the number of m-apps, facilitated by the rapid evolution of mobile networks and by the increasing functions and falling prices of mobile handsets. M-apps are markedly different in developing countries because they typically run on second-generation (2G) phones rather than smartphones, which are far more common in developed countries. (Christine Zhenwei Qiang, 2012)

### **2.4.3 Mobile application platforms options**

Mobile application development platforms have been identified as a factor affecting mobile application development. Mobile applications come in two distinct formats: native apps and web apps.

#### **Mobile Native Apps**

A native mobile app is built specifically for a particular device and its operating system. Unlike a web app that is accessed over the internet, a native app is downloaded from a web store and installed on the device. Native apps are written in Java, Objective C, or some other programming language. Native apps have a major advantage over web apps—the ability to leverage device-specific hardware and software. This means that native apps can take advantage of the latest technology available on mobile devices and can integrate with on-board apps such as the calendar, contacts, and email. However, this is a double-edged sword:

while mobile technology is wildly popular, it is also constantly changing and highly fragmented. This makes the task of keeping up with the pace of emerging technology onerous and costly, especially on multiple platforms.

### **Mobile Web Apps**

A mobile web app is a web application formatted for smartphones and tablets, and accessed through the mobile device's web browser. Like a traditional web application, a mobile web app is built with three core technologies: HTML (defines static text and images), CSS (defines style and presentation), and JavaScript (defines interactions and animations). Since web apps are browser-based, they're intended to be platform and device independent, able to run on any web-enabled Smartphone or tablet. A mobile web app is normally downloaded from a central web server each time it is run, although apps built using HTML5 (described below) can also run on the mobile device for offline use. The key advantage of mobile web apps over native mobile apps is cross-platform compatibility, allowing them to reach the broadest audience for the least effort. They're relatively cheap, easy, and fast to build, although some device-specific customization is usually required. Mobile web browsers are fairly standardized, making it much easier to create a universal mobile web app than a native one

### **Hybrid Apps**

In addition to building custom native apps for different mobile platforms or creating a single less-capable web app that works on any device via its browser, there's also a third option: blending the two approaches in a hybrid app. With a hybrid app, much or the entire user interface appears in a browser window, with a native app wrapped around it to provide access to device functionality not available via the browser. This ability to combine standard web apps with native code can significantly reduce development time and cost, minimizing custom coding work. To the user, a well-designed hybrid app looks very similar to a native

app: it is downloaded from an app store, stored on the mobile device, and launched just like a native app. But to developers there is a huge difference, because rather than rewriting the entire app for each mobile platform, they write at least some of the code in HTML, CSS, and JavaScript, and reuse it across different devices. (Lionbridge, n.d)

## **2.5 Critique of the Related Work**

All the discussed related systems are able to collect data using different technologies. This data ends up in a database in a server for consumption by many interested parties such as individuals, organizations, and the government. The related systems do not provide personalized data about an individual rather general data about pollutions in a given area over a period of time. The data sent to the server in all systems is not analyzed to provide insights and patterns regarding the different levels of pollutions at different locations. The proposed and implemented systems do not provide a tool to access and manipulate the data from the servers to enable users to be able to understand the impact of pollutions on their lives.

## **2.6 Conclusions**

The proposed visual analytic tool is made not only to capture air pollution levels but also to be able to visually analyze the data on air pollution. The proposed tool is able to monitor user movements over a period of time and record automatically in an online database. The locations visited by an individual can be analyzed visually to provide up-to-date information about individual accessibility to air pollutants and give appropriate advice to the users. With this the researchers hope that individual members of the public can be able to make sound decisions based on their life patterns such as places to stay and visit.

## **CHAPTER THREE:**

### **RESEARCH METHODOLOGY**

#### **3.1 Introduction**

This chapter provides a clear roadmap for the research process. It details key aspects of research methodology such as the research design, research procedure and evaluation of different methodologies that are important to any successful research activity.

#### **3.2 Research design**

The researcher applied quantitative research design because the project was data based. Quantitative research design in a formal, objective, systematic process for obtaining quantifiable information presented in numerical form, and analysed through the use of statistics for purposes of describing and testing relationships.

#### **3.3 Software development methodologies review**

A software development methodology is a framework that is used to assist one to structure, plan, and control the process of development of an information system.( Association of Modern Technologies Professionals, 2015). A big number of such frameworks have been developed over the years, each having its own recognized strengths and weaknesses. Each of the available methodologies is developed to be applied to specific kinds of projects, based on various organizational, technical, and team considerations (Centers for MediCare and Medicaid Centers, 2008). They include:

##### **a) Agile Software Development Methodology**

Agile software development is a conceptual framework for developing a variety of software engineering projects. There are a wide variety of agile software development methodologies for example Scrum, Dynamic Systems Development Model (DSDM), and Crystal Methods.

Most agile methods endeavour to minimize risk by developing software in short modules, which typically last within four weeks. Each module is like a small software project of its own, and includes necessary tasks to release the mini-increment of new functionality. This new functionality may include planning, requirements analysis, design, coding, testing, and documentation. While each module may not add enough functionality to merit releasing the overall product, an agile software project aims to be capable of releasing new software at the end of every completion of the module. The primary measure of progress is working software. Agile methods produce very little written documentation relative to other methods especially if combined with the emphasis for face-to-face communication.

#### **b) Dynamic Systems Development Model Methodology**

The Dynamic Systems Development Model is software methodology that was developed in the U.K. in the mid-1990s. It is the evolution of rapid application development (RAD) practices. In Europe Dynamic Systems Development methodology boasts to be the methodology that supports training and documentation more than any of the agile software development techniques. It also favours the philosophy that no software is built perfectly at any instance of development. Dynamic Systems Development Model looks to software development as an exploratory endeavour.

#### **c) Extreme Programming (XP) Methodology**

XP is a methodology for creating computer software within an environment that is unstable. Flexibility is clearly seen within the process of modelling. The main goal of XP is to lower the cost of change in software requirements. Requirements for the system in traditional system development life cycle are often determined and often “frozen” at the beginning of the development project. This automatically means that the cost of changing the requirements is high if any at a later stage in the project. The important practices are derived from generally accepted best practices, and are taken to extremes.

#### **d) Joint Application Development (JAD) Methodology**

JAD is methodology in which developers, executives, and end-users attend powerful off-site meetings to work out a system's details giving emphasis to requirements-definition and user-interface design. Involvement of client in the design and development of an application is the pillar of Joint Application Development (JAD). This is done in a series of joint workshops called JAD sessions. JAD is best applicable to business process rather than technical details. It reduces cost by shortening the elapsed time required to gather a system's requirements and by gathering requirements better. The success of JAD highly depends on effective leadership of the JAD sessions in terms of participation by developers, key end-users, and executives, and on achieving group synergy in JAD group sessions.

#### **e) Evolutionary Prototyping methodology**

According to softdevteam (2013), evolutionary prototyping model is a software development lifecycle model in which software prototype is created for demonstration and requirements elaboration. The main concept is to build a robust prototype and constantly improve it. It has the advantage of giving end users an accurate and complete description of the system.

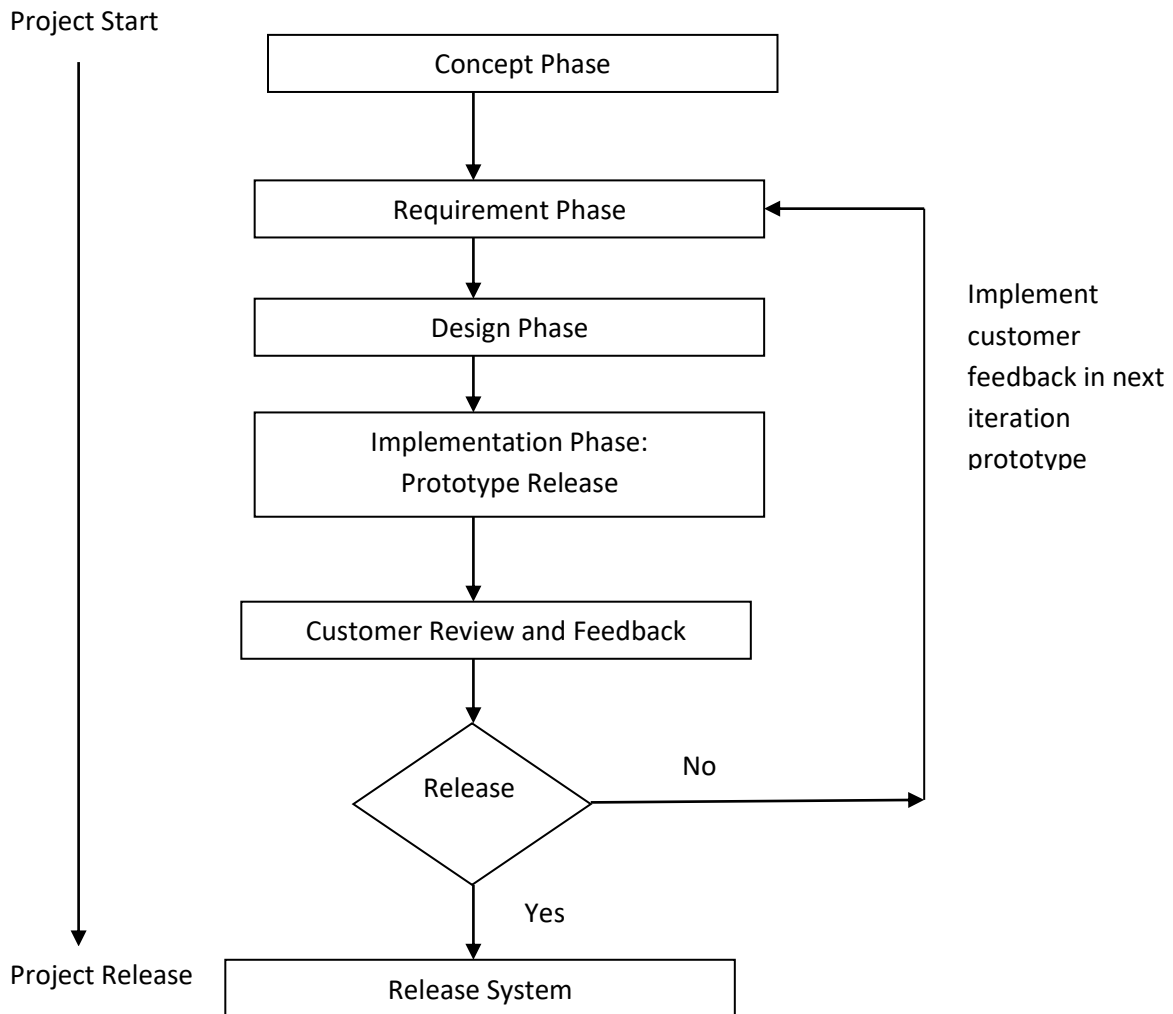


Figure 2: Evolutionary prototyping model (Lenz & Moeller, 2008)

### 3.4 Evaluation of software Development Methodologies

#### 3.4.1 Introduction

Evaluation is a process that can be characterised by the following features among others: Evaluation is viewed as a task, which must result in reported outcomes, Evaluation can also be thought to be as an aid for planning, and therefore the outcome is an evaluation of different possible actions, Evaluation is goal oriented venture. The primary aim is to check results of actions, in order to improve the quality of all the possible actions or to choose the best possible alternative action.(Gediga & Kai-Christoph, nd)

Although software development methodologies have affected significant improvements in the quality of software, the steady proliferation, growth, and diversity of development approaches now foster new concerns. In particular, it is becoming increasingly difficult to: choose an appropriate methodology approach, recognize what one should expect from a methodology as opposed to environments, tools and techniques and understand the relationship and role of a methodology within a given environment and vice versa. (Arthur, Nance, & Henry, n.d)

### ***3.4.2 Goals and results of evaluation***

Any evaluation has rationally chosen goals. The main goal in the domain of software evaluation can be characterised by one or more of the following three simple questions. The first question is; which one is better?. The evaluation at this stage aims to compare alternative software systems, e.g. to choose the best software tool for any given application, for making a decision among several prototypes, or it could be for comparing several editions of a software system. In the second question how good is it? The evaluation process aims at the determination of the degree of required qualities of a finished system. One of the applications of this second goal involves evaluation of the system with respect to “Usability-Goals. The third question why is it bad?; The evaluation aims to establish the weaknesses of a given software in a such a way that the result generates suggestions for further development.

### ***3.4.3 Criteria for system development methodologies comparison***

According to (Benzine, 2002) The following criteria can be used to determine the best methodology one can use to developed an application in any environment.

**Processes definition:** Process definition is set to determine if the methodology assume that every step in the development life cycle is well known by developers to be and evaluates if there is no room for environmental changes. This evaluation may also assess if the methodology allow a big deal of flexibility in all stages of the development cycle to integrate those changes that needs to be integrated in the project before its closure.

**Final product determination:** Another criterion is to evaluate if the methodology define the final product early on in the planning stages of development. This criterion also checks if the product is defined during the project and close to project closure time

**Project cost:** This criterion involves the estimation of the cost of developing the whole project to its completion and to determine at what stage of the project it's done.

**Project completion date:** This criterion involves estimation of a schedule of deliverables on the basis of estimation of the tasks to be accomplished. The question to be answered is estimation done up front or as the project progresses?

**Responsiveness to environment:** In this criterion the flexibility to what extend does the methodology allows to incorporate changes during the project development is measured. Also included to incorporation changes due to the technology, environment or competition

**Team dynamic and creativity:** This criterion attempts to measure the ability of allowing some of the team work and interactions among members of the team developing the software.

**Role of the upper management:** This criterion attempts to measure if management is an an obstacle in creating a better system. It examines the role of management in empowering the team by taking care of any obstruction that impact the team performance during the development of the entire project

**Training and knowledge:** the valuation is done to determine if the methodology steps allow training and knowledge transfer during the project development. It also determines if there is a limitation to what a team member can do and learn.

**Probability of success:** This criterion measures the probability of success of a project using a certain methodology by embracing a certain degree of complexity and unpredictability.

## **3.5 Selection of methodology**

### ***3.5.1 Evolution prototyping***

The evolutionary prototyping approach will be used to build the system. The researcher will systematically build the system by:

The researcher studied data obtained for insights and interesting patterns. The researcher will also establish realistic user expectation, defines data elements required and determines data availability. Using this data the researcher was develop the initial working/interactive prototype quickly, which meets the user's stated basic requirements. The prototype, performing only the basic functions will be tested. The researcher will refine the prototype and perform final testing. The researcher will take due notice of the changes suggested by the user and revises, enhances and refines the proto type accordingly. (CrackMBA, 2012)

### ***3.5.2 Justification of evolution prototyping***

Evolutionary prototyping is best suited because it will enable the developer to 'tryout' the basic idea of information dissemination on air pollution without incurring large/ huge costs, lower overall development costs when requirements change. Evolutionary prototyping is also best suited for online system hence the right choice because the system to be developed will be an online system. Evolutionary prototyping will be used to clarify patterns of air pollution by embodying the better-understood requirements in a tangible form. The researcher will be able to see requirements in the prototyped systems, and therefore can validate the requirements reflected in the prototype.

Once a prototype baseline is established, the researcher will be able to find additional functions that the prototype must provide in relation to location of the resident and the amount of air pollution. Evolutionary prototyping is useful for the purposes of facilitating communication the process of developing the mobile application. The prototypes produced allow all involved to have a common 'language' from which to speak about the system

### **3.6 Development tools and technologies**

The researcher intends to use the following for system building:

#### **Hardware**

1. Mobile phone for testing the system.
2. Desktop computer with 2 GB RAM and a hard disk space of 320 GB for building the system.

#### **Software**

1. Windows operating system because popular and easily available. .
2. Android studio Integrated Development Environment (IDE) software because it is open source application.
3. Wamp or Xamp and sql servers which will provide support for access of databases and the related connectivity. Wamp or xamp is also an open source
4. Database design was done using MySQL server
5. Development language will be Java SE 7, PHP and HTML 5
6. Mobile platform was Android Studio 4.4.2 and above

*Justification:* The main advantage is the fact that open source applications can be easily customized by anyone with the required skills. During customization, open source software can be readily modified to meet specific user needs. Open source software can also be customized to meet users needs (Wilson, 2012) Open source software development produces software that are reliable and of high quality quickly and inexpensively.

### **3.7 Summary**

This chapter discussed how the research will be carried out in a systematic manner so as to collect correct data. The chapter also discussed research design different methodologies that can be used to develop a system and evaluation criteria. The chapter also discussed the

Software development methodology and development tools used in developing mobile based tool for assessment of air population were also discussed.

## CHAPTER FOUR

### 4.0 MODELING AND IMPLEMENTATION

#### 4.1 Introduction

This chapter outline various requirements for the project such as functional and non-functional requirements. The chapter also outlines system modelling the system using unified structured language and design.

#### 4.2 Requirements for visual analytic tool for assessment of air quality levels.

##### 4.2.1 User Requirements

Understanding user requirements is an integral part of systems design and is critical to the success of interactive systems. The system under development will be used by many people it should able to meet specific user requirements. Usability is key in ensuring that system is accepted by as many people as possible.

##### 4.2.2 Functional Requirements

The following were identified as requirements

- i. Should be able to allow members of public to register as users.
- ii. Should be able to perform an automatic scan of the current location and record the data in a table.
- iii. Should be able to send alert in form of SMS to the user when requested and when entering location that is perceived to be with high pollution levels.
- iv. Should be able to analyze data on air pollution over a period of time.
- v. Should be able to represent the data in graphical format for visualization.

- vi. Should be able to store data about the individual based on access of particular areas in the city.
- vii. Should be able to provide popup messages about air pollution in a given area.

#### ***4.2.3 Non-Functional Requirements***

The system should be able to meet the following requirements

1. A system should be easy to learn and use.
2. A system should have an element of error validation, one that prompts the user on entering unusual command or data format inconsistent.
3. A system should be faster, flexible and consistent
4. Reliability – The system should be available to carry out the key tasks it was made for.
5. Usability – the user interface should be designed such that screens are similar therefore it will be easy to use and learn to work with the software

#### ***4.3 System Modeling***

The Unified Modelling Language (UML) a language made of graphics to visualize, specify, construct, and document the artefacts of a software system that will be used. UML also uses object oriented design concepts and it is independent of any specific programming language. It also provides a standard way to come up with a system's blueprints, including conceptual aspects of a system such as business processes and system functions. It also conceptualizes concrete things such as programming language statements, database schemas, and reusable software components.

### 4.3.1 The case model of the system

It's the discreet unit of interaction between the user and the system

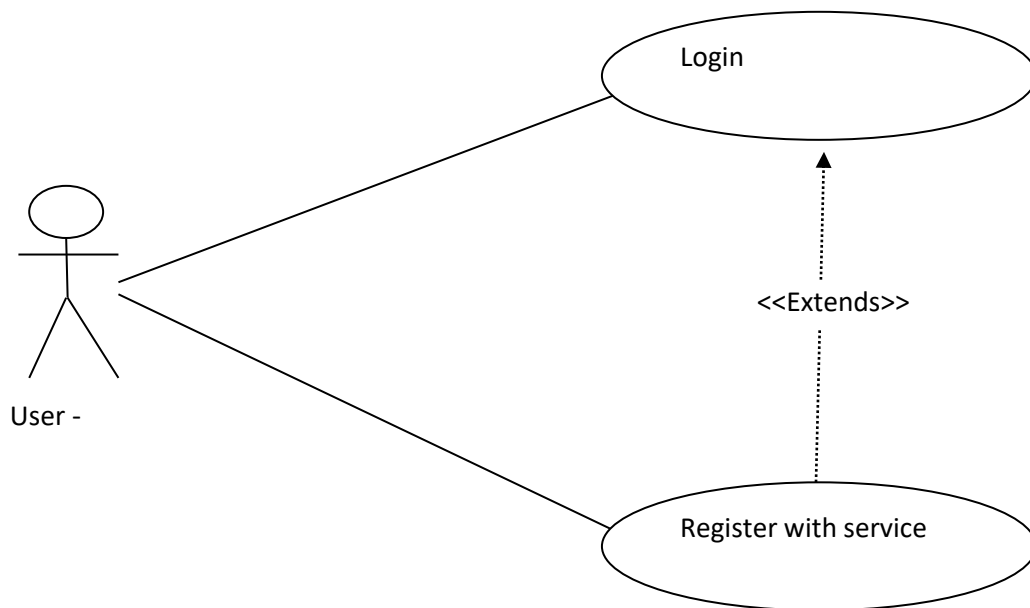


Figure 2 UML Use case diagram for visual analytic tool of air quality assesment

#### Actors

Actors are human or machine entities that use or interact with the system to perform a piece of meaningful work that helps them to achieve the goal. The actors in the application system include following:

Internet enabled smart mobile phone- The mobile is used by the registered user to interact with the system by way of access and receiving of services as per the requests made.

Registered User - Interacts with the system by sending requests through the mobile phone and receiving data analysis based on users requests.

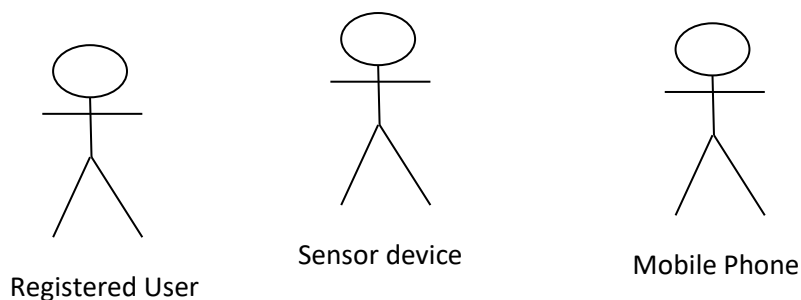


Figure 3: Diagram showing the Actors of Mobile based visual analytic tool of air quality assesment

### 4.3.2 The use case diagram for the system

A use case diagram is a sequence of actions a system performs that will be able to produce an results as per particular user's request. The following is the use case diagram for a visual analytic tool for assessment of urban air quality in developing countries and shows how the users interact with the system.

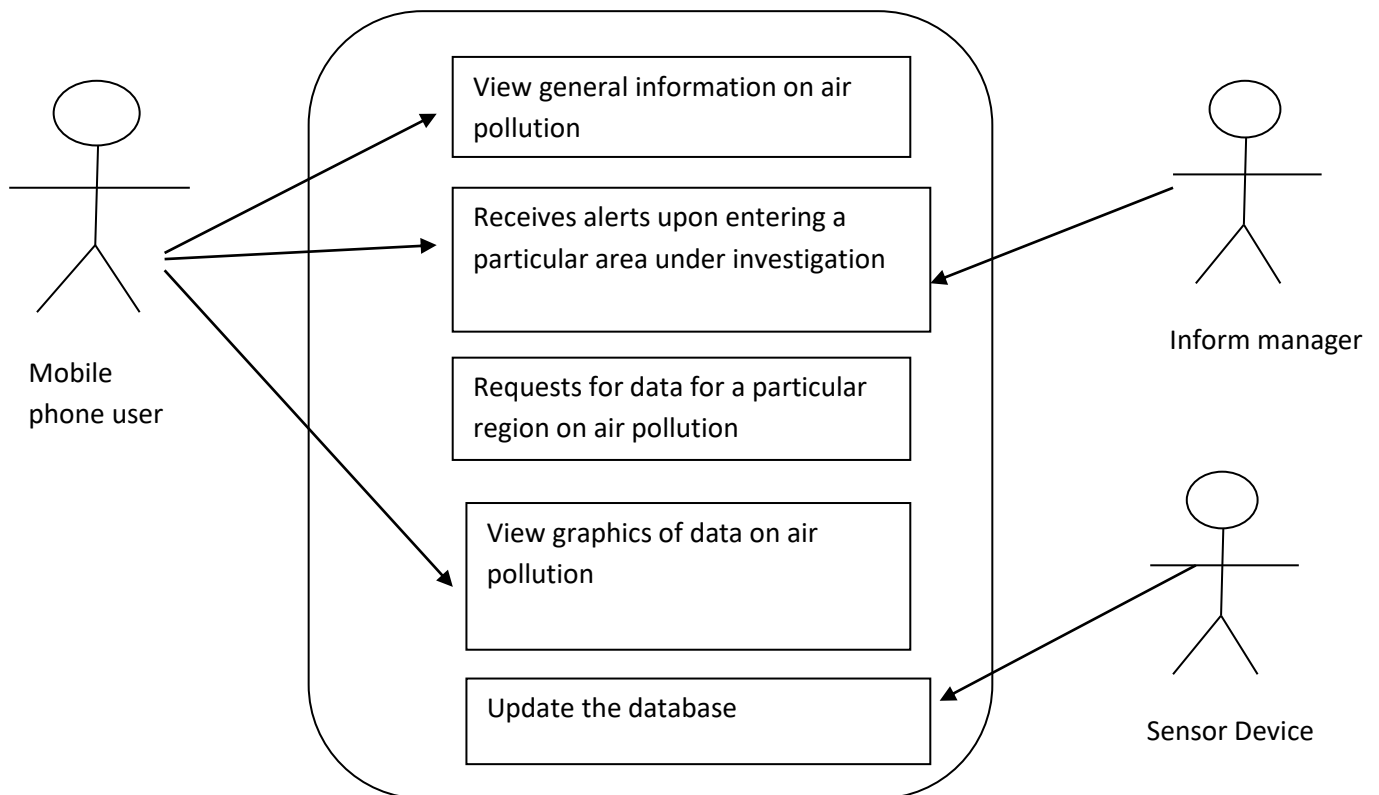


Figure 4:UML Case diagram for Mobile based visual analytic tool of air quality assesment

### 4.3.3 Activity Sequence Diagram of the system

Sequence diagrams are used to display the interaction between users, screens, objects and entities within the system. It provides a sequential map of message passing between objects over time.

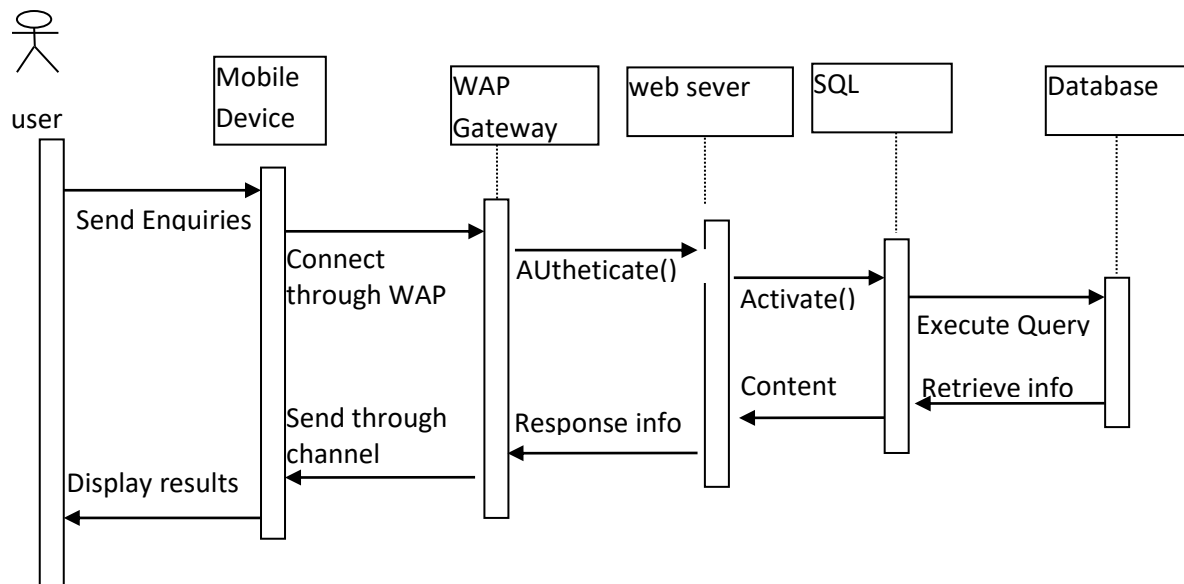


Figure 5: UML Activity sequence diagram for Mobile based visual analytic tool of air quality assesment

### 4.3.4 Activity diagrams of the system

Activity diagrams are used to show how different workflows in the system are constructed, how they start and the possibly many decision paths that can be taken from start to finish. They may also illustrate the where parallel processing that will be present in the system involving execution of some activities.

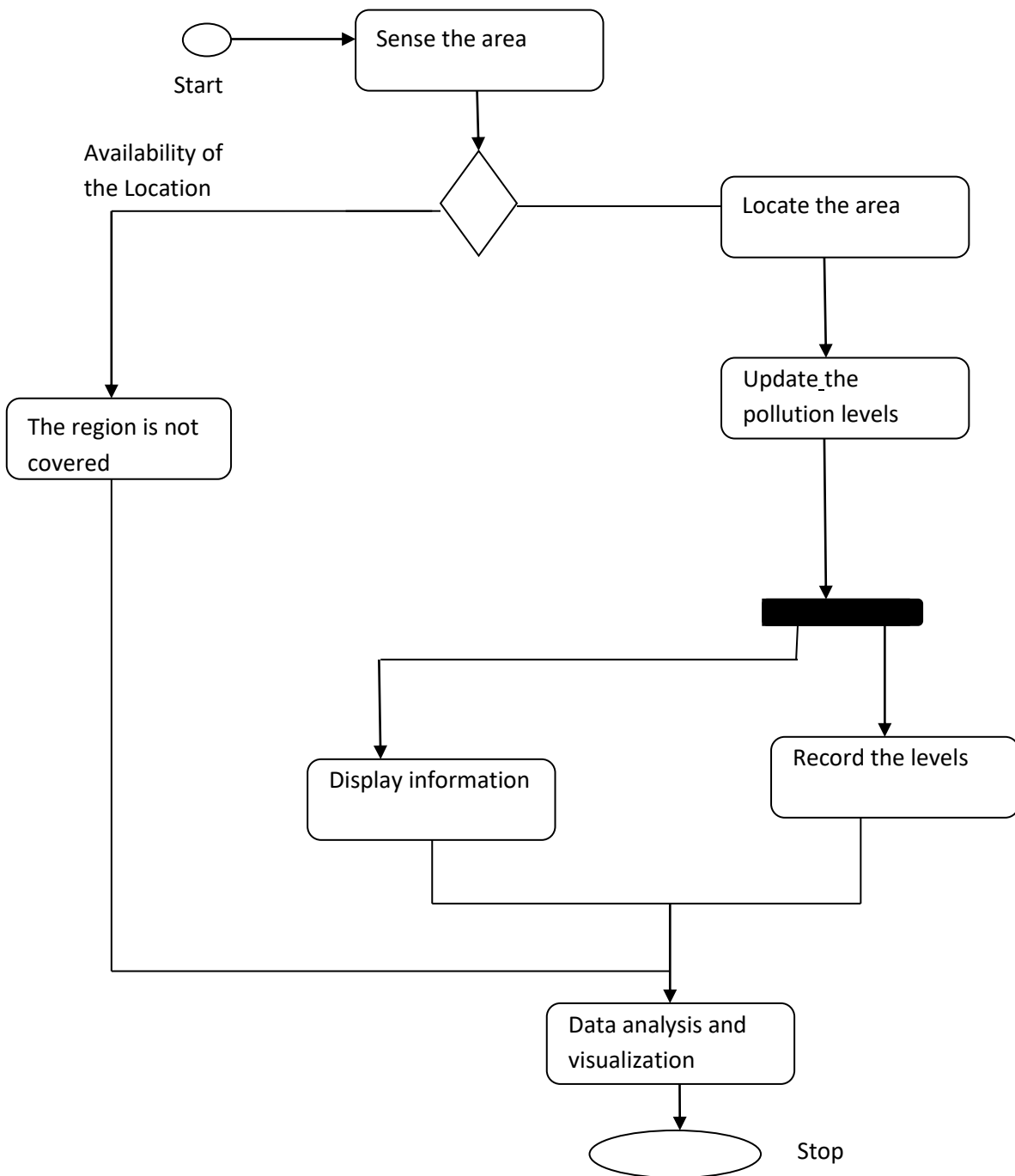


Figure 6: UML Activity Diagram for Mobile based tool for Air pollution assessment

## **4.4 System Development**

The system was developed using prototyping approach. . In evolutionary prototyping the system concept is developed as you move through the project. You begin by developing the most visible aspects of the system. You demonstrate that part of the system to the customer, and then continue to develop the prototype based on the feedback you receive. At some point, you and the customer agree that the prototype is “good enough,” and you release the prototype as the final product. It is probably best suited because developers can have frequent, informal interactions with end-users. The user interaction for these kinds of projects will generally need to be more structured and formal.

### **4.4.1 Description of the Datasets**

#### **Pollution Level**

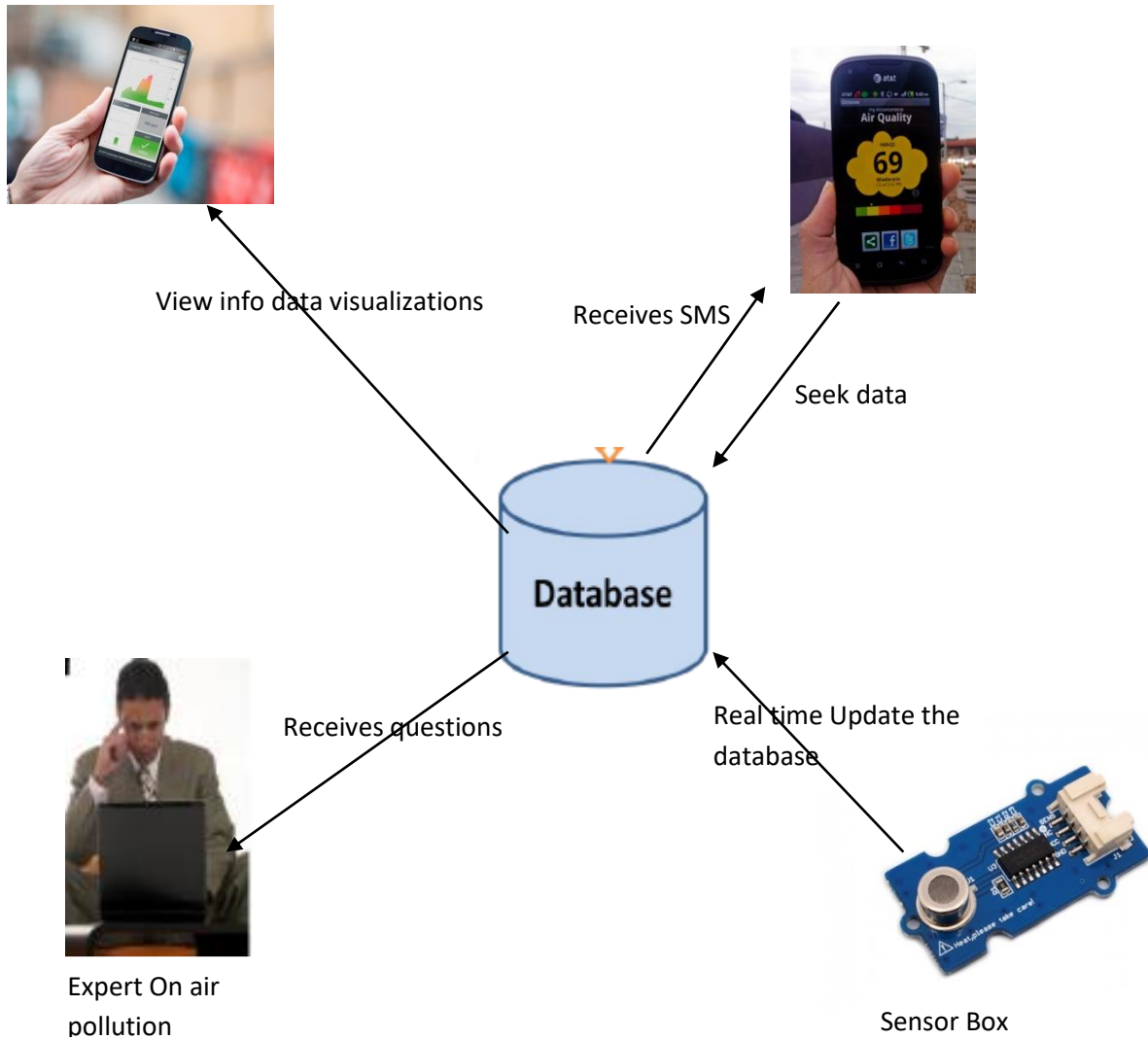
Data on pollution levels was collected using the sensor and recorded in the system to be used as reference data. This was done in various spots in the city.

#### **Pollution Scale**

The system is built on the following scale of air quality index developed by U.S. Environmental Protection Agency (EPA) . This is the U.S. government Office of Air Quality Planning and Standards Outreach and Information Division ((U.S. Environmental Protection Agency, 2014) see appendix I

### 4.5 Conceptual design

The conceptual design for the proposed application model is as shown below;



## 4.6 Database design

### 4.6.1 Table design

The system will consist of the following tables

#### Trail table

This table is used to store pollution levels for the uses of the tool. The system will continuously store the data after every 10 minutes. This is the data that will be used to trail and display information for each user

Field name	Data type	Comment
Idno	Numeric	Auto number
Longitude	Numeric	Of location
Latitude	Numeric	Of location
Phone number	Numeric	Users phone number
Location	Text	Location visited
Time	Date/time	Time taken in allocation
Level	Numeric	Level of pollution

Table 1 The Trail table that records users movements

#### Users table

Used to store users details

Field name	Data type	comment
Idno	Numeric	Auto number
Names	Text	Users names
Email Address	Text	Users email address
Password	Alphanumeric	For logging in the system
Level	Text	User level
Registration date	Date	Date of registration

Table 2 Table of stored users of the system

## Level table

This is the table that is used to store pollution level for different locations in the study area

Field name	Data type	Comment
Idno	Numeric	Auto number
Longitude	Numeric	Of location
Latitude	Numeric	Of location
Location	Text	Location name
Level	Numeric	Amount of pollution in the area

Table 3 A Table for storing levels of different locations.

## Messages table

Will be used to store messages send to the users of the system as advice

FIELD NAME	DATA TYPE	COMMENT
Idno	Numeric	Auto number
Phone	Numeric	Phone number
Level	Numeric	Level of pollution
Message	Text	Message send to users in sms

Table 4 The table used to store all messages send to users.

### 4.6.2 ENTITY RELATIONSHIP DIAGRAM

Entity relationship diagram is among high-level data modeling technique that assist designers to create a more accurate and useful conceptual models. An entity relationship diagram shows the relationships of entity sets stored in a database. An entity in this context is a component of data. In other words, ER diagrams illustrate the logical structure of databases. An ERD is also provides a visual, graphical model of the information content of a system. It represents the data at a high level of abstraction. The ERD for this system is as illustrated in the figure below

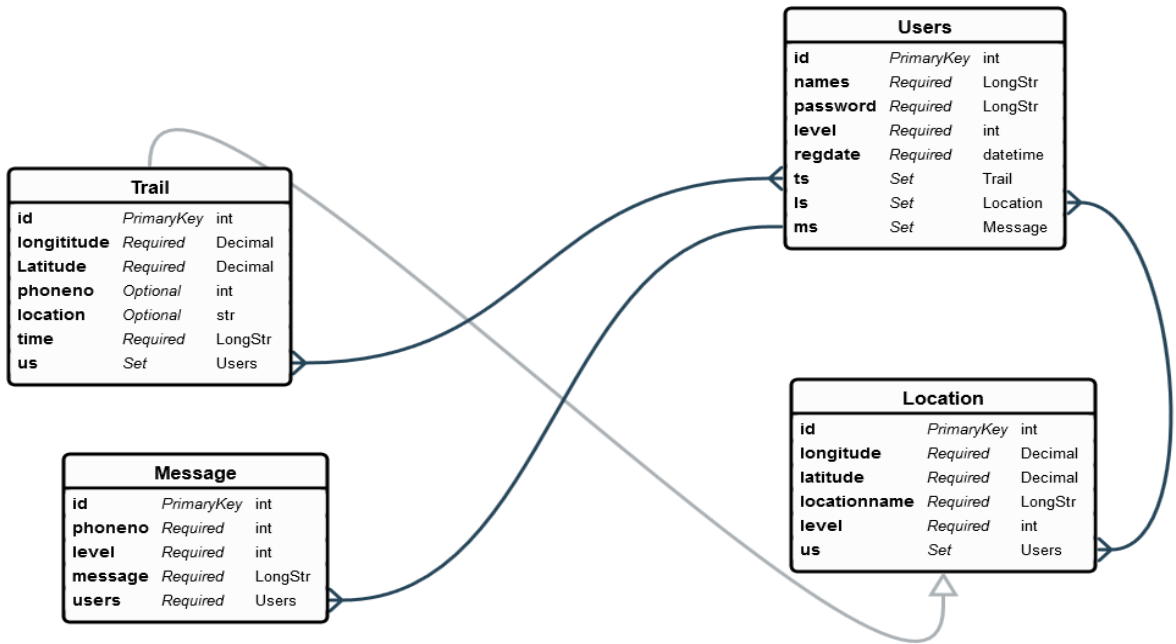


Figure 7 ERD for the proposed system

### 4.6.3 Graphical User Interface Design

## USER REGISTRATION FORM

Full Names

Phone number

Password

#### **4.7 Description of Major Modules of the proposed system**

The main modules of the system and the system interface is explained below

**i). User Accessibility Module**

This is the module that used to manage user accounts. After downloading the tool one is required to register by providing mobile phone numbers and their names. Already registered users can automatically access system after verification done by the module.

**ii). Reading sensor module**

This module is used to read data from the sensor and transmit it to the server through gateway. These values are recorded in a table to be used by other modules

**iii). Pollution Levels Module**

This module is used to display pollution levels both in a table and on a map. One can also search for a region and be able to view the levels recorded over a period of time either in the table or line graph. Tthe map display amount of air pollution on a pop up message with a warning depending on the region.

**iv). Alert module**

The alert module is used to e display to the user the current location pollution level accompanied with a health message according the used scale.

**v). My records module**

This module provides statistical and graphical analysis of users exposure to various level of pollution over a period of time. This is an average pollution categorized base on air quality index. This will assist members to know how they are doing in terms of exposure.

**vi). My Trail module**

This module is used to display table, graph and map showing daily exposure of the active user over a period of time.

**vii). My statistics Module**

This module is used to display statistical data of an individual periodically .i.e daily, monthly or yearly. The module show amount of time in minutes spends in a given area and the level of exposure.

**viii). Admin module**

This module is used to view all users of the system. It's able to display how many records are recorded for a particular user and calculate average exposure.

## **4.8 Techniques Used In Testing**

### **4.8.1 System testing**

This is carried out to ensure all system programs written in isolation work properly when integrated into the main system. The program codes are tested to ensure they work as expected. It involves checking that incorrect data is prevented from being entered by the user in the forms. If the user enters a wrong user name or password an error is generated. Otherwise if login is succeeded the user gains access to the database. This deals with the security issue.

### **4.8.2 Usability testing**

This is making sure that the system is user friendly. This involves checking whether the users can use the system with ease and without confusion and whether they find the system attractive and appealing for use. It involves installing the systems in a number of user's devices so that they can use it for some time. The user testing was done by installing the

system in seven members of public working in Nairobi who used the application every day. Mobile application usability testing solution, allows the researcher to get real people to test the mobile app, so you can measure, manage and improve the application performance during the phases of deployment.

Because achieving a high level of user satisfaction is critical to the success of mobile applications, usability testing is a mandatory process to ensure that a mobile application is practical, effective, and easy to use, especially from a user's perspective.

#### **4.8.3 Incremental testing**

Incremental testing is where codes of a software system are tested as they are being written. Incremental testing was used in the development of the software of the evolutionary prototyping methodology used. Any time there was new prototype developed with additional features, application it was tested. This form of testing was used because it generates working software quickly and early during the software life cycle. This model is more flexible, easier to test and debug during a smaller iteration and easier to manage risk because risky pieces are identified and handled during it'd iteration.

#### **4.8.4 Testing Results**

*See appendix IV*

#### **4.9 System installation and deployment strategy**

A deployment strategy is a plan for ensuring that you get your mobile apps out to all of the relevant client devices. A deployment strategy ensures that all clients can start using the app immediately, which means you don't have to waste time (and billable hours) chasing down client who haven't downloaded the app. There exist several ways of deployment of mobile applications however the researcher intends to use the following

**(a) Manual Deployment:**

Manual deployment is a great strategy for few individuals or small-scale organizations that need to get apps out to users in short order. Manual deployment relies on an IT expert physically acquiring all of the devices and installing the app manually. Sometimes this means downloading the app from the app store on each device, or sometimes the admin can deliver the app from their computer terminal to the mobile device.

The researcher intends to use this strategy to install the applications in few devices for testing purposes. This is mainly because Manual deployment takes a much shorter deployment period since there are only a few devices that need the app for testing purposes. Manual deployment is also very easy to do, as it doesn't require any additional software or hardware – all you need is a computer terminal, your team's mobile devices, and the app itself.

**(b) Use of standard app store**

An app store (application store) is an online portal through which software programs are made available for procurement and download. The researcher intends to make available in the app store so that users can easily download and install in their devices. With this option, you can remove the Apple App Store or Google Play Store from the device and replace it with a corporate app store if the body concerned has policies regarding the application store.

A corporate app store makes it easy to distribute paid applications, for instance, using the Apple Volume Purchase Program, and it's also a great way to ensure that all of the apps your team uses are secure and have IT support. However, using a corporate app store means that you'll have to rely on members of public to install their own apps. This means you have no guarantee that every member of public has the latest version of critical apps, and it may

create problems for users who aren't tech savvy. This can be minimized with campaigns to popularize the app.

## CHAPTER FIVE

### 5.0 CONCLUSION AND RECOMMENDATIONS

#### 5.1 Summary

The study found out that air pollution provides challenges of human health in cities developing countries. This is mainly due to lack information on level of pollution and their effects on health of the residents. Most of the available systems and tools do not provide personalized data about an individual rather provide general information about air pollution. This research therefore concentrated on developing a tool that can provide data to individual members of public. The study was largely successful because it resulted into development of the tool to address this limitation. The presented visual analytic tool for Assessment of Urban Air Quality integrates mobile application, location data from the dust sensor and air quality information in order to give registered users a complete visual analytic view of their daily exposure to dust. This tool will enable users to continuously check their exposure to dust pollutants using smart mobile phones at any given instant.

#### 5.2 Conclusions

Although mobile phones are widely across the world today; their application is limited to traditional communication. This study reveals that they are underused tools that have the ability to offer a wide range of benefits through remarkable continuous monitoring and recording of users trail throughout the day thus, becoming a means to provide their users with individual data on air pollution for a healthier lifestyle based on air quality. Mobile application in monitoring air pollution is an emerging area that has the potential to change the way the information is disseminated to members of the public. Use of mobile technology in information distribution may improve the quality of life of members of public by, ensuring that they are more aware of the dangers of different levels of pollutants. Use of

The study has been largely successful as it can be illustrated clearly by examining its objectives as presented below together with brief explanation of their achievements.

*Objective 1: To investigate how a mobile phone based visual analytic tool may be used to assess air quality to create awareness to members of public.*

From the study, it was concluded that Mobile phones can be used potentially to offer a wide range of benefits through unobtrusive continuous monitoring, becoming a means to provide their users with personalized advices for a healthier lifestyle based on air quality. Members of public can easily get update information that is analyzed for quick and better understanding of air quality in the surrounding environment. This will assist them make informed choices and petition the government on the same.

*Objective 2: To design and develop mobile based a visual analytic tool for assessment of air quality in cities in developing countries.*

The study has come up with a visual analytic tool for assessment of air pollution to achieve the both functional and non functional requirements of the system identified in 4.2.2 and 4.2.3 respectively. The system development is explained in details 4.4. Users of the system can easily download it from Google play store and install as illustrated in details in 4.9. The major components or modules of the system if the tool is explained in 4.7

*Objective 3: Test the mobile based visual analytic tool for assessment of air quality.*

Testing was done using various testing techniques as explained in 4.8 with the aim of ensuring that it is achieving the main goal of the study. Test results are clearly shown in appendix iv during model description.

After achieving all specific objectives the aim of the study was achieved through the development of a visual analytic tool for assessment of air quality in urban areas. The tool if adopted can be used effectively to continuously monitor air quality in a given area. The tool can also collect data about air quality in all places visited by an individual over a period of time. Analyzed data collected over a long period of time can be presented using various formats and techniques for better understanding. The tool is also able to provide real time

data about air quality in all areas that are covered. The tool is also highly interactive because it utilizes features of smart mobile phones to view data and accompanied analytics. The tool uses the AQI to provide the results using the associated colours and it also provided the level of health concern for a particular area. The tool is very flexible, very easy and yet very powerful due to its ability to provide highly summarised results as well as fine-grain results at the level of sensors.

### **5.3 Recommendation**

It is recommended that there be continuous and accurate observation of air pollution activities in Kenya using better equipments placed permanently on site. This can be done by integrating air quality measurement as a routine just like the daily weather reporting system. This should be directly linked to systems which continuously update such applications. There is need for the government agencies dealing with pollution to develop or adopt a scale of measuring the pollution levels in Kenya. There is need to create intensive awareness for many members of public to make use of the tool in order to benefit. The researcher believes the tool is well suited to power small- to medium-sized campaigns more research is necessary to come up with strategies to truly foster cooperation between participants, local authorities and experts and to enable the transformation of collected data into to policy-relevant, actionable knowledge. Only then will it be possible to fully integrate participatory sensing assessments into environmental policies.

### **5.4 Further Work**

The tool can be improved to include other modules that can used to provide projections using data mining and machine learning tools and techniques. The projections will enable the government and other interested parties to come up with policies that can improve public awareness. Further enhancements can also be done on security of the tool to guard against possible vulnerabilities and attacks.

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## Appendix I

Pollution scale used

<b>Air Quality Index Levels of Health Concern</b>	<b>Numerical Value</b>	<b>Meaning</b>
Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Moderate	51 to 100	Air quality is acceptable; however, depending on pollutant; there may be a moderate health concern for a very few numbers of people who are sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	Members who are sensitive may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Members of general public may begin to experience health effects; Those of sensitive groups are most likely experience more serious health effects.
Very Unhealthy	201 to 300	The whole population is more likely to be affected.
Hazardous	301 to 500	Health alert: everyone may experience more serious health effects.

Table 5 Showing Air quality index developed by U.S. EPA

## Appendix II

### System codes- Programming the Dust Sensor

```
// Include the GSM library

#include <GSM.h>

#define PINNUMBER ""

// initialize the library instance

GSM gsmAccess;

GSM_SMS sms;

const int gasPin = A0; //GAS sensor output pin to Arduino analog A0 pin

void setup() {

  Serial.begin(9600); //Initialize serial port - 9600 bps

  // initialize serial communications and wait for port to open:

  Serial.begin(9600);

  while (!Serial) {

    ; // wait for serial port to connect. Needed for native USB port only

  }

  Serial.println("SMS Messages Sender");

  // connection state

  boolean notConnected = true;

  // Start GSM shield

  // If your SIM has PIN, pass it as a parameter of begin() in quotes

  while (notConnected) {

    if (gsmAccess.begin(PINNUMBER) == GSM_READY) {

      notConnected = false;

    } else {

      Serial.println("Not connected");

    }

  }

}
```

```

    delay(30000);
}
}
Serial.println("GSM initialized");
}
char remoteNum[20]; // telephone number to send sms
void assign(char* arr)
{
    strcpy(arr, "254734427172");
}
String gasLevel="Air Quality "+String(analogRead(gasPin));
void loop() {
    assign(remoteNum);
    Serial.println("SENDING");
    Serial.println();
    Serial.println("Message:");
    Serial.println(gasLevel);
    sms.beginSMS(remoteNum);
    sms.print(analogRead(gasPin));
    sms.endSMS();
    Serial.println("\nCOMPLETE!\n");
}
/*
    Read input serial
*/
int readSerial(char result[]) {

```

```
int i = 0;
while (1) {
    while (Serial.available() > 0) {
        char inChar = Serial.read();
        if (inChar == '\n') {
            result[i] = '\0';
            Serial.flush();
            return 0;
        }
        if (inChar != '\r') {
            result[i] = inChar;
            i++;
        }
    }
}
}
```

## Appendix III

### a) System codes- Mobile Application Code For current location

```
package com.achi.airquality;

import android.content.Context;
import android.location.Address;
import android.location.Geocoder;
import android.os.Bundle;
import android.os.Handler;
import android.os.Message;
import android.util.Log;
import java.io.IOException;
import java.util.List;
import java.util.Locale;
/**
 * Created by AchiSystems on 6/17/2016.
 */
public class LocationAddress {
    private static final String TAG = "LocationAddress";

    public static void getAddressFromLocation(final double latitude, final double
longitude,
                                           final Context context, final Handler
handler) {
        Thread thread = new Thread() {
            @Override
            public void run() {
                Geocoder geocoder = new Geocoder(context, Locale.getDefault());
                String result = null;
                try {
                    List<Address> addressList = geocoder.getFromLocation(
                        latitude, longitude, 1);
                    if (addressList != null && addressList.size() > 0) {
```

```

        Address address = addressList.get(0);
        StringBuilder sb = new StringBuilder();
        for (int i = 0; i < address.getMaxAddressLineIndex(); i++)
    {
            sb.append(address.getAddressLine(i)).append("\n");
        }
        sb.append(address.getLocality()).append("\n");
        sb.append(address.getPostalCode()).append("\n");
        sb.append(address.getCountryName());
        result = sb.toString();
    }
} catch (IOException e) {
    Log.e(TAG, "Unable connect to Geocoder", e);
} finally {
    Message message = Message.obtain();
    message.setTarget(handler);
    if (result != null) {
        message.what = 1;
        Bundle bundle = new Bundle();
        result = "Latitude: " + latitude + " Longitude: " +
longitude +
            "\n\nAddress:\n" + result;
        bundle.putString("address", result);
        message.setData(bundle);
    } else {
        message.what = 1;
        Bundle bundle = new Bundle();
        result = "Latitude: " + latitude + " Longitude: " +
longitude +
            "\n Unable to get address for this lat-long.";
        bundle.putString("address", result);
        message.setData(bundle);
    }
    message.sendToTarget();
}

```

```

        }
    }
};
thread.start();
}
}

```

## **b) PHP code for Retrieving pollution level for the current location**

```

<?php
session_start();

require_once("config.php");

//Details//

$longitude=$_POST['longitude'];

$latitude=$_POST['latitude'];

$phone=$_SESSION['phone'];

$imei=$_SESSION['email'];

$msgdate=date('d-m-Y');

$timeadded=date('d-m-Y H:m:s');

//get address name from Longitude and latitude

function getaddress($lat,$longi)

{

$url =

'http://maps.googleapis.com/maps/api/geocode/json?latlng='.trim($lat).',' .trim($longi).'&sensor=fal

se';

$json = @file_get_contents($url);

$data=json_decode($json);

$status = $data->status;

if($status=="OK")

```

```

return $data->results[0]->formatted_address;

else

return false;
}

$address= getaddress($latitude,$longitude);

if($address)
{
//Address found
}

else
{
//Address not found
}

//Insert//
if($longitude!=""){
mysql_query("INSERT INTO android (id,longitude,latitude,phone,imei,address,timeadded)
VALUES ('','$longitude','$latitude','$phone','$imei','$address','$timeadded')");
}

//-----

//Search the levels database for the level of this location

$lo=substr($longitude, 0, 4);

$la=substr($latitude, 0, 4);

$result = mysql_query("SELECT * FROM levels WHERE longitude LIKE '%$lo%' AND latitude LIKE
'%$la%'");

```

```

while($row = mysql_fetch_array($result))
{
    $location=$row['location'];
    $levelvalue=$row['level'];
    if(($levelvalue>0)&&($levelvalue<51))
    {$lev="GOOD";}
    if(($levelvalue>50)&&($levelvalue<101))
    {$lev="MODERATE";}
    if(($levelvalue>100)&&($levelvalue<151))
    {$lev="UNHEALTHY FOR SENSITIVE GROUPS";}
    if(($levelvalue>150)&&($levelvalue<201))
    {$lev='UNHEALTHY*';}
    if(($levelvalue>201)&&($levelvalue<301))
    {$lev='VERY UNHEALTHY';}
    if(($levelvalue>300)&&($levelvalue<501))
    {$lev="HAZARDOUS";}

    $result2 = mysql_query("SELECT * FROM recommendations WHERE lowerbound>='$lev' AND
upperbound<='$lev'");
    while($row2 = mysql_fetch_array($result2))
    {
        $recommendation=$row2['recommendation'];
    }
    $level="You are at ".$row['location']." RECOMMENDATION : ".$recommendation.".";
}

//check if message sent

$counter=0;

```

```

$resultm = mysql_query("SELECT * FROM tblAlerts WHERE messagedate='$msgdate' AND
user='$imei'");

while($rowm = mysql_fetch_array($resultm))

{

    $counter=$counter+1;

}

//-----

include "smsGateway.php";

$smsGateway = new SmsGateway('asirigwaantony@gmail.com', 'ndagenda');

$deviceId = 30650;

//get user number

$resultm = mysql_query("SELECT * FROM users WHERE email='$phone'");

while($rowm = mysql_fetch_array($resultm))

{

    $num=$rowm['phone'];

    $num = "254".substr($rowm['phone'], -9);

}

$number = $num;

$message = "Air Quality Analysis Tool : ".$level;

if($counter==0)

{

    $result = $smsGateway->sendMessageToNumber($number, $message, $deviceId);

    //insert message in database

    mysql_query("INSERT INTO tblAlerts(id,message,messagedate,user) VALUES(", '$level',
'$msgdate', '$imei')");

}

```

```
echo json_encode($lev." (".$location." : ".$levelvalue."");
```

```
mysql_close($myconn);
```

```
?>
```

## Appendix IV

### Test Results

- a) This results show tracking of an individual user

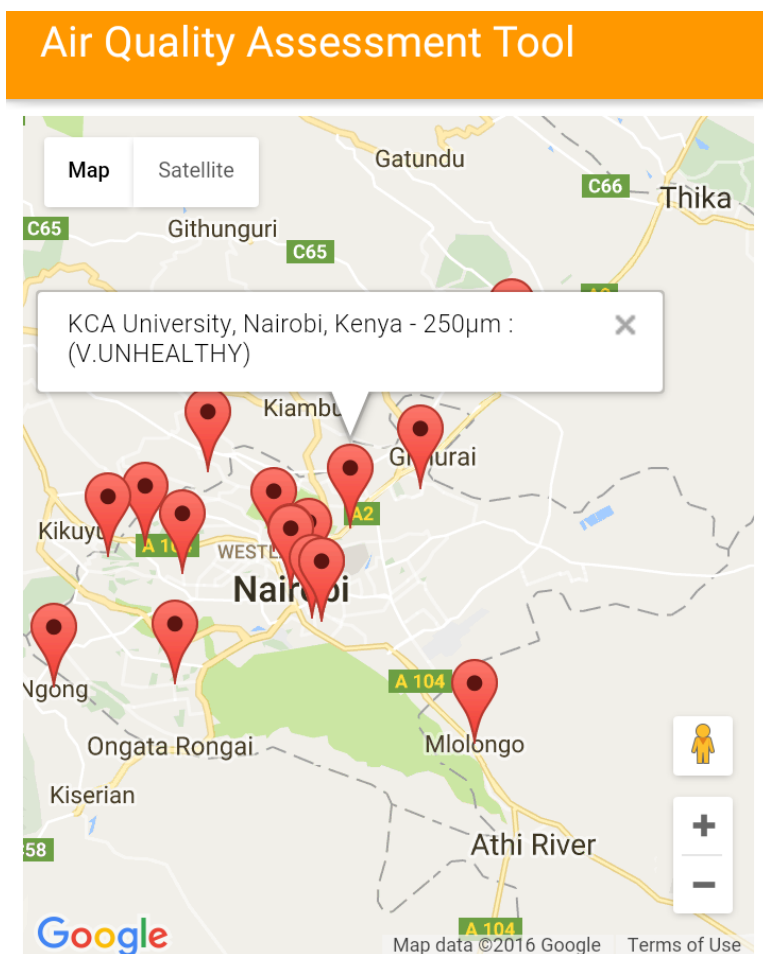
Air Quality Assessment Tool			
Location	Level	Time In	Duration (Min)
	101()		0
Unnamed Road, Kenya	101()	02-06-2016 14:06:25	1
ILRI Rd., Nairobi, Kenya	60( <i>Moderate</i> )	02-08-2016 13:08:28	17
The Sarova Stanley, Standard St, Nairobi, Kenya	101( <i>Moderate</i> )	05-05-2016 05:05:06	2
Kenwood House, Nairobi, Kenya	101( <i>Moderate</i> )	05-05-2016 05:05:13	1
Diamond Building, Nairobi, Kenya	101( <i>Moderate</i> )	05-05-2016 05:05:21	15
Nation Centre, Nairobi, Kenya	101( <i>Moderate</i> )	05-05-2016 05:05:28	1
Gaberone Ln, Nairobi, Kenya	101( <i>Moderate</i> )	05-05-2016 05:05:34	0
ICEA Building, Nairobi, Kenya	101( <i>Moderate</i> )	05-05-2016 05:05:34	1
Kibetco House, Nairobi, Kenya	101( <i>Moderate</i> )	05-05-2016 05:05:37	82
		05-05-2016 05:05:56	512
Mugi Road, Nairobi, Kenya	60( <i>Moderate</i> )	06-10-2016 02:10:35	74
Gloty Flats, Nairobi, Kenya	60( <i>Moderate</i> )	08-04-2016 10:04:03	412
Adminstration Block, Thiongo Rd, Nairobi, Kenya	60( <i>Moderate</i> )	08-04-2016 10:04:12	1275
Kirinyaga Rd, Nairobi, Kenya	101( <i>Moderate</i> )	08-10-2016 04:10:15	5
Plainsview Ln, Nairobi, Kenya	101( <i>Moderate</i> )	11-10-2016 23:10:08	3
View Park Towers, Utalii St, Nairobi, Kenya	101( <i>Moderate</i> )	12-10-2016 06:10:58	0
Fox Drive-In Cinema, Nairobi, Kenya	101( <i>Moderate</i> )	12-10-2016 09:10:01	2
Kamiti Rd, Githurai, Kenya	101( <i>Moderate</i> )	13-04-2016 08:04:03	5
Kawangware	60( <i>Moderate</i> )	13-04-2016 08:04:07	1
Kapenguria Rd, Nairobi, Kenya	60( <i>Moderate</i> )	13-04-2016 08:04:33	22

Naivasha Rd, Nairobi, Kenya	60(Moderate)	14-04-2016 14:04:36	16
Fresco Flats, Waiyaki Way, Nairobi, Kenya	60(Moderate)	15-06-2016 10:06:16	1
Dunga Rd, Nairobi, Kenya	101(Moderate)	15-07-2016 02:07:13	0
Muratha Rd, Nairobi, Kenya	60(Moderate)	16-04-2016 15:04:54	1
Loresho Ridge, Nairobi, Kenya	60(Moderate)	16-06-2016 03:06:03	8
Kendong Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:01	1
Security Office, Mariakani Gardens, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:04	2
Specialized Power Systems, Shimo la Tewa Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:05	1
E.M Kiosk, Chepkorio Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:08	1
Classes, Commercial St, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:09	2
Landhies Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:22	1
Classrooms, Race Course Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:23	7
Mariakani School Admin Block, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:34	1
Nand Plaza, Hola Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:38	1
Workshop Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:39	1
City Clock, Bondo St, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:51	2
MSK Office, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:51	1
Josh House, Ukwala Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 06:06:53	4
City Square Flyover, Nairobi, Kenya	101(Moderate)	17-06-2016 07:06:07	0
Chambers Rd, Nairobi, Kenya	101(Moderate)	17-06-2016 07:06:10	1

## b) Results of an alert while at Kabete Technical

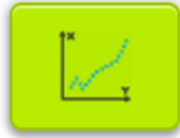


## c) Results showing pollution levels per location



d) Results showing average exposure of an individual

## Air Quality Assessment Tool



EXPOSURE in Minutes	TIME
Good	97
Moderate	875.7
Unhealthy for Sensitive Groups	194.3
Unhealthy	194.8
Very Unhealthy	377
Hazardous	0

