DESIGN AND DEVELOPMENT OF A SYSTEM FOR DATA CAPTURE IN A MONITORING AND EVALUATION ENVIRONMENT

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Abstract

Monitoring and evaluation (M&E) is an extremely complex, multidisciplinary and skill intensive endeavor. Government-wide M&E is even more so because it requires detailed knowledge across and within sectors. New technologies are changing the nature of monitoring and evaluation in the world today. Information and communication technology (ICT) tools such as computers, mobile phones and tablets, together with applications/software systems which allow users to upload data to storage facilities in real-time are being utilized. The use of mobile computing tools and the Internet in this research provides an efficient and effective way of performing Government-wide M&E functions. The system provides functionality for data capture and analyses in an M&E environment. It utilizes the internet to reach out to all stakeholders in the M&E processes. Furthermore it uses the Short Message Service (SMS) for its real-time impact assessment functions. The system was developed using open source development tools and languages. A working prototype version of the system, has been deployed successfully on an experimental basis.

Keywords: SMS/ICT, Monitoring, Evaluation

1 Introduction and Background

One major challenge faced by African governments is to be more effective. Monitoring and Evaluation (M&E) processes or procedures can assist the public sector in evaluating its performance and identifying the factors which contribute to its service delivery outcomes.

M&E is uniquely oriented towards providing its users with the ability to draw causal connections between the choice of policy priorities, the resourcing of those policy objectives, the programs designed to implement them, the projects or services actually delivered and their ultimate impact on communities. In this context, a government-wide M&E policy helps to provide an evidential basis for public resource allocation decisions and helps identify how challenges should be addressed and successes replicated.

In most cases, African governments are at varying points of establishing government-wide M&E systems. Countries such as Ghana, South Africa, Uganda and Kenya are using M&E to assess its progress against national development plans.

1.1 The Problem

In Ghana, the Policy Unit at the Presidency has the mandate to effectively manage government policies, programs and projects towards the achievement of the government’s vision. One way of carrying out this mandate is through the monitoring and evaluation of all government policies, programs and projects. It has the mandate to monitor and evaluate the performance of 23 ministries, 10 regional coordinating councils, 275 metropolitan, municipal and district assemblies and over 290 departments and agencies. This means that on a daily basis, the policy unit at the presidency needs to monitor over 598 government agencies which are dispersed throughout the country.

However currently, feedback from the various government agencies are sent to the policy unit on a monthly basis, the feedback is paper-based making them prone to error, difficult to conduct on a large scale and high in transaction cost. Furthermore, there is no correspondence with the direct beneficiaries of these policies, programs and projects in order to access the impact of those activities. There are also delays in responses from the various respondents, due to transportation issues. Sometimes posted responses fail to arrive on time or they never even arrive at all. All the issues discussed above represent challenges faced by the policy unit in the execution of their M&E functions.

This research seeks to leverage the use of ICT to solve M&E challenges as outlined above, and as a case study, to deal with issues faced by the Policy Unit at the Presidency in Ghana. An ICT platform has been designed and implemented for M&E data collection and monitoring by the Policy Unit to track the implementation of government policies, programs, and projects by all government agencies. This
are several challenges in documents to applications. Facilities earning from past It also allows project managers to analyze phone (Short Messaging and storage as well as er information about the status of data on an enterprise information system, such as a these technologies can be important role in significantly mitigating climate change and Information and Communication Technologies play an important tool to aid in monitoring, and sharing of outcomes with the communities.

According to Raftree (2013b), what ICT is doing for M&E is really broadening it out and allowing more people to participate in it. It also allows project managers to analyze data better and to make decisions more quickly. New ICT tools can make monitoring faster and more accurate. Using mobile phones can also help in reaching out to a wider group, and get feedback from the communities. Some of the new ICT-enabled visualizations tools, including maps, graphs and charts, make it easier to analyze collected data with feedback and sharing of outcomes with the communities.

It is evident that ICT is an important innovative tool to aid in an efficient and effective M&E processes. Its implementation can be seen in diverse sectors to provide solution to budding problems. According to Zanamwe and Okunoye (2013), Information and Communication Technologies play an important role in significantly mitigating climate change and these technologies can be used in both developed and developing countries even though developing nations lack the much needed information and communication technology infrastructure when it comes to mitigating climate change.

The UNDP (2013) report on innovations in monitoring and evaluating results provide many good examples of ICT technologies that are providing innovative ways of performing monitoring and evaluation in various fields of endeavors. Despite all this, it is important to note that ICT for M&E is still emerging and there are several challenges in the out-years.

2.3 ICT as a tool for data collection

Data collection has always been an integral part of monitoring and evaluation (M&E). Collecting data on policies, programmes and projects by government, helps the government to efficiently monitor and evaluate the impact of these activities on its populace. One way to facilitate as well as reduce the cost of data collection, is the use of ICT tools.

Examples of ICT-based technologies which aid in data collection include: Mobile phones (Short Messaging Service), Personal Digital Assistants (PDA’s), Web Technologies, Audio Computer-assisted Self-Interviewing, Mapping & Geographic Information Systems, Photo/Video Monitoring, and Social Media Channels. For the purpose of this research, two of these ICT tools (i.e. Web and SMS) are discussed in the following.

2.3.1 Web as a tool for data collection

Although the World-Wide Web was initially conceived as a vehicle for delivering and viewing documents, its focus has gradually shifted from documents to applications. Facilities such as Javascript, the Document Object Model (DOM), and Ajax have made it possible to offer sophisticated interactive applications over the Web.

Web-based applications run on a web application server and access data on an enterprise information system, such as a MYSQL database server. The components of web-based applications are spread across multiple tiers, or layers. In general, the user interface is on the first or top tier, the application programs are on the middle tier, and the data sources that are available to the application programs are on the enterprise information system tier. Developing web-based applications across a multi-tiered architecture is referred to as server-side programming. Writing server-side programs is complicated and requires a detailed understanding of web server interfaces. Fortunately, application servers, such as Apache Geronimo Server, are available to simplify this task. Each of these application servers defines a development environment for web applications and provides a runtime environment in which the web applications can execute. The application server code, which provides the runtime
environment, supports the appropriate interface for interacting with the web server.

A survey of all the web applications that are available today, shows many variations. For example, the database servers can run on various platforms, as can the clients. Designers of web applications use various tools, which affect how the applications work and how they look.

In many cases, the client and server for a web application are on different operating systems. The client, for example, can be on a workstation-based operating system, such as Windows XP or Linux Ubuntu. The server for the application can also be on a workstation-based server, or it can be on an enterprise server, such as windows server. The browser uses Hypertext Transfer Protocol (HTTP) to forward user requests to a second-tier server machine. (HTTP is a communication protocol that the web uses.) The web server on the second tier invokes the local database server to satisfy the data requirements of the application.

### 2.3.2 Mobile phone as a tool for data collection

In the past decade, mobile phones have become an ubiquitous feature of life in developing countries. According to (World Bank, 2013), between 2005 and 2011 mobile cellular subscriptions nearly tripled in the developing world, increasing from 1.2 to 4.5 billion. In Africa, the region with the fastest mobile subscription growth rate, mobile cellular subscriptions increased from 87 million in 2005 to 433 million in 2011. The rapid growth of mobile phones can be attributed to enhanced features and user interfaces, increasing penetration of faster wireless broadband networks, increased screen size, and more attractive pricing. Mobile phones leverage the latest cellular technology and wireless Internet capabilities, providing a wide range of features such as texting messages, connecting to the Internet, use of third-party applications, e-commerce, and GPS.

One other very important feature of mobile phones which is aiding data collection is the Short Messaging Service (SMS). This basic service allows the exchange of short text messages between phones and also between phones and other applications like a web application.

Although the popularity of text messaging is well established in many countries, in Ghana, interest in the thumb-driven phenomenon has only recently skyrocketed. Though text messaging is currently limited to 160 characters, it is not dependent on making direct two-way contact with the respondent as in the case of the smartphone GPS. Thus, it can serve as a powerful survey tool for short, frequent data collection or for inviting respondents to complete surveys at their convenience (Callegaro, 2002).

**FIGURE 1: SMS SYSTEM ARCHITECTURE.**

The SMS system architecture depicted in Figure 1 shows that content providers go through a message aggregator rather than communicating directly with the various Short Message Service Centers (SMSCs). The message aggregator uses the Short Message Peer-to-Peer (SMPP) to maintain connections with carrier networks. An aggregator is a business entity that negotiates agreements with network providers to act as a middleman providing access to a cellular network for messaging services to third parties who have no direct relationship with the cellular network.

The message aggregator uses the SMPP to maintain connections with carrier networks. Aggregators typically provide access to their servers either through SMPP or using customized APIs written in Java, PHP, Perl, and so on. Most aggregators will also manage the rental of the common short code for clients who do not want to deal directly with the telecom company. Another important function of the aggregator is to assist with provisioning of the short code on the various carriers.

### 3 Methodology – System Specification and Design

The challenge in selecting and following methodology is to provide the right processes and guidance to deliver the system. In this research, the “waterfall cycle” method of the traditional system development life cycle was used.

### 3.1 Functional Requirements of Web and Mobile-Based Data Capture System

Requirements are defined in terms of specific behaviors or functions which require a set of inputs for required outputs or outcomes. The functional components in this system includes:

- **The Web Module**: This module handles the storage and processing of uploaded data and facilitates the viewing and analysis of the data on the web using a web browser.
- **The SMS Module**: This module is used to send and receive messages between the web module and the various stakeholders. The module needs a GSM handset to be able to receive and send the SMS messages.
These are the two most important components of the IT-Based M&E system.

3.2 Workflow Diagram

Figure 2 shows the communication flow between the web application and the project beneficiaries using SMS. In this workflow diagram, when the status of a project changes to “completed”, the web application sends an SMS message to beneficiaries of the completed project using the Twilio SMS gateway. The project beneficiaries reply to the message. The replies are stored in the Twilio database. The web application picks up these replies and updates the system database.

3.3 System Design

During the design phase, a system is designed to satisfy the requirements identified in the previous phases. The requirements identified in the requirements analysis phase are transformed into a system design document that accurately describes the design of the system and that can be used as an input to system development in the next phase. Figure 3 shows the system architecture that has been developed for this system.

3.4 Security

Nowadays, security on the web is very essential in order to ensure data is secure and safe from intrusion during transmission and for maintaining the integrity and reliability of the data. Encryption was implemented as the key security feature. The PHP MD5 algorithm was used to encrypt data. This algorithm was mainly used during the storage and retrieval of passwords and also in providing a secure channel for updating the database. Additionally, only the administrator is able to implement changes to the system while it is offline in order for security to be effective.

4 System Development and Piloting

In this section, the various implementation techniques used are identified and discussed. The process of building and testing the various components are also described.

4.1 System Implementation

The completed system is made up of a web application which provides users with the interface to upload project data and view various project status and analysis. The system relies on the Twilio SMS gateway to provide the SMS services required by the web application to successfully communicate with the various beneficiary. There is a backend database system for permanent retrieval and storage of information. There is a real-time communication between the frontend and backend systems.

4.1.1 Development Tools

PHP: Hypertext pre-processor is a server-side scripting language that handles data submitted from the web application and SMS messages from beneficiaries. This was chosen as the server-side scripting language because of its compatibility with the Database Management System (DBMS) and interfaces with HTML to display dynamic objects.
MySQL: The DBMS used because of its low storage needs and its open source nature.

JavaScript: The primary client-side scripting language for the application, it was used for data manipulation on the client-side of the web application.

HTML and CSS: This integrated environment was used for structuring and styling the appearance of the web application.

XML: Representational language for transporting and storing data between the backend and the mapping to the frontend. It was used for transporting data between the web application and the SMS gateway.

Internet Explorer, Mozilla Firefox, and Google Chrome: These are web browsers used to test the web application.

Eclipse Integrated Development Environment (IDE): This IDE provides the tools for PHP developers creating web application. It was used in developing the web application module of the system.

Twilio REST API: This API is provided by Twilio messaging. It provided the platform for sending messages to phone numbers.

Twilio TwiML: This is an XML platform, provided by Twilio(tm). It helps in controlling messages. It is integrated into the system to provide responses to messages. It also helped to control message flow as well as trigger other application logics.

4.1.2 Web Application Login Screen

Figure 4 shows the login screen of the web application. It is the first screen displayed when the application is launched. Users are required to input their username and password to access the system.

There are four levels of users in the pilot system, and each user is assigned to a security clearance level upon creation. These four levels are explained below:

**Administrator** – This user has the clearance to view/edit/delete data from all Municipal and District Assemblies (MDAs) who are registered in the system. They can add users and delete users. An administrator virtually manages the frontend of the web application.

**Desk Officer** – Desk Officers are research officers at the Policy Unit who have the responsibility of overseeing the various categories of MDAs. They have the privilege to view/edit data from all MDAs, but are unable to perform any deletion function.

**Viewer** – The VIEWER is only able to view data from all MDAs. They are unable to either edit/delete records.

**Respondent** – Users in this category are usually stationed at the various MDAs. They are limited to the view of only the MDA they represent. They can add/edit/view records that belongs to their MDA. They are unable to view records from other MDA.
Figure 5 shows the dashboard that is seen by the user after login. It provides easy access to important functionalities such as policy, programme and project details, EIS (Executive Information System), Image Upload etc.

The EIS shows the status of a project in real-time. It depicts the status using a color code as displayed in Figure 6 below.

<table>
<thead>
<tr>
<th>COLOR</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>blue</td>
<td>Completed</td>
</tr>
<tr>
<td>red</td>
<td>Overdue</td>
</tr>
<tr>
<td>green</td>
<td>On-going</td>
</tr>
<tr>
<td>yellow</td>
<td>At Risk</td>
</tr>
</tbody>
</table>

**FIGURE 6: EIS PROJECT STATUS INDICATORS**

4.1.3 Twilio for Sending and Receiving SMS

Twilio SMS enables sending and receiving SMS messages programmatically between the web application and project beneficiaries through a Twilio phone number. The web application triggers an event which sends a request to the Twilio SMS gateway server when the status of a project changes to ‘Completed’. The Twilio server, sends a preconfigured message to the beneficiaries of that particular project. The Twilio server receives an SMS reply from the beneficiaries and stores them in a database table. The web application then picks up the data from the Twilio database and then replicates it on the application/database server.

For this to work, Twilio exposes outbound SMS messaging functionality through its Twilio REST API as shown in Figure 7. When the web application makes a POST request, the Twilio SMS Messages resource sends an SMS message to the phone numbers specified.

**FIGURE 7: SEND AND RECEIVE SMS IMPLEMENTATION**

4.2 Piloting

The pilot was conducted with about 300 participants from the various government ministries, departments and agencies in Ghana (as a case study). The pilot test was considered to be a success by both the project team and the policy unit. It was observed that the set of deployed technologies as well as those that were developed enabled the collection of meaningful and accurate data on the policies, programmes, projects, staff details, travels, loans, grants, and even contracts of the various MDAs at all times.

One of the main goals for this pilot was to find out whether or not the resultant data could be effectively and reliably collected using this web-based application and SMS.
technology. It was concluded that the system proved to be a better option in providing the Policy Unit with an improved way of performing their M&E functions

5 Conclusion and Recommendation

In conclusion, the research explored the use of ICT in a monitoring and evaluation environment. It showed through a pilot implementation that the use of ICT in M&E data collection is realistic. However implementing a web-based tracking system as well as an SMS feedback system even on a pilot scale is not an easy task, a lot more research will be required for a nation-wide implementation.

Due to the fact that the usage of the web has recently gained momentum, many of the technologies standards in this field are still in a state of change. It is therefore advisable to use open standards, or source, solution for robustness and also provide more tested technologies. It is also very important that special consideration is given to the information system design to prevent a “data avalanche” situation. Providing meaningful views to a database containing thousands of data is a challenge to the application designers not only on the performance of the application, especially in real-time mode, but also on the application logic side.

Overall, the outcomes of the project are very encouraging, but more research is required before a nationwide implementation of this kind of data collection system. This research provides a good foundation upon which to base future work.

6 Bibliography


