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# Assessment of Water Rights Database System for Supporting Sustainable Water Resources Management: A Case of Water Resources Commission, Ghana

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**ABSTRACT:** *The use of technology to managing water resource of a nation is important, and the management of such an organization is required to timeously deliver good fresh water to distributors to in turn supply good and treated quality water to the citizenry. Therefore, there is no gain saying the fact that the production of appropriate information/reports that would enable the management to discharge its functions effectively and efficiently, is a sine qua non. Any management of water institution, globally, that deprives the citizenry from getting good and treated quality water for use should not be entertained at all, as 'water is life' and about 70% of the human body is composed of water. There are many internation water bodies, including the UN Water Organization, who are always championing clean and quality treated water for human consumption. Many sicknesses and deaths that occur to humans are from the cause of using untreated water in homes, offices and organizations that use water to prepare its products, for example, food. Governments are making available huge budgets to cater for the use of good and treated quality water for their citizenry, and organizations in charge and mandated to carry out this important task, should not negate on their mandate at all. Management should equally be well trained on water needs of the citizenry to make sure this important commodity is readily available and for use by all.*

**KEYWORDS:** Water body, citizenry, technology, database/software, organization, government and pollution.

## INTRODUCTION

The Government of Ghana in December 1996 enacted the Water Resources Act 522 to establish the *Water Resources Commission (WRC)* to regulate and manage the utilization of water resources in Ghana (WRC, 2024). Subsequently, the then Ministry of Works and Housing (MWH) in 1997 commissioned the Water Resources Management Study (WARM) to find ways to facilitate *WRC's* responsibility of regulating and managing Ghana's water resources on a sustainable basis (WRC, 2024).

The *WRC* was therefore, formed in 1998 and commenced operation in 1999; the organization has adopted integrated, cross-sectoral and catchment-area approach to Water Resources Management (WRM). With this new approach to tackling WRM problems, emerged the

Integrated Water Resources Management (IWRM) plans and strategies, based on the area/environment and prevailing conditions under investigation (WRC, 2024).

Accordingly, representatives of the stakeholders within the water sector constitute the board of the *WRC*; and the organization is using river-basin (any area of land where rainfall collects and drains off into a common outlet, such as a river, stream or other body of water) approach to managing the water resource of the country. The four (4) operating departments within the *WRC* are: Administration/Finance, Policy/Regulation, Engineering/Planning, and Information Management (WRC, 2024).

The *WRC* has installed a Local Area Network (LAN), Intranet and Wireless facilities at the head-office, where computer machines of staff are connected electronically to the internet through a server. There are computer applications designed and mounted on the LAN for monitoring the management of water resources of the nation, including invoicing of registered distributors of the resource. The staff is adequately trained to use the computer facilities for furnishing their tasks and there is information on, for example, the initial pilot-basin conducted, international co-operations and partner-organizations' activities, among others (WRC, 2024).

**Background and Statement of Problem**

The Government of Ghana in the last decade of the 20$^{th}$ century enacted the Water Resources Act 522 to enable the nation to solve its numerous water resource problems (WRC, 2024), including effective marketing of the resource (raw water) to the distributors, example, Ghana Water Company Limited (GWCL) and Irrigation Development Authority (IDA) to serve the citizenry.

The Act 522 that was passed by the Parliament of the Republic of Ghana contained operational instructions which would enable the *WRC* to handle/solve any problems (including contamination of the water bodies), that would hinder the supply of clean raw water to the distributors for use by the citizenry (WRC, 2024). To effectively manage the water resource of the nation, the *WRC* has a LAN with the necessary computer applications/software installed to enable her to efficiently discharge its duties.

As spelt out in the Act 522 of the Republic of Ghana, the *WRC* is to:

i. monitor and evaluate programmes for the operation and maintenance of water resources;

ii. advise the Government on any matter likely to have an adverse effect on the water resources of Ghana; and

iii. advise pollution control agencies in Ghana on matters concerning the management and control of pollution of water resources (WRC, 2024).

However, the country has been saddled with numerous problems confronting the maintenance and management of the water resource. The resource is polluted to the extent that promoting the product to the organization in charge of delivering/distributing treated surface water (product) to the citizenry, GWCL, has become very difficult; the GWCL has therefore come out several times to offer strong warning (to the people and government of Ghana) that it may not be possible to furnish homes with clean water in the nearest future. The warning was

emphasized/confirmed by a director of the *Water Resources Commission* in a discussion with City News Room (CNR) anchor (Welsing, 2022).

This is a sad situation and Ghanaians should be seriously concerned about how to stop the pollution of the water resource. The author is therefore, undertaking this research to explore: the support of the technology system of the *WRC*, comprising computer systems (hardware) and application programmes (software) which have been developed and installed for managing the information/records of the *WRC* (including information on the distributors of the resource to the populace); and to assess the contribution of the technology system to the success of the *WRC* in a sustainable water resources management for the nation.

**Objectives of the Study**

The main purpose of this study is therefore, to assess the effectiveness and efficiency of the computer systems (hardware) and application programmes (software), including the water rights database systems and the invoicing sub-system, amongst others, developed for supporting the management of sustaining the water resources of the nation.
The objectives of the study are therefore, to determine:
i. the capacity of the hardware and software being used by the *WRC*,
ii. the functions of the software (including the strength and weaknesses) to administering the activities of the *WRC* for a sustainable water resource management, and
iii. the adequacy of the software to generating the right information/reports for effective decision-making by management.

**Research Questions**

The research questions that would help collect good data from respondents to achieve the objectives are:
i. What are the capacities of the hardware (RAM & Hard Disk) and Software?
ii. What are the functions of the software (including strength and weaknesses) for administering the activities of the *WRC* for a sustainable water resource management?
iii. Is the information/reports generated for management decision-making adequate*?*

**Significance of the Study**

According to WRC (2024), Ghana is well endowed with water resources, but the amount of water available changes markedly from season to season as well as from year to year. Again, the distribution of water within the nation is not uniform, as the south-western part is better watered than the coastal and northern regions. Nevertheless, availability of water is decreasing owing to rainfall variability (climate change), rapid population growth, increased environmental degradation, pollution of rivers and draining of wetlands (WRC, 2024).
In addition, the attitude of some of the citizenry has rendered most of the resource contaminated; especially the 'galamseyers' ('galamsey' is a local parlance, meaning 'gather them and sell'), mining companies, sand winners near river bodies and fisherfolks who use dangerous chemicals in their expedition. This has affected the availability of the raw resource for distribution by the *WRC* to the distributors of treated water to the citizenry (Welsing, 2022).
Moreover, USGS.gov (2019) announced that approximately 97.5 per cent of water on earth is salty with the greater part in the oceans, and of the 2.5 per cent of freshwater, about 70 per cent is frozen in polar iceberg; less than 1 per cent (about 0.007%) of the world's freshwater is readily accessible for direct human use. No wonder about 3.4 million people, mostly children,

die annually from water-related diseases (Biko & Mwaniki, 2020). Again, the UNWater,org (2023) reported that there has been water crisis leading to 2.2 billion people living without access to safe water.

Furthermore, for Ghana to attain the universal and equitable access to safe and affordable drinking water for all, which is enshrined in the MDG 6, and improving water quality by reducing pollution and minimizing release of hazardous chemicals and materials, are worrisome to the researcher, as these are to be achieved by 2030 (UN, 2018). The nation, certainly, is in an indefensible situation and all Ghanaians should arise and help stop the destruction of the scarce water resource by 'galamseyers', mining companies, sand winners and fisherfolks who use destructive chemicals in their activities.
The above facts have rendered the researcher to look at how technology can be of help to providing the necessary information/reports to management of the *WRC*, especially in the area where the management of the *WRC* could make effective decisions from these reports to support the sustainability of the nation's water resource management.

**Scope of the study**
The research entailed assessing the technology installed at the *WRC*, including computer systems and application programmes developed to provide information/records on the activities of the *WRC*; then the information on distributors of treated water resource to the citizenry would also be assessed and finally the effectiveness of all this information to supporting the sustainability of water resource management for Ghanaians.

The *WRC*, Ghana, was used for the study, where computer systems (hardware) and application programmes (software) are currently installed to manage the information/records on Ghana's water resource management. The technology system and information/records generated from the system installed at the *WRC* would be analysed and assessed to know how effectively they contribute to a sustainable water resource management for Ghanaians.
In Ghana, the organization responsible for managing water resource is the *WRC*, as enshrined in the Act 522 of the Republic of Ghana and assented by the President of the nation (WRC, 2024).

The data collection was, consequently, restricted to respondents from the Information Management and Accounts Departments of the *WRC*, as the data collected was highly technical and therefore, only the personnel who operate the machines and generate the necessary information for the Commission's tasks would be able to supply this data.
Optimistically, the conclusions from the findings were generalized to reflect the effectiveness of the information/records churned out from the technology system at the *WRC*, and how they contribute to a sustainable water resource management, globally.

## LITERATURE REVIEW

The review has been organized to highlight the activities that should take place within the Information Management Department to enhance the attainment of information technology (IT) goals/objectives of the *WRC*. The attainment of the IT goals/objectives is critically based

on the generation/production of required information/records from the water rights database system that would contribute to the attainment of a sustainable water resource management by the *WRC* for Ghana.

## Technology and Information Technology

### Technology

According to Hornby (2020), technology is written instructions designed and embedded scientifically in a machine for practical purposes or applications to change the environment in which humans live; the purpose could be for a personal or business change in the environment. Furthermore, Britannica.com (2024) defined technology as the application of scientific knowledge for the manipulation of the environment to achieve the practical aims of human life.

### Technology for Climate Change

Technology use in the organization and how it impacts the environment has been of concern to all. Globally, governments spend a lot of their budgets on technology in the areas of automation, infrastructure, cyber security, scale of technology disruption, communication gadgets and how data/information is manipulated/processed for the benefit of the citizenry (Peterdy, 2022; Kenton, 2022).

According to Bardell (2023), COP27 in Egypt drew a lot of attention from participants about how technology through digitization of most business activities would be the key to dealing with decarbonization and net zero, so as to mitigate the effects of climate change. Bardell (2023) therefore, advised on the realistic work needed with stakeholders to implement systems that function, as there is the hope that technology could be the solution to the current unfriendly climate change being observed globally.

### Information Technology

Hornby (2020) defined Information Technology as the study of electronic equipment, especially computer systems, for collecting and processing data to generate information, storing, analysing and sending out the information to users. Furthermore, Castagna and Bigelow (2024) explained Information Technology as the use of any computer system, storage, networking and other infrastructure, such as, physical devices to create and process data into information, store and deliver to other users. However, they added that typically, information technology is used in the context of business operations, as opposed to technology used for personal use; according to them the Harvard Business Review coined the term information technology to make a distinction between purpose-built machines designed to perform a limited scope of functions and the general-purpose computing machines built and programmed for various tasks.

## Computer Hardware and Software

### Computer Hardware

Hornby (2020) described hardware, as a machinery and electronic parts of a computing system. According to Awati and Rosencrance (2021), hardware is a term used to describe the physical components of a computer system; the physical components distinguish the tangible aspects of

a computing device from the software, which is about written, machine-readable instructions or programs that instructs the physical components what to do and when to execute the instructions.

Awati and Rosencrance (2021) further elaborated that hardware and software are complementary, as a computing device can only function effectively/efficiently and produce useful information/outputs only when both the hardware and software work together as instructed.

Moreover, Awati and Rosencrance (2021) mentioned that computer hardware could be categorized either as internal or external components, where the internal components might include the memory (ROM & RAM), arithmetic & logic unit (ALU) and control, whilst the external hardware components are attached for enhanced functionality, example input (keyboard) and output (screen).

In addition, the internal components collectively store and process the instructions delivered by the program, known as the operating system (OS), which include the following:

i. Motherbord,
ii. CPU,
iii. ROM,
iv. RAM,
v. Hard drive,
vi. Solid-state drive,
vii. Optical drive,
viii. Heat sink,
ix. Graphic processing unit, and
x. Network interface card (Awati & Rosencrance, 2021; Brush, 2019).

i. Motherboard – a printed circuit board that holds the central processing unit (CPU) - comprising the memory, control and arithmetic & logic unit, and other essential internal hardware and executing functions as the central hub which all the other hardware components pass through (Awati & Rosencrance, 2021).

ii. CPU – the brain of the computer system that processes and executes the digital instructions from the various programs. The clock speed determines the computer system's performance and efficiency in processing data (Awati & Rosencrance, 2021).

iii. ROM – Read-only memory is a type of computer storage that contains non-volatile, permanent data, which normally can only be read and not written to, according to Brush (2019). It contains the programming that allows a computer system to start up or regenerate each time it is turned on. It performs large input/output (I/O) tasks and protects programs or software instructions; once data is written on a ROM chip, it cannot be removed. Almost every computer system contains the start-up instructions, called firmware. This boot firmware is the basic I/O system and is known as the BIOS (basic I/O system). This software consists of codes that instruct the boot-up process for the computer system, such as loading the operating system (OS) into the RAM or running the hardware diagnostics. Consequently, ROM is most often used for firmware updates (Brush, 2019).

iv. RAM – random access memory or dynamic RAM is a temporary memory storage that makes information immediately accessible to programs. RAM is a volatile memory; in that

case stored data is immediately cleared when the computer system is put off (Awati & Rosencrance (2021).
v. Hard drive – the physical storage devices that store both permanent and temporary data in different formats, including programs, OS, device files, etc (Awati & Rosencrance, 2021).
vi. Solid-state drive – the SSDs are solid-state storage devices based on NAND (NOT AND) flash memory technology. SSDs are non-volatile, so they can safely store data even when the computer system is put off (Awati & Rosencrance, 2021).
vii. Optical drive – these drives typically reside in an on-device drive bay and they enable the computer system to read and interact with nonmagnetic external media, such as compact disc read-only memory or digital video discs (Awati & Rosencrance, 2021).
viii. Heat sink – this is a passive piece of hardware that draws heat away from the components of the computer system so as to regulate/reduce the temperature to help ensure the continued proper functioning of the components. The heat sink is installed directly on top of the CPU, which produces the most heat among the internal components (Awati & Rosencrance, 2021).
ix. Graphic processing unit – this chip-based device processes graphical data and often functions as an extension to the main CPU (Awati & Rosencrance, 2021).
x. Network interface card – a NIC is a circuit board/chip that enables the computer system to connect to a network. Also called a network adapter or local area network adapter. It supports connection to an ethernet network (Awati & Rosencrance, 2021).
There are other computer system components, such as USD ports, power supplies, transistors and chips, which are also types of the internal computing components (Awati & Rosencrance, 2021).

The computer system is also made of external hardware components, also known as peripheral components, and these items are externally connected to the computer system to control either input or output functions; these hardware devices are designed to either provide instructions to the software (input) or give results from its execution (output) - (Awati & Rosencrance, 2021). The common input hardware components include the following, amongst others:

i. Mouse,
ii. Keyboard,
iii. Microphone,
iv. Touchpad,
v. USB flash drive, and
vi. Memory card (Awati & Rosencrance, 2021).
i. Mouse – a hand-held pointing device that moves a cursor around the screen of a computer system. This enables interaction with objects on the screen and may be wired or wireless (Awati & Rosencrance, 2021).
ii. Keyboard – an input device that features a standard QWERTY (based on the order of the first six {6} keys on the top letter row of the keyboard) keyset, which enables users to input text, numbers or special characters (Awati & Rosencrance, 2021).
iii. Microphone – a device that translates sound waves into electrical signals and supports computer-based audio communications (Awati & Rosencrance, 2021).
iv. Camera – captures visual images and streams them to the computer or through a computer system to a network device (Awati & Rosencrance, 2021).

v. Touchpad – an input device, which is external or built into a laptop and used to control the pointer on a display screen; normally an alternative to an external mouse (Awati & Rosencrance, 2021).
vi. USB flash drive – an external and removable storage device that uses flash memory and interfaces with a computer system through a USB port (Awati & Rosencrance, 2021).
vii. Memory card – a portable external storage media, example a CompactFlash card, which is used to store media or data files (Awati & Rosencrance, 2021).
There are other input hardware components, including joysticks, styluses and scanners (Awati & Rosencrance, 2021).
In addition, there are output components, which includes, amongst others:
i. Monitor.
ii. Printers.
iii. Speakers, and
iv. Headphones, earphones and earbuds.
i. Monitor – an output device which is similar to a TV screen; it displays information, documents or images generated by the computer system (Awati & Rosencrance, 2021).
ii. Printer – extracts electronic processed data from a computer system into printed material (Awati & Rosencrance, 2021).
iii. Speaker – an external audio output device that connects to a computer system to generate a sound output (Awati & Rosencrance, 2021).
iv. Headphones, earphones and earbuds – these are similar to speakers and they provide audible audio output only to a single listener (Awati & Rosencrance, 2021).

**Computer Software**
Hornby (2020) defined software as the programs that are used to operate a computer system. Furthermore, software is a set of instructions, data or programs that are used to operate computer systems to execute specific tasks; it is a generic term used to refer to applications, scripts and programs that run on a computer system (Rosencrance, 2021).
According to Rosencrance (2021), there are two (2) main categories of software and these are:
i. Application software, and
ii. System software.
However, there are other types and these include:
iii. Driver software,
iv. Middleware software, and
v. Programming software (Rosencrance, 2021).
i. Application software – this software is purposely developed to perform a specific function for a user or another application; an application can be self-contained or a group of programs that run the application for the user. Examples of contemporary application software include – office suits, graphics software, database management software, web browsers, word processors, software development tools, image editors and communication platforms (Rosencrance, 2021).
ii. System software – this is a program designed to run a computer system's application programmes and hardware; it co-ordinates the activities and functions of the hardware and software. Again, it controls the operations of the computer hardware and provides the environment/platform for all types of software to work. Examples include – operating system (OS) which manages all the other computer programs, firmware, computer language translators and system utilities (Rosencrance, 2021).

iii. Driver software – also called device drivers control the devices and peripherals connected to a computer system and enabling them to perform their specific tasks. Every device connected to a computer system needs at least one device driver to operate. Examples are – software that comes with any nonstandard hardware, including special game controllers, as well as software that enables standard hardware, such as USB storage devices, head-phones and printers (Rosencrance, 2021).
iv. Middleware - this describes software that mediates between application and system software or between two (2) different kinds of application software. For example, middleware enables Microsoft (MS) Windows to talk to Excel and Word. In addition, it is used to send a remote work request from an application in a computer system with a different OS. Furthermore, it enables newer applications to work with legacy ones (Rosencrance, 2021).
v. Programming software – this is the software written by computer programmers using programming language to write codes; programming software and programming tools enable developers to develop, write, test and debug (identifying and removing errors of) other software programs. Examples of programming software are assemblers, compilers, debuggers and interpreters (Rosencrance, 2021).

**Information System and Management Information System**

**Information System**
Information System (IS) could be defined as the integrated set of components for facilitating the collection, controlling, organising, storing / retrieving and processing of data to derive information (Kwadade-Cudjoe, 2020). According to Nowduri cited in Kwadade-Cudjoe (2020), IS could be categorized into three (3) main groups, namely:
i. Transaction processing system,
ii. Expert systems, and
iii. Management Information Systems.
i. Transaction processing system (TPS) - TPS is a computer processing in which the computer responds immediately to user requests. Each request is considered to be an activity that needs performance. Transaction processing requires interaction with a user, and is normally divided into individual, indivisible operations, called transactions. Each transaction must succeed or fail as a complete unit; it cannot be only partially complete. Automated Teller Machines (ATM) for banks is an example of transaction processing (Nowduri cited in Kwadade-Cudjoe, 2020).
ii. Expert systems (ES) - ES are computer programs that simulate the judgement and behaviour of a human or an organization that has expert knowledge and experience in a particular field. Typically, such a system contains a knowledge base of accumulated experience and a set of rules for applying the knowledge base to each particular situation that is described to the program. Among the best-known expert systems are those that play chess and systems that assist in medical diagnosis (Nowduri cited in Kwadade-Cudjoe, 2020).
iii. Management Information System (MIS) - MIS is the information on the people, technology and the organization as an entity, and the relationships amongst them for the overall efficiency of the system (Nowduri cited in Kwadade-Cudjoe, 2020).

**Management Information System**
The relation between people, technology and the organization as an entity, is so vital to enable MIS function efficiently to achieve organizational goals. Through this relationship, MIS can

provide vital information, which as a resource can help management to efficiently plan, organize, direct, control and govern organizations (Daft, 2022; OECD, 2015).
There are different types of MIS and some of them are:
i. Decision Support System, and
ii. Executive Information System (Nowduri cited in Kwadade-Cudjoe, 2020).
i. Decision Support System (DSS) - DSS is user-friendly software that is versatile for analyzing an organizational business input (data) by modelling the various decision-scenarios based on the condition / situation existing at any particular time of using the inputs (Nowduri cited in Kwadade-Cudjoe, 2020). DSS therefore, as an informational application system takes data (inputs) for modelling and produces answers for solving business problems and queries. The input that gives the best answer for solving, for example, business problems, becomes the input for developing your decision. This makes MIS an important business tool and a powerful resource for assisting corporate management in taking strategic business decisions to achieve sustainability and competitive advantage of the organization (De Wit & Meyer cited in Kwadade-Cudjoe, 2020).
ii. Executive Information System (EIS) - EIS is another type of MIS that facilitates and supports senior executive information and decision-making needs. It provides easy access to internal and external information relevant to organizational goals. EIS emphasizes graphical displays and easy-to-use user interfaces. They offer strong reporting with powerful capabilities for easy understanding. In general, EIS are enterprise-wide DSS that help top-level executives analyse, compare and high-light trends in important variables so that they can monitor performance, and identify opportunities and problems (Nowduri cited in Kwadade-Cudjoe, 2020).
However, in recent years, the term EIS has merged with Business Intelligence (BI). BI is a set of theories, methodologies, architectures, and technologies that transform large raw data into meaningful and useful information for performing business activities, including decision-making by management (Nowduri cited in Kwadade-Cudjoe, 2020).

**Databases**
According to Hornby (2020), a database is an organized set of data which is stored in the computer system and may be used in numerous ways. Databases are also organized collection of structured information which is stored electronically in a computer system and are generally helpful when they contribute to the processing and management of specialized business tasks. They may be developed for general use and as such could be purchased off-the-shelf (at shops), in-house by programming staff of an organization or by an agency contracted for a tailor-made package for a specific task.

According to Dancuk (2021), databases are organised set of logically connected data which transform into helpful knowledge, structured and maintained to fit the user's needs; they also keep relationships between the data points. Dancuk (2021) added that they are integrated set of information about a system and there are procedures for maintenance and usage. Furthermore, unlike spreadsheets, database applications could be accessed by multiple users simultaneously (Dancuk, 2021).

**Different types of Databases**
Dancuk (2021) mentioned several database types currently available, the benefits and drawbacks associated with each of them, and added that every database type has a specific

environment for storing data, including the relationship between the information held. The types include, amongst others:
i. Relational,
ii. Object-oriented,
iii. Distributed,
iv. Data warehouses,
v. NoSQL,
vi. Graphic,
vii. OLTP,
viii. Open-source,
ix. Cloud,
x. Multi-model, and
xi. Self-driving cloud (autonomous) - (Dancuk, 2021).
i. Relational – stores data in table-like structures of rows and columns with a focus on data consistency. It focuses on relationship between data and the most widely used database type (Dancuk, 2021).
ii. Object-oriented – a style of programming characterized by the identification of classes of objects closely linked with the methods/functions associated and the relational database standards. This is in addition to ideas of inheritance of attributes and methods (Dancuk, 2021).
iii. Distributed – this data type spreads across multiple sites and with horizontal scale (Dancuk, 2021).
iv. Data warehouses – there is integration of data from various sources into a single decision support system. Normally, caters for large volumes of data which commonly reside on big data servers (Dancuk, 2021).
v. NoSQL – structurally made up of diverse types of databases with a focus on high availability and are best suited for large volumes of unstructured data (Dancuk, 2021).
vi. Graphic – similar to NoSQL database, but with a focus on relationships between data points. When dealing with a topographical network structure, this database is the best system for exploring and discovering relationships amongst data (Dancuk, 2021).
vii. OLTP – focuses on short day-to-day transactions, support a large userbase with high data integrity and very effective for simultaneous queries (Dancuk, 2021).
viii. Open-source – open to modifications and free to use with customizable user preferences, and in addition its low cost make it widely adopted for use (Dancuk, 2021).
ix. Cloud – has all the traditional database features with cloud computing flexibility (Dancuk, 2021).
x. Multi-model – provides a single engine for working with multiple database model types (Dancuk, 2021).
xi. Self-driving cloud (autonomous) – uses machine learning to automate the various tasks in the Database Management System (DBMS) - (Dancuk, 2021).

**Water Resource Management System (WRMS)**

Research work done on water resource management system is very scanty, and therefore, making the environment lack literature on its activities. However, one of the few institutions to have operated in water resource management is the Environmental Software and Services Organization (ESS), which developed an optimization database system for sustainable water resource management-based basin approach (ESS cited in Kwadade-Cudjoe, 2019).

The ESS water rights database system was developed from water resource management issues in the areas of identification, definition and classification of problems, using the decision-support system approach. According to (ESS cited in Kwadade-Cudjoe, 2019), water has always been a key resource in the Mediterranean enclave, so it is important to prioritize its allocation for use to achieve sustainable development, with regards to the southern and eastern coastal areas which are undergoing rapid economic development, land use and demographic change.

The water rights database systems developed for the water resource management has the objective to test, critically evaluate and implement an innovative, scientifically rigorous yet practical approach to increase efficiencies and reconcile conflicting demands of water within the Mediterranean area (ESS cited in Kwadade-Cudjoe, 2019).
Water rights database system developed for water resource management, globally, should have the main purpose of solving conflicting demands of water; furthermore, effectively managing individuals water demands/needs, to make the demand management approach of the database system effective, is very vital for successful water resource management (UN Habitat cited in Kwadade-Cudjoe, 2019).

## METHODOLOGY

Most of the river bodies in Ghana are polluted, thereby exposing the resource to contamination, which invariably affects the citizenry in getting the right amount of treated quality water for use, as the water distributers go through hard time in getting treated water for consumption (Welsing, 2022). This research therefore, looks at the activities/functions of the *WRC* in the areas of technology and databases available within the organization for generating the appropriate information/reports to support the sustainability of the water resource management for the Ghanaian populace.

Consequently, the main thrust of this research is to access by examining the hardware and the software of the *WRC* for generating the right information/reports to enable management of the commission to sustainably handle the water resource management of Ghana for use by all.
Survey/questionnaire design approach was essentially employed due to the nature of the research, where data was collected exclusively from the technical staff of the Information Management and the Accounts departments of the *WRC*, the supervisors of the technology and producers of information/records for generating revenue, respectively, for the *WRC*. To secure a favourable and sizeable sample size, an appreciable number of Information Management and Accounts technical staff completed the Questionnaire.
The qualitative research approach was adopted for the study, as it enabled the researcher to collect good primary data from the few technical respondents from the Information Management and Accounts departments. The data was coded and converted into frequencies, which gave averages and summations for good deductions from the analyses of the data (Bryman & Bell, 2015).
Questionnaire was used for the data collection, as it provided an effective and efficient way of collecting quick responses from the respondents.
The questionnaire as an instrument was developed, put into google-form, piloted and tested to verify that the questions were clear and unambiguous, such that the respondents would be encouraged and consistent with the purpose of the study.

Questions were reviewed where necessary, based on response from the respondents, during the pilot study. This was purposely done to improve the reliability and validity of the questionnaire. Secondary data was collected from the *WRC* library and other sources from Accra, Ghana, which was merged with the primary data collected from the questionnaire, where necessary. This was then coded for easy access, keyed into the computer system, qualitatively accessed, analyzed and presented in statistical summary Tables, as listed at the bottom of the study.
Findings were arranged in sequential and logical formats, which led to conclusions to be drawn from the analyses. Respondents were aware that their participation was confidential as the bio-data indicated and voluntary too, and they were moreover, assured of a copy of the results from the research, when a request is made.

**Analyses and brief discussions of Results**
This section deals with the data gathered from respondents through the questionnaire survey; the data was coded and categorized, and further summarized and analyzed for presentation. A total of twelve (12) Questionnaires were distributed (using online Google Forms) to the total staff of the Information Management and Accounts departments, which was a sample of the *WRC* staff.

National population of the WRC staff, Ghana, is about fifty-two (52). However, due to the highly technical nature of this study, only the personnel associated with the management of the technology system (amalgamation of technology and software) and users of the application programs (software) to generate revenue for the *WRC* was targeted, due to the specialized nature of the research. Ten (10) out of the twelve (12) Questionnaires sent out were responded to, duly completed and returned.

This gave the total Questionnaire for the analysis to be ten (10) out of twelve (12) sent out, which furnished a response rate of 83% which was very good, as it completely represented the views of the Information Management and Accounts departments' staff and pari passu (by extension) the entire research population. This was highly specialized research, as the Questionnaire was limited to be completed only by the employees of the Information Management and Accounts departments of the *WRC.*

**Bio Data Statistics**
The bio data characteristics of the sample included sex, educational background and position of the respondents in the *WRC*. These characteristics were found to be indicators of the importance of respondents within the *WRC* and were therefore, very vital for the research.
For sex, the study identified two (2) types – 'Female' and 'Male'. 'Female' obtained 30% and 'Male' obtained 70%, indicating that the respondents were mostly men; male surely had an edge over female in this research. See Table 1.

**For the educational background,** the study identifies types – 'SHS/Secondary/Technical School', 'Diploma', 'Graduate', 'Masters', 'Doctorate' and 'Professional'; however, the prominent educational backgrounds were Graduate and Masters, as both obtained 50% each out of the 10 technical employees who responded to the questionnaire of the survey. This indicates that the respondents are learned and would surely supply enhanced

information/knowledge from the organization for this important research. Unfortunately, there was no 'SHS/Secondary/Technical School', 'Diploma', 'Doctorate' and 'Professional' staff to complete the Questionnaire. See Table 2.

**About the position of the respondents within the WRC for the research**, the study identified 'Technical/Professional' (10%), 'Management' (40%), and 'Support Services' (50%); 'Directorate' and 'CEO' scored 0% each. Those in Support Services level was in the majority identifying the significance of technical/support officers being respondents and in the majority; demonstrating the importance of the information gathered. See Table 3.

## DETAILED FINDINGS & ANALYSES OF RESULTS

### Technology

To a question on the make of technology being used by the *WRC*, different answers were supplied, including 'web application', 'sever application/technology', 'server with data application', 'sever' and 'server and web application'. The most popular answer was 'Server' – 40%, Sever application/technology – 30% and the rest scoring 10% each. However, the answer being looked for was the manufacturer of the technology. In any case, the responses brought out the idea of a 'Server' being used with the technology to enhance the easy capture/flow of data from many points of the technology system at the *WRC*. See Table 4.

**Do the information technologies have the same capacity/size** obtained **Yes** scoring 60% from the 10 sampled respondents and the **No** scoring 40%. The 60% score of the technology being of the same size implies that the WRC purchased same-sized capacity of technology for use, whilst 40% were of a different view, **No**. See Table 5.

**The capacity/size of the RAM & Hard Disk was found to be** 8GB RAM & 2TB HDD, which scored 90% and one (1) respondent stating 16GB RAM & 8TB HDD, scoring 10%, which was likely a mistake from the respondents. 8GB & 2TB HDD are the capacity/size of the RAM and Hard Disk, respectively. See Table 6.

**To the question of the *WRC* using a Server**, all the Respondents answered Yes. 'Yes' therefore, scored 100%; indicating the presence of a Server connecting the computer systems. See Table 7.

**When asked to state the make of the Server**, the answer supplied by all was 'Dell Blade Server', which scored 100%; no argument about the make of the Server. See Table 8.

**To the question of the capacity of the Server being adequate for *WRC's* functions,** the answered from the Respondents were Very Adequate – 90% and Adequate scoring 10%; indicating a strong confirmation of the adequacy of the Server to provide the needed function to the technology system of the Commission. See Table 9.

**Furthermore, to the question of how many computer systems connected to the (Server) network,** the answers received were through a LAN with wireless – 10% and about thirty (30) computer systems including laptops, scoring 50%. Four (4) of the Respondents did not supply

any answer. The total technologies being used in the *WRC* to discharge her functions is about 30. See Table 10.

**List/names of Departments/Offices networked to the Server, Or with Computer Systems** yielded the following: Fin & Admin, Planning, Information Management & Education and Environmental Quality (20%); Planning, Environmental Quality, Fin & Admin (20%); Water Quality, Admin and Planning (40%); Environmental Quality, Planning, Fin & Adm (20%). The answers provided implied that all the departments have Computer Systems for work. See Table 11.

**Application software/database being used for the Water Resources Management.** The answers supplied were MySQL (10%); SQL (80%); and SQL and MS Access (10%). See Table 12.

**To the question about the functions of the database/software,** the following answers were produced: issuance of permits and license (10%); water accounting (40%); generation of water register and drilling licence register (10%); and generation of reports (40%). See Table 13.

**The strength of the software was scored:** Very effective (100%); Effective (0%), Uncertain (0%); Ineffective (0%); and Very Ineffective (0%). See Table 14.

**The Reports produced from the software generated the answers:** water use permits, drilling licence, dam safety licence, water quality reports, water accounting reports (60%); water accounting and invoicing (30%); and invoicing for clients (10%). See Table 15.

**To the question 'Are there weaknesses with the Software'** brought in the answers: No (100%) and Yes (0%). See Table 16.

**State the weaknesses with the software produced the following answers from the Respondents:** Not Applicable (70%). The rest did not supply any Answer. See Table 17.
**Does the software provide the required information/reports for management decision-making** gave out the following answers: Yes (100%). See Table 18.

**When the Respondents were asked to list the Reports produced from the Software/Database,** only four (40%) provided the Reports and the answers given were: water abstraction for mining, aquaculture, water supply for domestic use (10%); water rights and accounting reports (20%); and drilling licence, water rights and dam safety (10%). See Table 19.

**Does the Software provide the required Information/Reports needed by management?** This was about the adequacy of the Software to enable management to operate well. The Respondents answered Yes (100%); No (0%). See Table 20.

**If the answer to the previous question is Yes, List the Reports provided by the Software:** The Response from the Respondents was Water Rights and Accounting Reports and it scored 40%. The rest did not provide any response. See Table 21.

**Is management able to take effective decisions from the generated Reports to sustaining the managing of water resource in Ghana?** All the Respondents answered Very Effective (100%). See Table 22.

**If the answer to the previous question is Ineffective/Very Ineffective, give reasons why this is so?** The Responded answered Not Applicable (60%). See Table 23.
**Any other information relevant for the study. Kindly, State -** provided the following answers:
**i.** The software needs an upgrade because of advance in technology (10%)
ii. Not Applicable (30%).

## DISCUSSION OF RESULTS

The above findings are very technical and specialized, and apart from the departments of Information Management and Accounts departments that utilise the information technologies (computer systems) and software to perform their functions directly, it precludes any data collected from the other departments within the *WRC*.

The findings are therefore, generated from staff of the Information Management and Accounts departments and comprised 50 percent each of respondents with 1st and 2nd Degrees. Unfortunately, the employees from 'SHS/Secondary/Technical School', 'Diploma', 'Doctorate' and 'Professional' did not supply any data for the analyses. Male staff overshadowed females with the ratio 7:3; however this did not affect the analyses of the findings.

The position of the respondents who supplied data for the study are identified as: 'Technical/Professional' (10%), 'Management' (40%), 'Support Services' (50%); 'Directorate' and 'CEO' scored 0% each. This indicates that technical employees whose work is solely dependent on the technology system of the *WRC* supplied the data.
The capacity/size of the RAM & Hard Disk was found to be 8GB RAM & 2TB HDD, which scored 90% and 16GB RAM & 8TB HDD, scoring 10%, indicating 8GB and 2TB HDD is the RAM and Hard Disk size.

To the question of the *WRC* using a Server, all the Respondents answered Yes. This implies that the organization has a network of computer systems (information technologies) and the name of the Server is 'Dell Blade Server'; the answer was emphatic, 100 per cent. See Table 8.

To the question of the capacity of the Server being adequate for *WRC's* functions, the answered from the Respondents were Very Adequate – 90% and Adequate scoring 10%, indicating the adequacy of the Server for supporting WRC's tasks to achieve its objectives and goals. See Table 9.

Furthermore, to the question of how many computer systems are connected to the (Server) network, the answers received were 'Through a LAN with wireless' – 10% and 'About thirty (30) computer systems including laptops', scoring 50%. Four (4) of the respondents did not

supply any answer. Therefore, there are many machines (including computer systems, laptops and tablets) networked to the server, which are about 30. See Table 10.

Names of Departments/Offices networked to the Server yielded the following answers: 'Finance & Administration, Planning, Information Management & Education and Environmental Quality' - (20%); 'Planning, Environmental Quality, Finance & Administration' - (20%); 'Water Quality, Administration and Planning' - (40%); 'Environmental Quality, Planning, Finance & Administration' - (20%). The answers implied that all the departments at the *WRC* have computer system for work. See Table 11.

Answers provided for the application software/database being used for the water resources management at the *WRC* were 'MySQL' - (10%); 'SQL' - (80%); and 'SQL and MS Access' - (10%). Since SQL is just a query language used within MySQL, the software /database being used at the *WRC* is MySQL and MS Access. See Table 12.

The functions of the database/software were given as: issuance of permits and license (10%); water accounting (40%); generation of water register and drilling licence register (10%); and generation of reports (40%) and the various reports generated from the database were given as: water use permits, drilling licence, dam safety licence, water quality reports and water accounting. See Tables 13 and 15, respectively. The strength of the software was given to be very effective (superb) and in addition provide the required information for decision-making by management. See Table 14 and 18, respectively.

Furthermore, the respondents agreed that management is able to take effective decisions from the generated reports to sustaining the managing of water resource in Ghana, as all the respondents answered 'Very Effective' - (100%).

The above findings of the research expectantly indicate the contribution of the technology and software/database at the *WRC* for a sustainable water resources management. It therefore, behoves on the employees at the *WRC* to effectively and efficiently utilize the information and reports generated from the technology system to manage the water resources of the nation. The nation cannot continue to watch the 'galamseyers', sand winners and the fisherfolks who use hazardous chemicals for fishing to continue exploiting and destroying the water resources of the nation. The *WRC* should know the importance of freshwater for the livelihood of the populace and that if there is scarcity of freshwater, many citizenry would not have access to treated water from the distributors for use; and the fact that only 0.007% of freshwater is available globally for human use should inform the *WRC* to make sure Ghana does not lack clean water (UNWater.org, 2023; USGS.gov, 2019). Furthermore, the results of the research should alert the *WRC*, especially the management, that Ghanaians expect them to deliver on their goals, including mandate, of sustaining the management of water resources of Ghana, for the current and posterity.

The findings have also enabled the researcher to know that the Commission is well equipped with the necessary technology and software/database to generate the necessary information/reports to enable/assist management to contribute effectively to the execution of its mandate of a sustainable water resources management and extricate Ghanaians from any untoward destruction of the river bodies of the nation.

## CONCLUSION

The *WRC* as an organization is burdened with many problems, the principal being the deplorable water resources of the nation, which is the product from the organization for delivery to water distributors to feed homes, offices and workplaces needing treated water for their activities, for example the hotels and restaurants.

However, from the study, it has been revealed that the *WRC* is well resourced with the necessary technology system, comprising good technology and dependable database/software to supply all the information/reports for her activities. It behoves on the organization then to effectively and efficiently utilize the facilities to contribute to achieving its objectives and goals of sustainable water resources management of Ghana.

The capacity/size of the RAM and Hard Disk was found to be 8GB RAM & 2TB HDD, which is good for the tasks of the *WRC* and there is a Server, 'Dell Blade Server', which connects all the computer systems. The Server has adequately connected about 30 computer machines to enable the organization to deliver on its mandate.

All the departments at the *WRC* have computer system for work and MySQL and MS Access application software/database are being used for the water resources management. The database/software has been generating all the information/reports needed for effective functioning of the WRC, as these reports are generated: water use permits, drilling licence, dam safety licence, water quality reports and water accounting. Furthermore, the respondents agreed that management can take effective decisions from the generated information/reports for sustaining the management of water resources in Ghana.

The researcher strongly believes that the findings of the study, globally, would help all national water management institutions, including the *WRC*, to have a good technology and with the appropriate database/software to enable the technology system within the establishments to contribute effectively and efficiently to sustaining the water resources management of their nations. This would enable the global water institutions to supply clean fresh water to the distributors of the resource, who in turn would supply good and treated water (product) to their citizenry for sustainable water resource management for the current and future generations.

### Recommendation

The technology and the database/software installed at the *WRC* for the production of required information/reports to contribute effectively and efficiently to sustaining the water resources management of the nation has been confirmed by the study, to be very effective; this is laudable. However, it is unfortunate that the *WRC* is facing a crisis of having its products (surface and ground water) polluted by 'galamseyers', sand winners and fisherfolks who use wrong methods, including chemicals for fishing.

The provision of the required information/reports from the database should spur the organization to manage the water resources of the nation effectively and efficiently.

It is therefore, recommended that the *WRC* should:

i. maintain the hardware and software effectively to always deliver the required information for decision-making by management;

ii. periodic training of the employees responsible for using the hardware and software to discharge their functions effectively and efficiently;
iii. re-fresher courses in information technology should be periodically conducted for all the employees to enable them know the importance of the technology system at the *WRC* for churning out the required and timely information/reports for managing their operations;
iv. occasional seminars on information technology for management to enable them appreciate the technology system of the organization to make them abreast with technology and always demand information that would help them to deliver effective decisions to sustain the management of the water resources of the nation, and
v. upgrade of the software to the current version is very important, as to the question of any additional relevant information on the technology system, a respondent raised the issue of the upgrade of the current version of the software to match the advanced technology.

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## TABLES

### Bio Data

**Table 1: Sex**

| Sex Type | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Female | 3 | 30 | 30 |
| Male | 7 | 70 | 100 |

**Table 2: Educational background**

| Educational background | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| SHS/Secondary/Technical | 0 | 0 | 0 |
| Graduate | 5 | 50 | 50 |
| Master's | 5 | 50 | 100 |
| Doctorate | 0 | 0 | 100 |
| Professional | 0 | 0 | 100 |

**Table 3: Position**

| Position in Organization | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| CEO | 0 | 0 | 0 |
| Directorate | 0 | 0 | 0 |

| | | | |
|---|---|---|---|
| Management | 4 | 40 | 40 |
| Technical/Professional | 1 | 10 | 50 |
| Support Services | 5 | 50 | 100 |

## Technology

**Table 4: What make of the Technology do you use ?**

| Types | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Web application | 1 | 10 | 10 |
| Server application/technology | 3 | 30 | 40 |
| Server | 4 | 40 | 80 |
| Server with database application | 1 | 10 | 90 |
| Server and web application | 1 | 10 | 100 |

**Table 5: Are the technology of the same capacity?**

| Same capacity? | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Yes | 6 | 60 | 60 |
| No | 4 | 40 | 40 |

**Table 6:** What is the capacity/size of the RAM & Hard Disk**?**

| Capacity of RAM & Hard Disk | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| 16GB RAM and 8TB HDD | 1 | 10 | 10 |
| 8GB RAM and 2 TB HDD | 9 | 90 | 100 |

| Table 7: Do you use a Server? | | | |
|---|---|---|---|
| **Availability of Server** | **Frequency** | **Valid Percent** | **Cumulative Percent** |
| Yes | 10 | 100 | 100 |
| No | 0 | 0 | 100 |

| Table 8: What is the make of the Server? | | | |
|---|---|---|---|
| **Make of Server** | **Frequency** | **Valid Percent** | **Cumulative Percent** |
| Dell Blade Server | 10 | 100 | 100 |

| Table 9: Is the capacity of the Server adequate for WRC's functions? | | | |
|---|---|---|---|
| **Capacity of the Server** | **Frequency** | **Valid Percent** | **Cumulative Percent** |
| Very Adequate | 9 | 90 | 90 |
| Adequate | 1 | 10 | 100 |

| Table 10: How many Computer Systems are connected to the (LAN) network? | | | |
|---|---|---|---|
| **Machines Connected to LAN** | **Frequency** | **Valid Percent** | **Cumulative Percent** |
| Through LAN with wireless | 1 | 10 | 10 |
| About 30 with Laptops | 5 | 50 | 60 |
| No Answer | 4 | 40 | 100 |

| Table 11: Provide names of Departments network to Server OR with Computer Systems | | | |
|---|---|---|---|
| **List of Departments** | **Frequency** | **Valid Percent** | **Cumulative Percent** |
| All Departments | 2 | 20 | 20 |
| Planning, Env Quality, Fin & Admin | 2 | 20 | 40 |
| Water Quality, Admin and planning | 4 | 40 | 80 |
| Env Quality, Planning, Fin & Adm | 2 | 20 | 100 |

## Database/Software

| Table 12: Application software/database being used for the Water Resources Management | | | |
|---|---|---|---|
| **Application software Type** | **Frequency** | **Valid Percent** | **Cumulative Percent** |
| a. MYSQL | 1 | 10 | 10 |

| | | | |
|---|---|---|---|
| b. SQL | 8 | 80 | 90 |
| c. SQL and MS Access | 1 | 10 | 100 |

**Table 13: What are the functions of the software?**

| Function of Software | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Issuance of permits and License | 1 | 10 | 10 |
| Generating water accounting reports | 4 | 40 | 50 |
| generation of water register and drill licence register | 1 | 10 | 60 |
| Generation of Reports | 4 | 40 | 100 |

**Table 14:** What is the strength of the Software in providing the required Reports? Select one:

| Strength of Software | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Strongly Effective | 10 | 100 | 100 |
| Effective | 0 | 0 | 100 |
| Uncertain | 0 | 0 | 100 |
| Ineffective | 0 | 0 | 100 |
| Strongly Ineffective | 0 | 0 | 100 |

**Table 15:** What Reports does the Software provide?

| Types of Reports from Software | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Water use permits, drilling and dam safety licence, water quality and accounting reports | 6 | 60 | 60 |
| Water accounting & invoicing | 3 | 30 | 90 |

| | | | |
|---|---|---|---|
| invoicing for clients | 1 | 10 | 100 |

**Table 16: Are there weaknesses with the software?**

| Weaknesses with the Software | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| No | 10 | 100 | 100 |
| Yes | 0 | 0 | 100 |

**Table 17: State the weaknesses with the software**

| Software weaknesses | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Not Applicable | 7 | 70 | 70 |
| No Answer | 3 | 30 | 100 |

**Table 18: Does the software provide the required information?**

| Software information | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Yes | 10 | 100 | 100 |
| No | 0 | 0 | 100 |

**Table 19: If the answer to the previous question is Yes, List the Information provided**

| Information produced from the Software/Database | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Water abstraction for mining, aquaculture and water supply for domestic use | 1 | 10 | 10 |
| Water Rights and accounting information | 2 | 20 | 30 |
| Drilling licence, water rights and dam safety | 1 | 10 | 40 |

## Adequacy of the Software/Database

**Table 20: Does the Software provide the required Reports needed by management? Select one: Yes. No.**

| Adequacy of Software Reports | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Yes | 10 | 100 | 100 |
| No | 0 | 0 | 100 |

**Table 21: If the answer to the previous question is Yes, List the Reports provided**

| Reports produced from the Software/Database | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Water rights and accounting reports | 4 | 40 | 40 |

**Table 22: Is management able to take effective decisions from the generated Reports to sustaining the managing of water resource in Ghana?**

| Select Answer | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Very Effective | 10 | 100 | 100 |
| Effective | 0 | 0 | 100 |
| Uncertain | 0 | 0 | 100 |
| Ineffective | 0 | 0 | 100 |
| Very Ineffective | 0 | 0 | 100 |

**Table 23: If the answer to the previous Question is Ineffective/Very Ineffective, give reasons why this is so?**

| Reason | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| Not Applicable | 6 | 60 | 60 |

**Table 24: Any other information relevant for the study. Kindly, State:**

| Reason | Frequency | Valid Percent | Cumulative Percent |
|---|---|---|---|
| The software needs an upgrade because of advance in technology | 1 | 10 | 10 |
| Not Applicable | 3 | 30 | 40 |