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Digital Solution for Seamless Water Supply Management in Wukari Metropolis

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ABSTRACT
Access to safe and reliable water sources is a critical challenge faced by many urban areas, including Wukari Metropolis, Nigeria, where residents encounter significant difficulties obtaining clean water. Water vending is an ancient practice globally, especially in developing countries like Nigeria, where vendors deliver water by hand, donkey carts, pushcarts, or tank trucks. People patronize these informal water supplies despite lacking safety and quality assurance. Residents struggle with limited access to safe water sources and lack efficient water vendors. As such, this study addresses these pressing issues by proposing a web-based water supply management system designed to enhance accessibility and efficiency. The proposed system will allow users to conveniently order water through their smartphones, featuring functionalities such as user registration, order placement, order tracking, and flexible payment options. Utilizing an object-oriented design methodology, specifically the Unified Modelling Language (UML), the system development was guided by best practices in software engineering. This innovative solution addresses the limitations of the existing water supply system, providing a more convenient and effective means for residents to access clean water in Wukari metropolis.

INTRODUCTION

Water is a vital necessity for human existence. With the world water resource of 0.3% usable water, billions without adequate water supply in the world, especially in Nigeria and Wukari local government in specific (Cassardo and Jones 2011; Ezenwaji et al., 2015). Access to sufficient quantity and quality water remains a major problem in developing countries, particularly in low-income areas like Wukari (Ezenwaji et al., 2015). The water distribution challenge to the Wukari local government's population has led many residents to rely on unsafe and unreliable sources for their domestic water needs. The shortage of water makes water distribution to households difficult. This has compelled many residents of the Wukari metropolis to rely on unsafe and unreliable sources of water for their domestic water needs (Ishaku et al., 2010). Urban dwellers in Nigeria rely on small-scale private water vendors as their major source of water for domestic use (Bello et al., 2020). Water vending is an ancient practice worldwide, particularly in developing countries like Nigeria (Auwal et al., 2021). It is an integral part of the water supply system, with vendors providing home deliveries through various methods such as hand carts, donkey carts, pushcarts, or tank trucks (Wutich et al., 2016). Once viewed as a temporary solution to water supply issues, water vending is now a necessary and acceptable path toward achieving the Millennium Development Goals (MDGs) target of improved water (Ahmad, 2017). The government accepts the role of water vendors in water service delivery as an alternative source of water

distribution, replacing the conventional pipe-borne water supply (Nanle et al., 2024). Despite the lack of safety and quality assurance, people still patronize these informal water supplies, as they are the only readily available water sources. It involves the private vending of water for domestic use, not including bottled or packaged water (Tajuri, 2017) Water vendors can sell water directly to consumers or act as middlemen, selling drinking water to carriers who serve the consumers (Kılıç, 2020). Reselling refers to the owner of the water connection water of sale to customers who fetch it and pay the stipulated amount. One of the major problems observed with water supply and distribution in the Wukari metropolis is the inhabitants' inability to see some of the water vendors and distributors around their neighborhood (WHO, 2018; Kılıç, 2020). Therefore, this study aims to provide the inhabitants of Wukari with a platform where they can log in and place water orders, for direct delivery to their homes at a predetermined price using their phones. With over 300 million phones in use and 850,000 devices activated daily, a website offers flexibility and freedom (Kirthika et al., 2015; Manishaben, 2015). The web's potential in e-commerce and business activities, along with the growing use of smartphones, makes it an ideal platform for developing an application for water delivery to Wukari residents (Manishaben 2018) This study designed a web-based water supply management system that will enable the inhabitants of Wukari metropolis to place water orders using their smart mobile phones or devices and make offline payments.

Nigeria, a tropical country with a vast surface water resource of approximately 267.3 billion cubic meters, is home to numerous states with abundant water resources. Nigeria's 36 states have abundant water resources, some named after prominent rivers. The country's annual surface water volume of 215 cubic kilometers surpasses that of many other African nations (Haider, 2019). The country's annual precipitation levels vary significantly, ranging from over 4,000 millimetres in the South-Eastern areas to less than 250 millimeters in the extremely arid North-Eastern regions where Wukari metropolis is located. The contrast in precipitation levels between the north and south, around 500 millimeters and over 4,000 millimeters respectively, reflects the tropical climate's variability (Okoloye et al., 2013). This complexity, particularly in Nigeria's Sahelian region, requires meticulous water resource management. Understanding Nigeria's climatic diversity, water resource potential, and the parameters for evaluating water supply systems is essential for designing the Web-based water supply management system that meets the specific needs and challenges of the Wukari metropolis located in the Sahel region.

Sultana and Sultana, (2019) Conducted a study in Nelatur Village aimed to optimize the current intermittent water supply system using EPANET software, focusing on the importance of technological tools for efficient network design. In 2020 Umachagi et al., (2020) Introduced an innovative automated water distribution system using SCADA and PLC technologies, powered by water flow kinetic energy and incorporating a GSM modem for real-time monitoring, emphasizing automation's importance in controlling water supply and preventing theft. Li and Li (2021) conducted a comprehensive literature review and analysis, revealing shifting research trends in water distribution systems. Their work highlighted the evolving focus from water quality and network configuration to contemporary issues such as climate change, resilience, leak detection, and energy recovery. Mohammed et al., (2021) conducted a thorough literature review of related articles and subsequently explored the design of two specific components within the water distribution system to efficiently deliver water from reservoirs or aqueducts to end-users such as residential, commercial, and industrial using Erbil as a case study. The study focuses particularly on optimizing pumps and storage tanks. The optimization process aims to reduce the overall project cost by minimizing the volume of elevated tanks, aligned with the operational hours of the pumps. Khasraw et al., (2021) discussed the critical role of water distribution systems in ensuring the effective transport of potable water to consumers. They emphasized the importance of optimization methodologies in achieving cost-effective and well-designed water supply networks, considering factors like system scale and constraints. Their study underlined the need for optimal design practices in modern water distribution systems. Ye et al., (2018) and Salimi et al.,(2018) explored water management within buildings and water hammer phenomena, respectively. Ye et al., (2018) focused on enhancing water distribution and disposal systems within buildings, aligning with the growing demands for improved water-related functionalities. The reviewed studies collectively emphasize the significance of efficient and equitable water distribution systems. They showcase innovative technologies, optimization methodologies, and evolving research trends that inform the design and implementation of water supply management systems. By integrating these insights, a holistic and technologically advanced solution to ensure a reliable, sustainable, and responsive water supply was developed for Wukari metropolis. Therefore, this study aims to Design and Implement a seemless web-based Water Supply Management System for residents of Wukari metropolis.

MATERIALS AND METHODS

Analysis of Existing System

The water supply system in Wukari local government area, especially in the metropolis still relies on the old traditional

practice; that is, scouting for water vendors around the community to augment their water needs. Most often it is difficult for the residents of Wukari metropolis to find water vendors in their neighborhood.

Weakness of the Existing System

The existing system involves traditional water vending and scouting for water vendors to be able to buy water for the domestic and other water needs of the residents. Some of the weaknesses existing system include:

1. It often takes longer time for the residents to scout for water vendors in their area.
2. The water vendors are often not aware of the high water demand in other areas within Wukari metropolis.
3. The water vendors were most often confined to a particular area in the Wukari metropolis.

Methods

This research adopted an Object-oriented design methodology. The Unified Modelling Language method which allows for the development of a system is an iterative process that was adopted for the development of this system using the use case diagram a narrative that describes the sequence of events when an actor (external to the system) uses the system to complete a process and Class diagram that shows the structure of the software in terms of the constituent classes and how each class is related to other classes was used to model the system as seen in Figure 1 and Figure 2. The study focused on developing a secure web-based water supply management system using a combination of software applications and hardware components. These tools include: - front-end application design using HTML, CSS, and JavaScript languages; a database engine MySQL for back-end database storage, and operational logic languages PHP. This project's development relies on the following hardware components: Intel Pentium IV of at least 1.30 GHz, 4 GB of random-access memory (RAM), 20 GB of hard drive space, keyboard, LCD screen, and mouse.

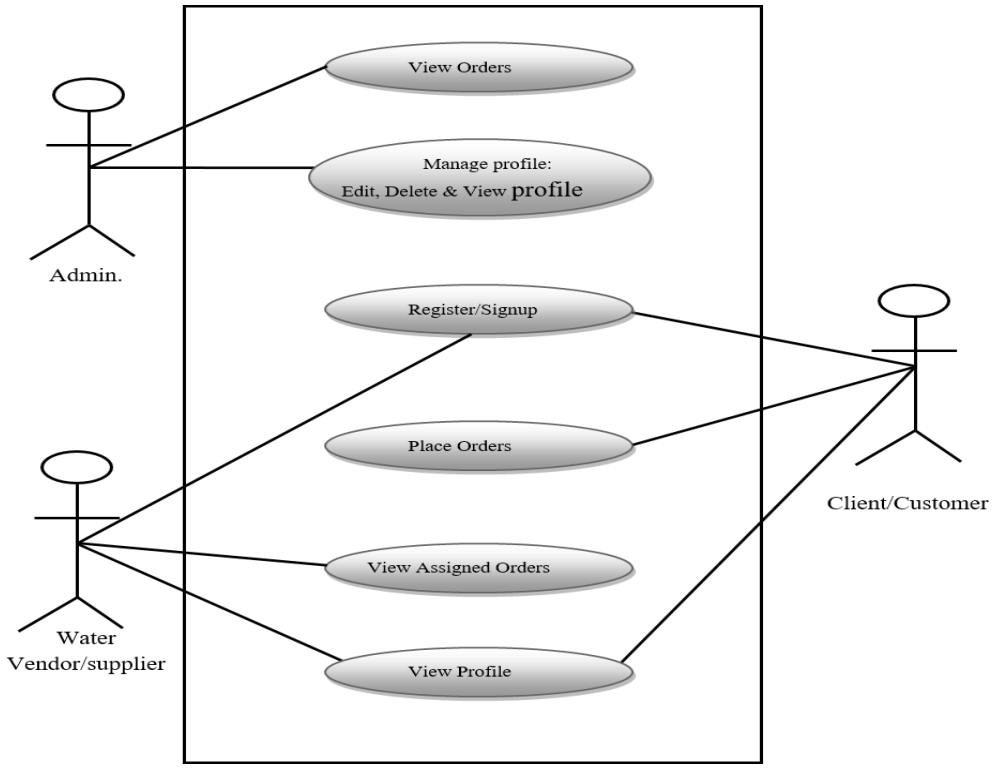

Figure 1: System Use Case Diagram

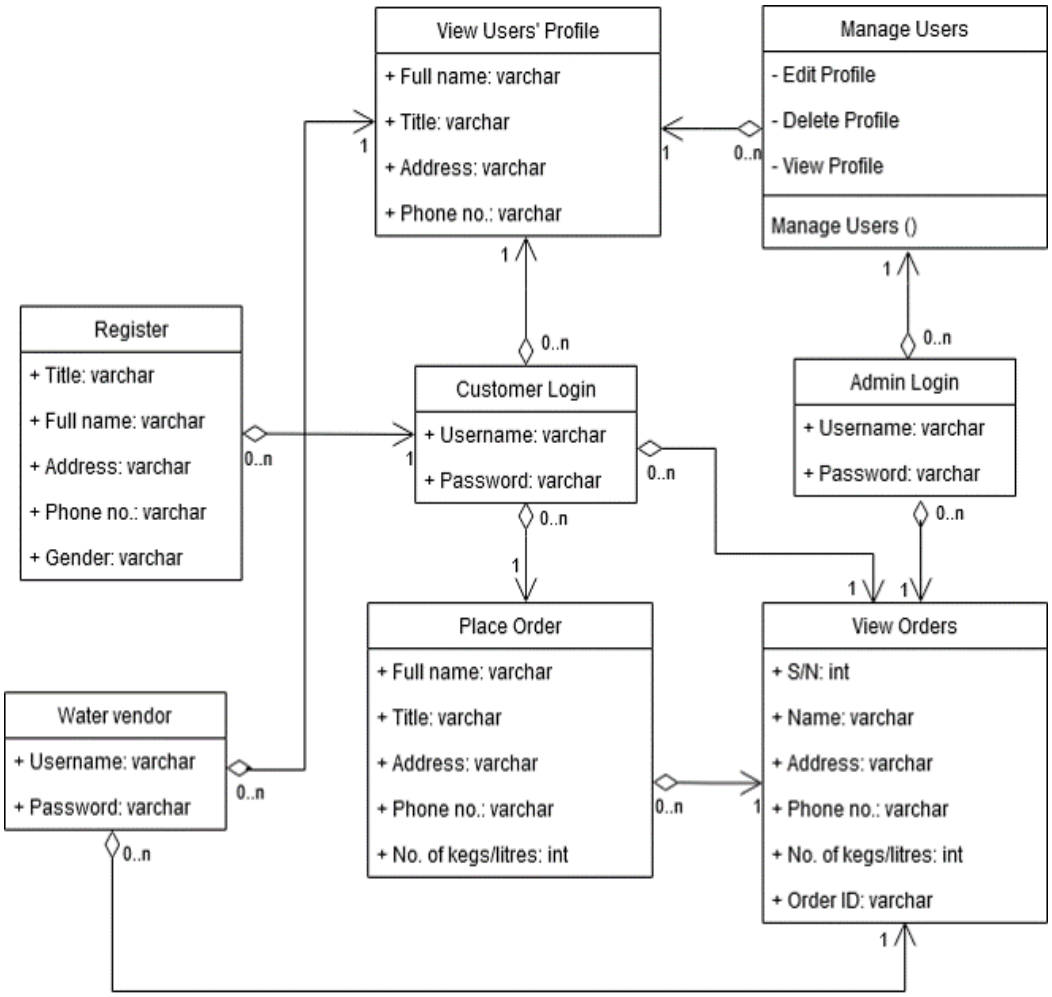

Figure 2: System Class Diagram

System Flow Chart

The users' functions within the system are depicted in the system flowchart in Figure 3. There is a two-way flow of information between users and the database in exchanging order-related data while administrators and the database communicate user and order information. This flowchart shows a simple system for placing orders and managing users, with a database serving as the core hub for storing and managing user and order information.

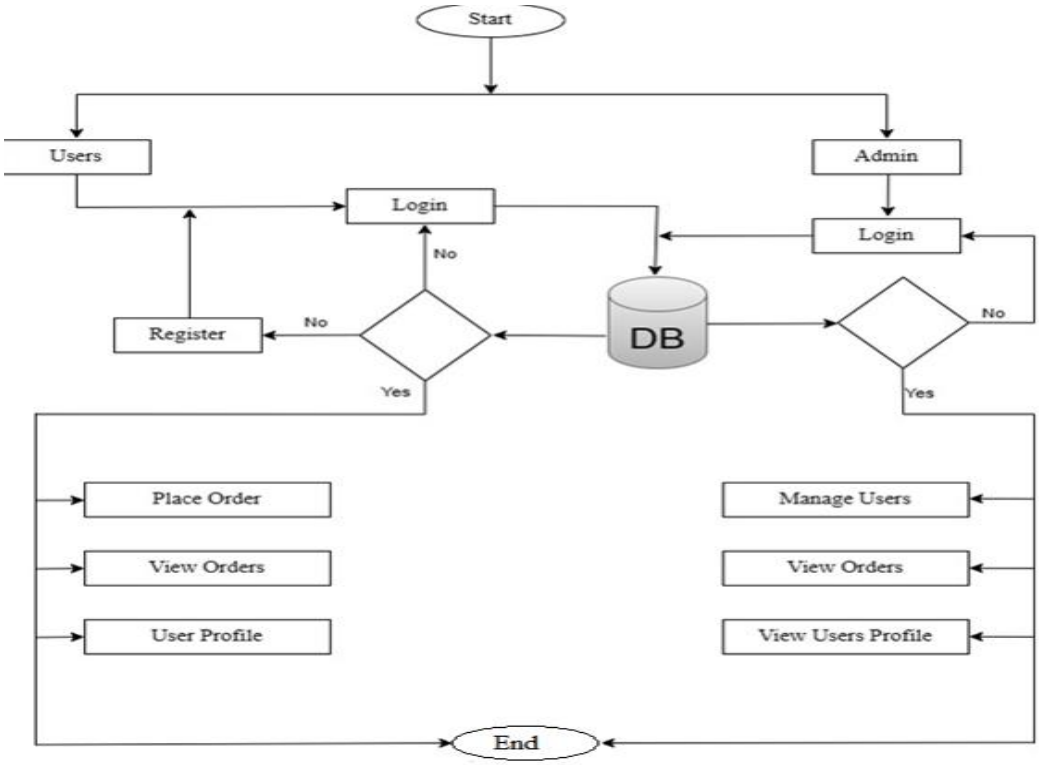

Figure 3: System Flow Chart

Database Design and Structure

The MySQLi database was chosen as the database development tool for the system design because it supports prepared statements, preventing intruders from attempting to gain authorized access to the system through PHP injection. A simple relational database design and structure were used during the enrolment phase to store information in tables (rows and columns). Each column was defined along with its properties. Figure 4 shows a vendor and customer entity relationship diagram. The vendor has an ID, full name, address, and phone number. The customer has an ID, full name, address, phone number, and the number of kegs they ordered.

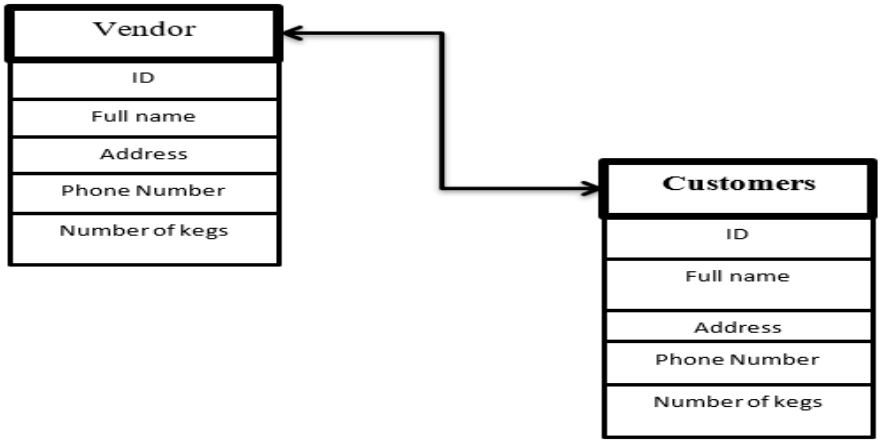

Figure 4: Database Entity Relationship diagram

RESULTS AND DISCUSSION

The proposed system was implemented for a digital, seamless water supply system for Wukari metropolis. The result of the implemented system shows the GUI of the different pages used for carrying out different tasks on the water supply management system. The Key modules developed and implemented for the effective use of the water management system include the account creation

module, the login module, the admin control menu module, which allows the admin to coordinate the activities of the system, the water vendor module, which allows water vendors to view orders placed by customers, and the customers' module, which allows consumers to place water orders and view the orders.

The login module

The login page as shown in Figure 5 was implemented for Customers, water vendors, and system administrators to log into the system and carry out necessary tasks according to their respective levels of privilege. The login page is displayed automatically when a user clicks on the login button. This form enables the user to submit their login credentials into the system; on submission of correct login credentials, each user of the system uses one login interface for all the levels of the system users (Admin, Water vendors, and customers). The system determines user privilege to load based on the login parameter supplied but when the login credentials are incorrect, the user is denied access to the system resources. A password reset option is also made available on the login for password resetting.

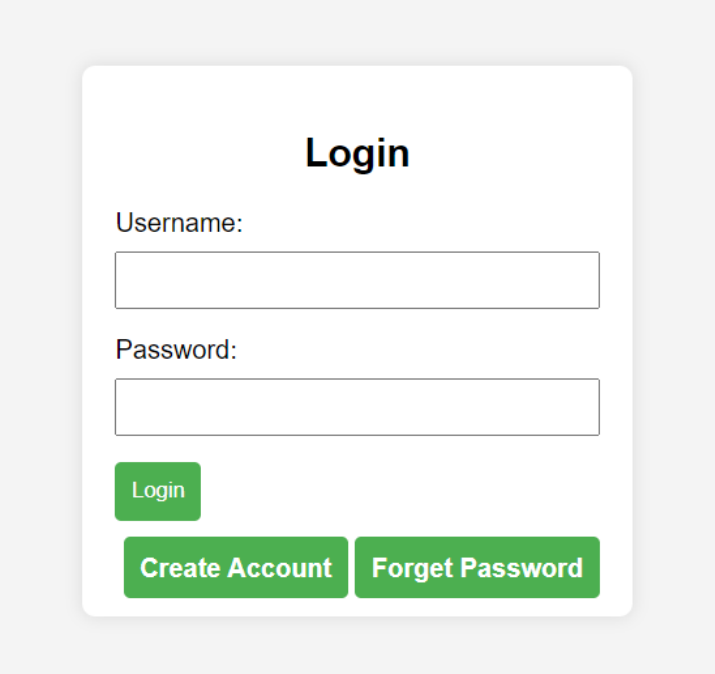

Figure 5: System login page

The Control module

This is the page that is been displayed when a user logs in to the system as an administrator. The control interface of the proposed system was implemented for all operations that will be carried out by the admin on the system. This page grants the admin the privilege to edit the system user profile, modify the user's biodata on the system, view the system user profile, display the complete list of both water vendors and customers registered on the system, view water order placed by the customers, drop/delete a water vendor/customer record from the system as shown in Figure 6.

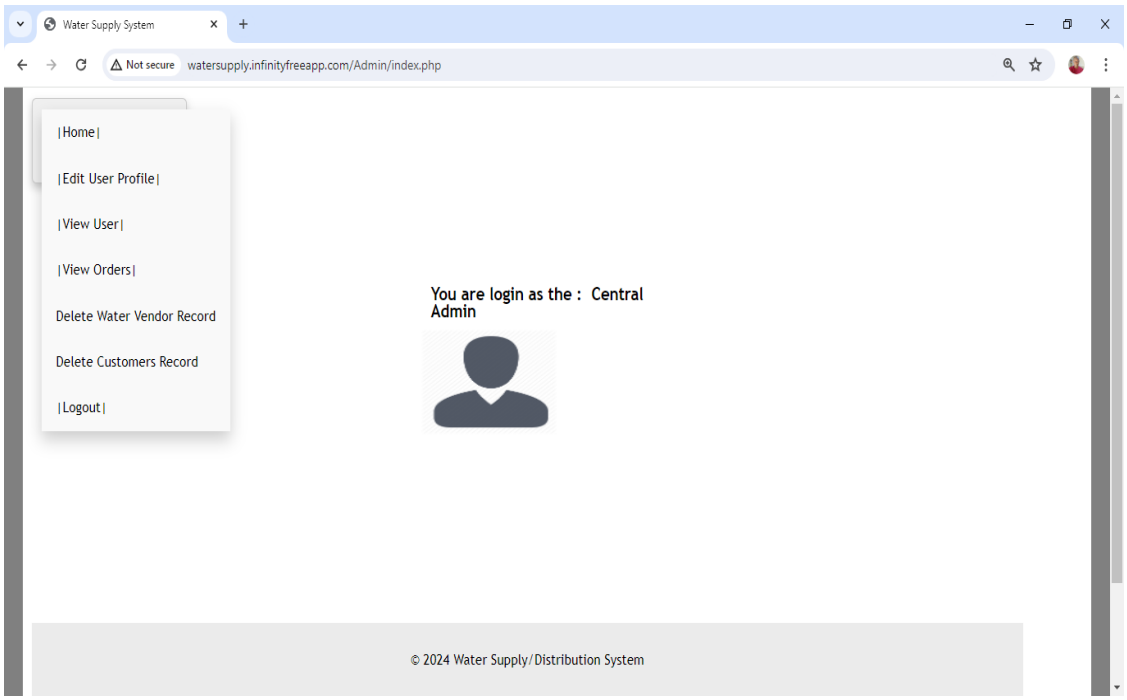

Figure 6: Control menus interface

Create Account module

The create account module of the proposed system was implemented to allow new water vendors and customers of the water management system to Sign up on their first visit to the system while subsequently, they will be required to use the login details created during the sign-up to log into the system. The Create Account module was implemented using the signup form shown in Figure7.

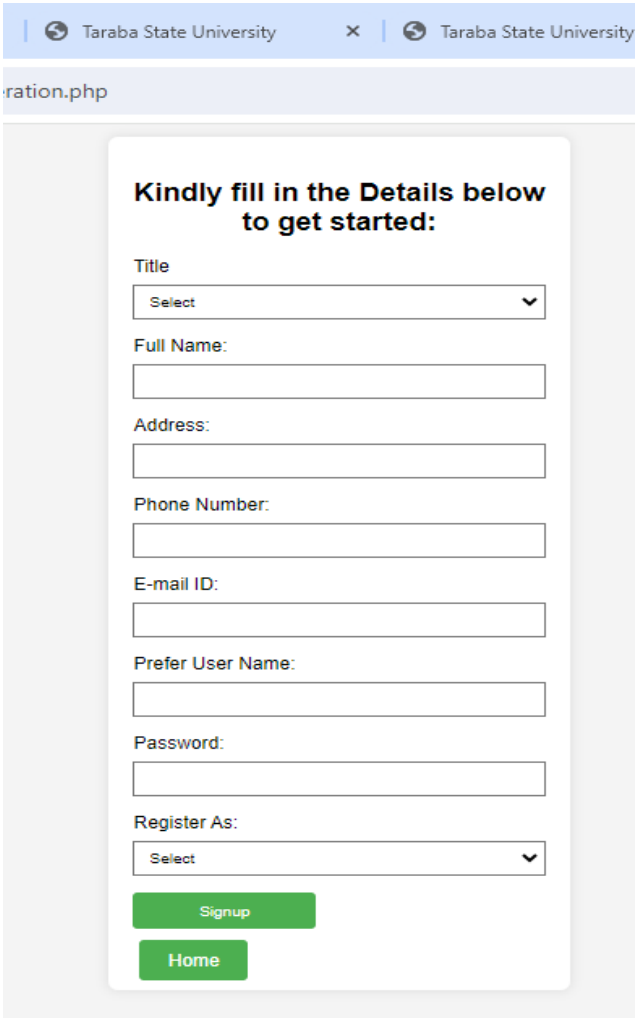

Figure 7: Create account form

Water Vendor Dashboard

The implemented water vendor dashboard is the page that is displayed when a user logs in to the system as a water vendor. This page gives the water vendors the privilege to view orders placed by the customers that were specifically assigned to him or her to make a delivery of the order. Figure 8 below displays the interface for a specific water vendor's list of assigned orders.

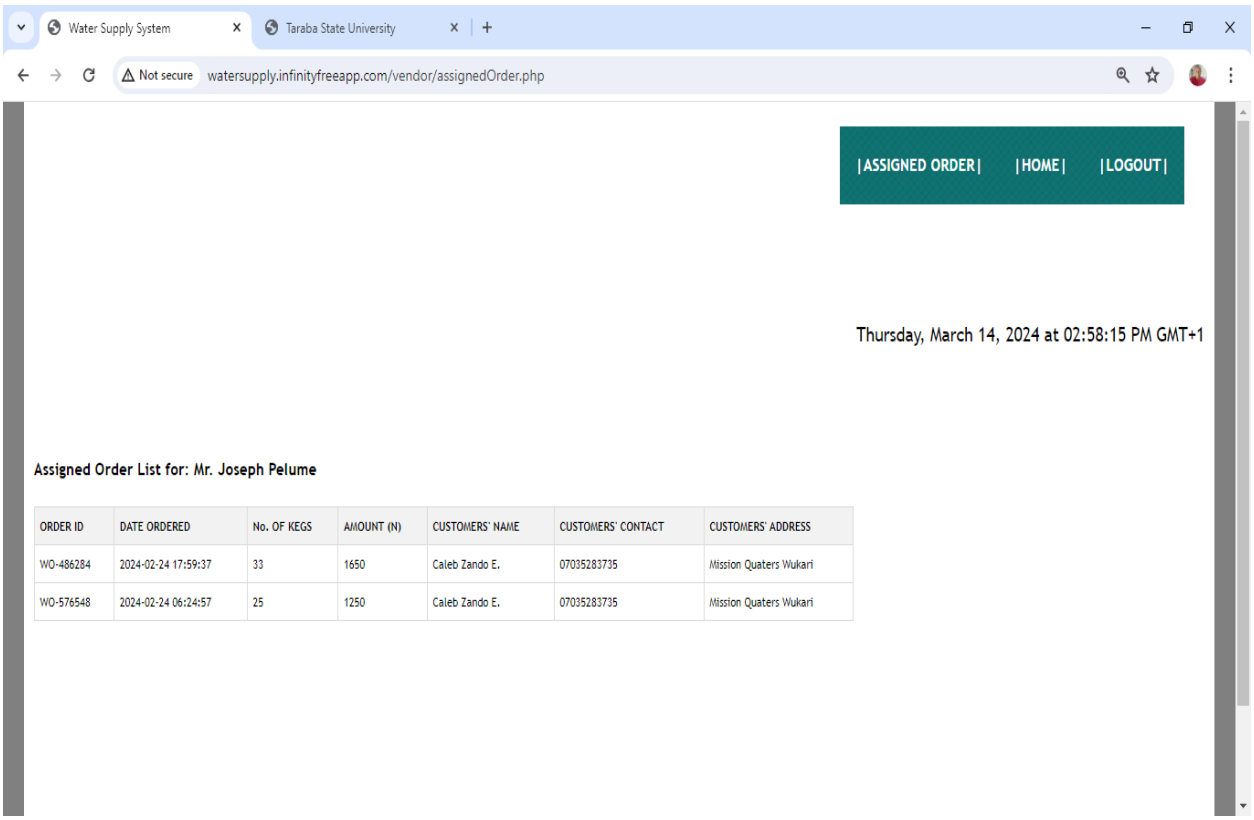

Figure 8: Water Vendor Dashboard

Customer's module

The customer module is the page that will be displayed when a user logs in to the system as a customer. This page was developed and implemented to allow the customer to place a water order as seen in Figure 9, and view their placed orders as seen in Figure 10. To place a water order, the customer clicks on the Place Order button and fills in the number of kegs (in figure) that he/she wants to order. The other details associated with the customer are automatically filled in by the system. This was to make the process of placing an order seamless and easier for the system users.

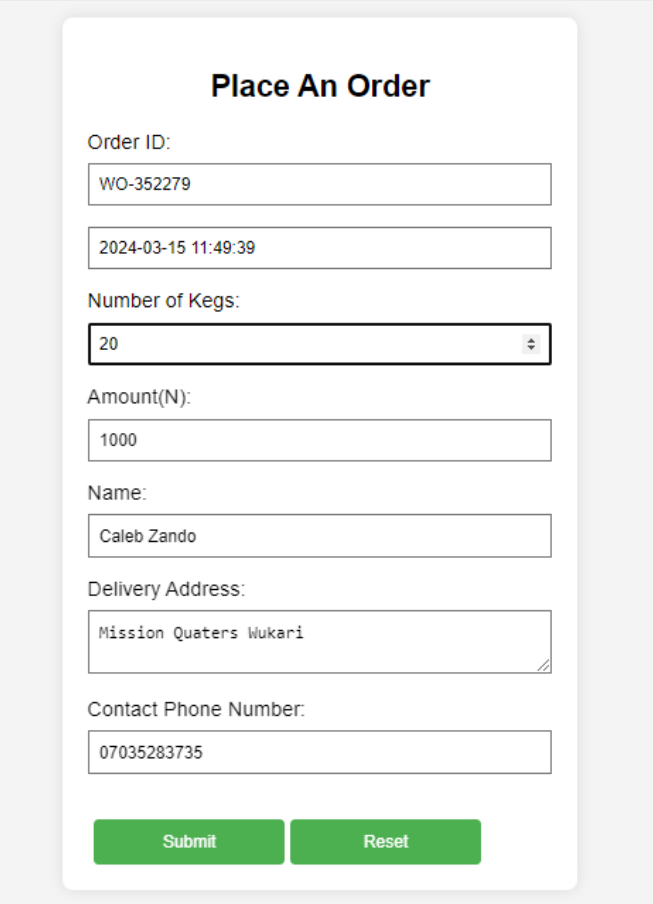

Figure 9: Customer Place Order Form

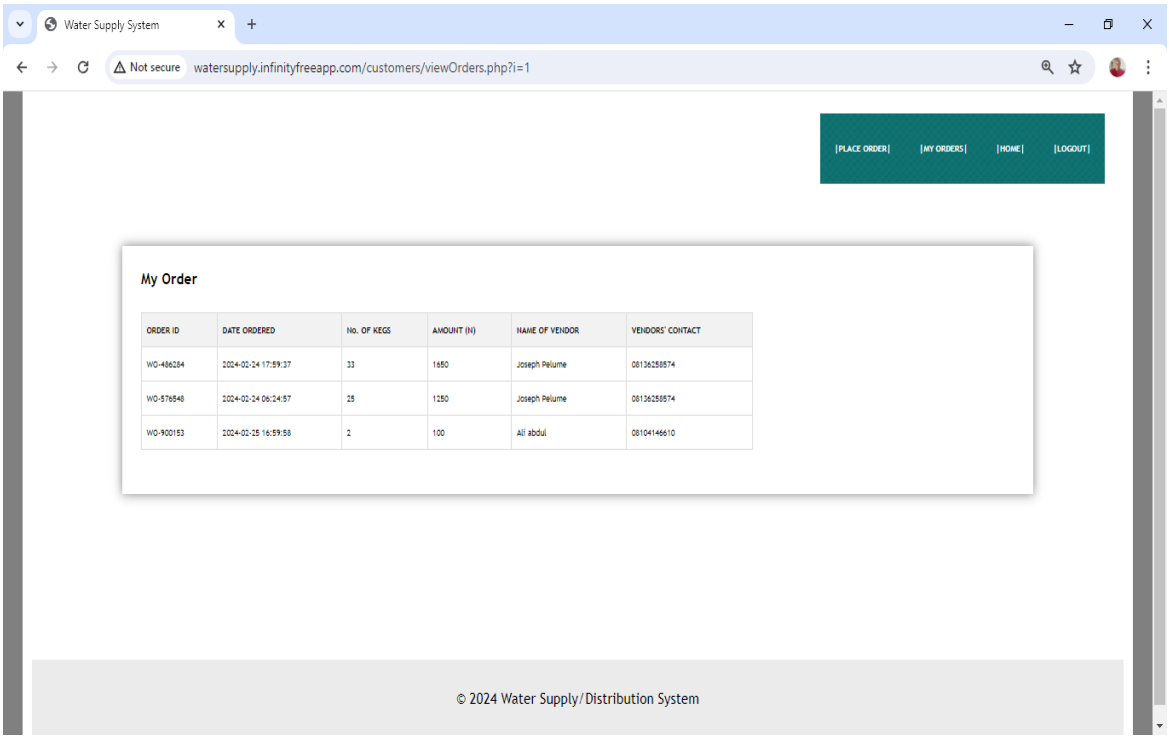

Figure 10: Customer Order List

Discussion

The main aim of this research was to create a seamless water supply management system for the residents of Wukari Metropolis that would maximise supply times and reduce costs. The development and implementation of the web-based water supply management system yielded significant results in terms of system efficiency, user engagement, and better water resource management. The end users of the system, including administrators, water vendors, and customers, required minimal training to effectively use the application due to the system's user-friendly interface (UFI), which is designed to be intuitive and simple to use. Using the Master Test Plan to test the functionality of the developed system and confirm whether it meets the SRS requirement, the system achieved a 99% test accuracy. Table 1 below summarises this test result. The implemented results show big improvements in several key areas, which are in line with similar findings in the work of Khasraw et al. (2021), which show that a water supply management system can improve the supply of clean water in rural areas. Additionally, the study found that the web-based water management system increased access to clean water by 50%, which is consistent with the findings of Sultana and Sultana (2019) in similar systems. The research by Mohammed et al. (2021) also highlighted how digital platforms enhance decision-making and optimise resources. This study further supports those findings, demonstrating how the proposed systems reduce manual work and save costs for water vendors and customers in the Wukari metropolis.

Table 1: Master test plan of the proposed system

Project name: Digital Solution for Seamless Water Supply Management in Wukari Metropolis

Test Case ID	Test title	Test Steps	Test Data	Expected Results	Actual Results	Pass /Fail
UI_01	Check Super Admin Login with valid Data	Go to http://watersupply.infinityfreeapp.com/index.php Enter Username Enter Password Click Login	Username = Admin Password = admin	The user should log in into the system	As Expected	Pass
Pre-conditions: User has a valid username and password. Pre-conditions: User is validated with the database and successfully log in to the account. The account session details are logged in the database.						
UI_01	Check Login with valid Data	Go to http://watersupply.infinityfreeapp.com/index.php Click on Signup/Login Enter Username Enter Password Click Login	Username = Username Password = password	User should Login into system based on the user privilege	As Expected	Pass
UI_02	Check place order by customer	Login to http://watersupply.infinityfreeapp.com/customers/index.php Click Place Order Enter number of kegs required Click Submit	Number of kegs = integer	Order should be submitted and stored in the database	As Expected	Pass
UI_03	Check view order by customer	Login to http://watersupply.infinityfreeapp.com/customers/index.php Click My Order	Null	List of Orders should be display	As Expected	Pass
UI_04	Check logout	Login to http://watersupply.infinityfreeapp.com/customers/index.php	Null	Session should end/terminated and user	As Expected	Pass

		Click Logout		redirected to index page		
UI_05	Check Assigned Order by Water Vendor	Login to http://watersupply.infinityfreeapp.com/vendor/assignedOrder.php Click view staff strength by MDAs	Null	List of orders specifically assigned to water vendor should be display	As Expected	Pass
UI_06	Check Edit User Record by Admin	Login to http://watersupply.infinityfreeapp.com/Admin/index.php? Click Edit User Profile		A specified user to edit his/her profile should be display for editing	As Expected	Pass
UI_07	Check view User Profile by Admin	Login to http://watersupply.infinityfreeapp.com/Admin/index.php? Click View User		Complete list of users (water vendors and customers) should be display	As Expected	Pass
UI_08	Check View Orders	Login to http://watersupply.infinityfreeapp.com/Admin/index.php? Click control menu Click View Orders		A list of orders placed by customers should be diplay	As Expected	Pass
UI_09	Check delete water vendor records/customers ' records	Login to http://watersupply.infinityfreeapp.com/Admin/index.php? Click delete water vendor records	Null	Specify the water vendor records should be deleted	As Expected	Pass
UI_10	Check log out by Admin	Login to http://watersupply.infinityfreeapp.com/Admin/index.php? Click logout	Null	Session should end/terminated and redirect to index page	As Expected	Pass

CONCLUSION

Water vending is an old activity across the world, especially in impoverished communities like Wukari. Vendors bring water to customers' homes using a variety of vehicles, including hand carts, donkey carts, pushcarts, and tank trucks; this system is essential to the water supply. One of the primary concerns noted with the water supply and distribution in the Wukari metropolis is the residents' inability to see some of the water sellers and distributors in their neighbourhood. The newly developed system is viable and promising in addressing the challenges associated with the traditional method of scouting for water vendors to buy water for domestic and other household needs in the Wukari metropolis. The developed system was able to meet the software requirement specification (SRS) which includes: the creation of a secure database for the system, signup/registration by new users, placing water orders, viewing orders, viewing users, editing users' records, and delete water vendors/customers records. The new system can be deployed by either private individuals or corporate business organizations to ensure efficient water supply distribution and management within the Wukari metropolis. For further research, the scope of the project can be extended to cover other areas in Taraba State and neighboring states. Google Maps can be embedded in future research in allocating/assigning water orders to water vendors. Future research should consider implementing an online payment module for the system.

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