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Automation of Drinking Water Collection Processes in the Rural Sectors of the Province of Chimborazo-Ecuador, using Free Software

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— Abstract—

The automation of drinking water collection processes in the rural sectors of the province of Chimborazo, Ecuador, arises in response to the need to improve the efficiency and transparency of the water resources management in these areas. The objectives of the research were to replace manual processes with an automated system using open-source software, specifically by creating a website for water billing. The scope of the project involved developing the application, providing training to users, and establishing a water resource management that was managed in a democratic and participatory manner by a board made up of the community members of the area. The main results obtained were efficient and transparent management of water resources, as well as a significant improvement in access and quality of basic drinking water services in rural areas. Furthermore, the inclusion of villagers in project management allowed for more fair and equitable management of resources.

Keywords:

Drinking wáter; automation; free software; rural sectors.

Water, as a vital and limited resource in the last decade, has led all actors of society, politicians, social organizations, and the general population to cooperate to maintain this resource for the next generations (Torres, 2019). As Cheza (2014) points out, in the province of Chimborazo, Ecuador, rural sectors face challenges in the management and collection of drinking water, which has resulted in problems such as lack of transparency, errors in the measurement of consumption, and delays in customer service. The lack of automation of these processes has led to inefficient and error-prone management.

According to Gómez et al., (2021), in Latin America there are challenges in the access and administration of drinking water services in the rural sectors, some places do not have access, while in others there are deficiencies such as continuity. Despite these shortcomings, the population shows high levels of satisfaction with the services received, which raises questions about drinking water services and their administration. On the other hand, Moreno (2020) states that, in Colombia, to improve the management of drinking water in rural areas, indicators must be established, associated with the administration, measurement, and continuity of the service. In addition, it seeks to strengthen community management and the participation of all levels of the State to guarantee, in a sustainable way, the coverage and quality of these services throughout the country. Soto et al., (2016) state that the administration of drinking water in rural areas of Costa Rica presents challenges due to the conditions of the land, the distance between the houses, and the low profitability of the service. In these areas, Aqueduct Management Associations have emerged as a response to the difficulties faced by the state in providing the service. Although these have worked thanks to the efforts of farmers, the increase in population and productive activities causes risks of contamination and deterioration of water, climate change, and inadequate land uses affect the distribution of liquid, causing rationing. From the point of view of Vásconez (2018), the management of drinking water in rural areas, through the Rural Drinking Water Boards in Ecuador, is based on the use of existing social capital. These organizations arose to meet the need for water in rural households due to government limitations. The Organic Law of Water Resources in Ecuador establishes that water administration can be public, being the responsibility of local governments through public water companies. For Quindi et al., (2018), access to water in rural sectors for human consumption requires a sustainable and solid technical infrastructure. The information collected by the diagnostics and monitoring of drinking water systems must be in reference databases that allow cataloging and managing public water management within the community.

Although the above studies are relevant and contribute to the research, it is crucial to point out some deficiencies and areas for improvement

that could optimize the understanding and approach to the challenges of drinking water management in rural areas of Latin America. The levels of satisfaction of the population must have a more detailed evaluation of the quality of water services but above all the administration. In the case of Colombia, the proposal to establish indicators is positive. However, more specificity is needed on how indicators would be implemented and managed. The management of drinking water in rural areas of Costa Rica presents challenges, such as the profitability of the service and geography, so further exploration of solutions is needed, especially for the administration. None of the studies examined addressed automation processes for water administration or collection in rural areas, none of them focusing on the use of automation technologies to improve the efficiency and transparency of management and collection processes.

This study focuses on the automation of drinking water collection processes in rural areas of the Province of Chimborazo, Ecuador, using free software. This research collaborates with the field of study of drinking water management in rural areas and also proposes a practical and technological solution to improve the management of vital resources in rural areas. The implementation of an automated drinking water collection system using free software can serve as a replicable and scalable model to solve specific administration and billing problems in rural communities in Latin America.

The article is structured as follows: the introduction presents a review of the existing literature on drinking water management in rural areas, highlighting the problems and solutions that have been found in previous research. Subsequently, the methodological framework was used to develop and implement the automation system. Then, the results and discussion of the implementation of the system that include improvements in the efficiency and transparency of the collection processes. Finally, the conclusions where suggestions for future research and practical applications of drinking water management in rural areas are given.

MATERIALS AND METHODS

Location of the study area

The research was carried out in the Tolte community of the Pistishi Parish, belonging to the Alausí canton, province of Chimborazo, Ecuador.

Methodology

To develop the system, two proposals were processed: a preliminary one, in which a process of gathering information was carried out, which started from a theoretical, conceptual, and legal level, with a review of bibliographic

sources in e Scielo, Scopus, and Latindex. Authors such as Gil et al., (2014) and Moreno (2020) stand out, who specify, from a judicial point of view, the specific legislation on the collection of drinking water in rural sectors that may vary according to the region. Generally speaking, however, there are likely to be laws and regulations that establish the legal framework for the provision of drinking water services in rural areas, including issues such as technological automation, water resource management, land ownership, and use, user rights, fee setting, and conflict resolution. In addition, the creation of public or private entities in charge of providing these services and ensuring compliance with established regulations may be required. According to Cabrera and Mardones (2015), the automation of drinking water collection processes can improve the efficiency, transparency, and accessibility of water services in rural areas. However, it is important to note that results may vary depending on the region and the specific circumstances of each community. For Cano and Flores (2021), the design of automation and control systems for water purification systems is presented as a solution to improve the efficiency and quality of water distribution in rural areas. These systems can be installed in a variety of infrastructures at a reasonable price. On the other hand, Escuintla and Domínguez (2020) mention that the automation of the administrative processes of drinking water associations in El Salvador has been fundamental to improving efficiency and reducing costs. Automation has reduced human errors, increased the speed of task execution, and provided timely information for more efficient water resource management. According to these successful experiences described above, where the automation of the administrative processes of drinking water associations has resulted in greater efficiency and cost reduction, they support the importance of automation in water resource management in rural settings. Therefore, based on previous research, two main variables were considered in this study: automation of processes and accessibility of services. Process automation refers to the implementation of systems and technologies that automatically perform tasks related to the collection and management of drinking water services. On the other hand, the accessibility of services refers to the ease with which users can access and use the website, including aspects such as availability, affordability, and quality of service. As for the methodology, the Unified Process, proposed by García and García (2019) for the development of the website, will be used. The Unified Process is an iterative and incremental approach that adapts well to projects where the requirements are not completely defined at the beginning and can evolve, in which the research base begins in the Conception phase, where the current management and the obtaining of basic operational information is evaluated, and then begins with the Elaboration of the collection system, its construction, and transition. According to Zumba and

León (2018), these processes allow systems to be developed quickly. For the programming, we use the PHP language through Laravel as a Framework, and MySQL as a database manager, both the methodology and the tools will allow greater flexibility to adapt the system to the specific needs of users and the context of the Province of Chimborazo, Ecuador.

To complement the research, surveys were applied to 70 users, who have a drinking water connection and who are part of the organization "Water Board for Human Consumption", which is a non-legalized association that depends on SENAGUA (National Water Secretariat), a state company of the Water Resource Administration in Ecuador. The objective of the survey was to know how the payment process is for consumption, depending on whether the value increases or decreases, whether payment receipts are delivered or not, and how the record of their payments is kept. Since the calculation of the water service fee is according to a value approved by the board and depends directly on the readings of the meters installed in the home of each partner who has previously requested drinking water service, the data obtained were as follows:

Table 1
Survey Data

Question	Answer
How often do you get drinking water service in your home?	• Daily (60%) • Weekly (15%) • Monthly (5%) • Occasionally (2 0%)
How would you rate the quality of the drinking water service you receive?	• Excellent (15%) • Good (45%) • Regular (30%) • Poor (10%)
Do you receive a payment receipt for drinking water service?	• Yes (70%) • No (30%)
How is the drinking water bill calculated? Is it based on the consumption recorded by a meter installed in your home?	• Based on consumption recorded by the meter (85%) • Not based on consumption recorded by meter (15%)
Do you consider the payment process for drinking water to be transparent?	• Yes (50%) • No (30%) • Not sure (20%)
How do you keep track of your payments for drinking water service?	• With payment receipts (80%) • With other records (20%)
Have you experienced any unexpected increase or decrease in the value of your drinking water bill?	• Yes (40%) • No (60%)
How do you evaluate the communication and coordination with the Water for Human Consumption Board about the collection for the drinking water service?	• Excellent (10%) • Good (50%) • Regular (30%) • Poor (10%)
Do you think the Water Board should implement an automated system for the collection of drinking water services?	• Yes (60%) • No (30%) • Not sure (10%)

RESULTS AND DISCUSSION

In the development and implementation of the Tolte community's drinking water collection website, the Initiation, Elaboration, Construction, and Transition stages were established.

Beginning Stage

For this stage, information was collected on the current process of collecting drinking water, including the number of users, the amount of water supplied, operating costs, and other relevant details. Once the data was obtained, the problems in the collection of drinking water were identified. Are there users who are not paying their water bills? Is there a low level of fundraising? Is the manual collection system difficult for collectors?, How is each partner's information handled? Can sanctions be implemented for users who do not pay? The rates were evaluated to ensure that they were fair and reasonable. Users' ability to pay was considered. This stage resulted in an overview and list of use cases such as System Authentication, Customer Management, Meter Management, Payment Management, User Management, Report Generator, and Reading Taking.

Development Phase

The design of interfaces allows you to have an idea of how navigation is intended to be within the page of the informative site, this can be structured with multimedia content that contributes to the aesthetic presentation of the website, in this way, you have a general idea of how the website of the Drinking Water Management Board will be composed. The elements to consider are:

- **Logo**. The image or name of the Board of Directors was placed, a space that serves as identification and exposure of the company on the website.
- **Menu**. It is an important navigation tool that allows users to quickly find and access the different sections of the website. A good menu can also improve usability and user experience by making information easier to find and accessible.
- **Informative Content**. All the elements of the site are arranged within this section; modules, contents, and images. This section is adaptable to all browsers and devices that control the collection system of the administrative board.
- **Content**. The content on the Drinking Water Board Collections page is meaningful because it contains what users are looking for

when they visit the page. Whether they're looking for information or the ability to take a specific action (like registering or signing up for updates), the content on the website was designed to meet those needs.

- **Page footer**. The footer is the section of the webpage at the bottom. It is an important section that contains valuable information of interest to the Management Board such as Contact Information, Important Links, Copyright Attribution, Legal Notices, Social Media, and Additional Information.

Based on the above, the main page is established according to Figure 1.

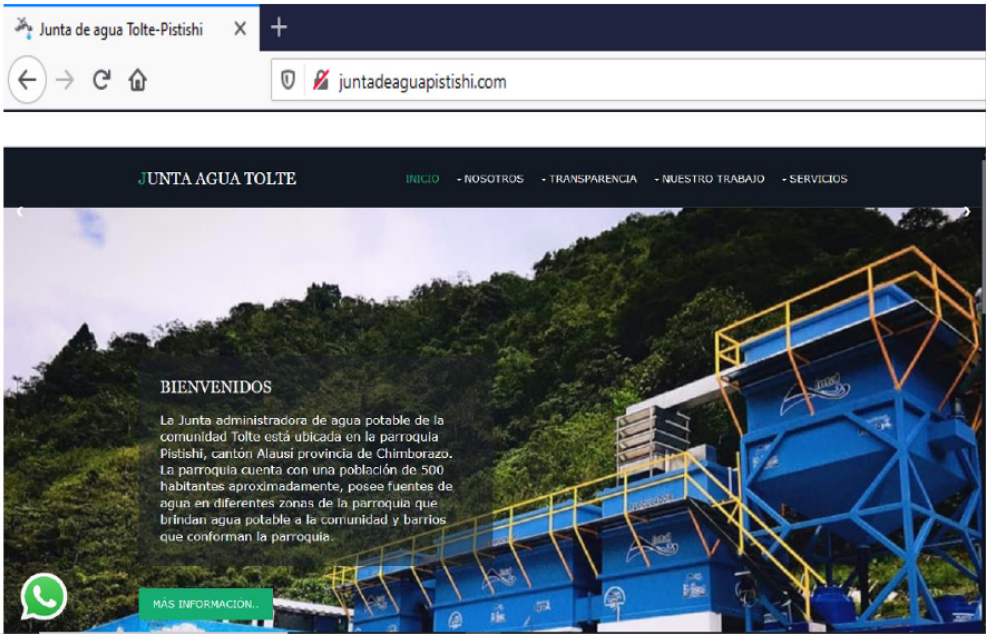

Figure 1. Home Drinking Water Board Pistishi

Construction Phase

Once the initiation and elaboration stages were completed, the development of the system began. This included:

- **Selection of tools**. PHP and MySQL are powerful tools that were used for the development of this site. During this stage, he made sure that the PHP and MySQL versions were up-to-date and compatible with the development tools used, such as IDE, and Laravel Framework.

- **Architecture Design**. During this stage of development, the system architecture was designed, including how the data in the MySQL database is structured, how the PHP application communicates with the database, and how user requests are handled.
- **Coding**. Once the architecture design was completed, coding of the system was started. Good programming practices were employed, such as writing clean, modular, and scalable code, and using software design patterns to improve code quality and efficiency.
- **Security**. During the development stage, the security of the system was taken into account. This included implementing security measures, such as using strong passwords, validating input data, and protecting against SQL injection and cross-site scripting (XSS) attacks.
- **Testing and Debugging**. After completion of coding, extensive testing and debugging were performed to ensure that the system was working properly. This included unit testing, integration testing, and acceptance testing to ensure that all system functionalities were running according to specifications.

Transition Stage

This stage was crucial to ensure that the web-based drinking water collection system in PHP with Laravel framework and MySQL database is effectively and seamlessly implemented on the Board. The following was considered:

- **System Delivery**. After system development and testing is complete, it is important to deliver the system to the end users (see Table 1), and to the Board's support team. A delivery meeting was held to ensure that everyone involved was aware of the details of the system, including how it is used, how maintenance is performed, and how problems are fixed.
- **User training**. It is important to train end users so that they can use the system effectively. This included providing detailed documentation, conducting personal or online training sessions, and providing ongoing support to help users solve problems and learn how to use the system effectively.
- **Data migration**. This involved transferring data of different formats to the MySQL database, ensuring that the information is complete and not lost during the process.
- **Server Configuration**. Ensured that the system is properly configured on the servers that will be used for its deployment. This included installing additional software needed, configuring user permissions, and configuring networks and security protocols.

- **Acceptance Testing**. Before deploying the system in a production environment, acceptance testing was performed to ensure that the system was functioning properly in the production environment. This included performance testing, load testing, and safety testing.
- **Implementation and monitoring**. After acceptance testing, the system was deployed in a production environment. The system was monitored regularly to make sure it was working properly and to troubleshoot any issues that might arise. In addition, backup and data recovery procedures were established to ensure that critical information is protected in the event of a system outage.

The results of the validation of the drinking water collection website are presented below, taking into account user satisfaction surveys (Table 2). End-user surveys (testers) were conducted to assess their satisfaction with the website and to obtain feedback on how to improve functionality. According to Redrován et al., (2020), specific questions were asked about system usability, effectiveness, efficiency, ease of use, responsiveness, and overall site quality. In which 10 questions were handled, the evaluation criteria in this metric goes from 1 to 3 respectively. Table 2 shows the evaluations obtained from the Potable Water Board Tester staff, to analyze the questions.

Table 2
Administrators, Tester, and Developer

Organization	Clerks	Testers	Developers	Total
Tolte Community's Administration Board	2	3	1	3

Table 3
Tester Evaluation

	Grade from 1 to 3 (3=excellent, 2=good, 1=bad)		
QUESTION	1	2	Average
1. Do you find the website easy to navigate?	3	3	3,00
2. Was it easy for you to find the information you were looking for on the website?	3	2	2,50
3. Do you find the menus and website structure clear and organized?	3	2	2,50
4. Is the website loading speed right for you?	3	3	3,00
5. Do you find internal website searches effective?	3	2	2,50
6. Did you find it easy to access the different sections of the website?	3	2	2,50
7. Do you think the design of the website makes it easier to navigate?	3	3	3,00
8. Was it easy for you to take actions like registering and logging in as an admin on the website?	1	3	2,00
9. Was it easy for you to perform actions such as making a pay-out and issuing a voucher to the subscriber on the website?	2	2	2,00
10. Was it easy for you to create reports on payments, subscribers, collection by dates, and collection by subscribers on the website?	2	2	2,00
Total average		2.50	

Note. Adapted (Redrován et al., 2020; López et al., 2016).

CONCLUSIONS

The Drinking Water Management Boards have a fundamental role in the management of drinking water in rural areas of our country because they are responsible for managing, maintaining, and operating the drinking water systems in their communities. It is important that training and technical advice be provided to the Boards to strengthen their capacities in the management of drinking water systems and decision-making. In this way, a more efficient and sustainable management of water resources in rural areas is guaranteed.

The automation of drinking water collection processes in rural areas of our country allows us to perform tasks more quickly and accurately, which reduces the time and resources needed against tasks when they are performed manually, in a manual process the possibility of human errors when entering data and performing calculations is very feasible, automation reduces the number of errors especially when issuing invoices and improve the accuracy of records.

The use of free software can make the automation of water collection processes more accessible to rural communities in our province that do not have the resources to acquire proprietary software, since it is not necessary

to pay for licenses or make significant investments in hardware. This can enable more efficient management of economic resources, democratize access to technology, and improve the efficiency and sustainability of drinking water through the administrative boards in these areas.

This research contributes to emphasizing the use of free software with adaptable methodologies when developing websites with specific organizational requirements to support rural farmer organizations, which means that they can access a community of developers and users to collaborate in the development of specific tools and solutions.

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