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Digitalizing Medical Equipment Maintenance: A CMMS Approach Using Google Forms and App Script

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***Abstract*—This research addresses the challenges of technology management in hospitals and clinics, which stem from the limited use of information technology. This limitation leads to adverse consequences, such as delays in maintenance scheduling and inefficient resource utilization. To tackle this issue, a Computerized Maintenance Management System (CMMS) was proposed using Google Forms, specifically adapted to the context of a private clinic in Tegucigalpa, Honduras. A qualitative approach was employed, involving interviews and detailed observations to understand the maintenance department's workflow. Key sections of this process were then digitally replicated using Google Forms and automated with App Script. The resulting system consists of two forms: one for reporting medical equipment failures and another for documenting maintenance work orders. Functionality tests demonstrated that the implementation successfully eliminated paper-based work order management and automated maintenance notifications.**

***Index Terms*—App Script Integration, Biomedical Equipment Maintenance, Digital Workflow Optimization, Google Forms Automation, Preventive and Corrective Maintenance**

I. INTRODUCTION

Currently, hospitals are facing significant challenges in managing medical devices, a problem stemming from the overwhelming number of these devices and the shortage of biomedical engineers willing to assume the corresponding responsibility. This issue is not confined to a specific region, as it has manifested in various countries, with a clear example being the case of Thailand evidenced by a study in which the design of a specialized CMMS for the area was required [1].

Honduras is in a transitional phase toward the adoption of technology across various sectors. Although it is classified as a developing country and, consequently, does not typically allocate substantial resources to innovation and technology, the strategic application of these tools in business and industrial management has proven highly beneficial worldwide. From an objective perspective, implementing these technologies is crucial for optimizing processes, whether in administration or other areas. Despite this progress, medical equipment maintenance systems still lack fully digitized management and remain in the early stages of implementation.

In the field of maintenance, the lack of a computerized management system leads to various detrimental consequences. This results in significant delays in maintenance scheduling, unplanned disruptions in medical services, unforeseen costs due to equipment failures, inefficient resource utilization, reduced staff productivity, and, most critically, a potential impact on the quality of patient diagnoses and treatments. The absence of an effective management system in this area poses a significant challenge, affecting the efficiency and effectiveness of healthcare services in our country.

The objective of this research is to design a Computerized Maintenance Management System (CMMS) using Google Forms, focusing on the administration and monitoring of preventive and corrective maintenance activities for medical equipment. This will be achieved by designing a form structure that aligns with the workflow of a private clinic in Tegucigalpa, Honduras, and implementing security measures to safeguard the information stored in the system. This study aims to address the lack of CMMS for the management of medical equipment, as well as the limited budget available for acquiring such systems.

A. State of the Art

It is crucial to highlight that the use of computer systems is experiencing significant growth in various industries and organizations. CMMSs, in particular, are playing a prominent role in automating maintenance systems. Case studies, such as those from Thailand and Benin, support the effectiveness of CMMSs in terms of monetary efficiency and staff productivity [2].

However, the sudden implementation of these systems in unfamiliar environments can pose challenges. Administrative measures are required to facilitate the integration of administrative staff into these systems [3].

Various specialized CMMS systems have been developed to adapt to specific work environments. Notably, some of these systems focus on deeper automation of preventive maintenance schedules. An outstanding example is designed to centralize maintenance action information in the laboratories of Pascual Bravo University Institution. This automates scheduling for conducting preventive maintenance on laboratory equipment, significantly improving process efficiency [4].

According to a study, most private companies in the industrial sector may choose a commercial CMMS, but they opt to develop a customized one to adapt to the peculiarities of their company [5]. An example of this customization is observed in the Biomedical Engineering Department of the Chilean Naval Hospital, where a tailor-made system was designed to meet the specific needs of the military installation. This system follows the generic workflow of clinical engineering maintenance management, which, according to the study, streamlines implementation by following a process already established in the hospital [6].

Within a 2013 study, it is mentioned that a training program should be designed to support an evolving CMMS. Providing multiple formats of specific training for the environment and configured procedures; all aimed at aiding the agile adaptation of the software within the staff [7].

The cases found demonstrate that a popular approach when creating a CMMS is to make it work or maintain the same workflow that was previously in place, with noticeable improvements in the process upon implementing the CMMS, such as the automation presented in the previous cases. In Honduras, the successful implementation of an electronic application in a private hospital has significantly reduced the time spent on the work order storage process. This case highlights the effectiveness of the tool in process optimization and resource consumption reduction [8].

The results of a study provide a successful case of CMMS integration. The implementation of this system has led to significant improvements in data quality and has institutionalized more efficient maintenance practices, establishing a solid foundation for the continuous development of a comprehensive asset management program. These combined efforts have not only optimized operational management but also resulted in substantial cost savings. Specifically, there has been a 30% reduction in overtime hours and a 21% decrease in costs associated with maintenance services and supplies [9] .

Given the importance of real-world case studies, a study closely aligned with the situation in Honduras was identified. Conducted in Burundi, a low-resource country undergoing the implementation of new technologies, this study demonstrated that the adoption of a CMMS in hospitals produced significant positive outcomes. For instance, the average delays in corrective maintenance decreased from 106 to 26 days, and the proportion of functional medical assets increased from 88% to 91% over a three-year CMMS implementation period. This study supports the feasibility and effectiveness of sustainable maintenance software implementation in low-resource settings [10].

Within the realm of maintenance, it is proposed that the application of inspection, preventive, and corrective maintenance strategies is essential. This is supported by international organizations such as the World Health Organization (WHO). The WHO recommends the use of these techniques in medical equipment to extend their lifespan and reduce failure rates. Additionally, it advocates for the use of the GE number, which takes into account the function, application, maintenance, and history of a piece of equipment to calculate a value. This resulting number is utilized to establish the frequency of inspections and preventive maintenance for medical equipment [11].

Furthermore, WHO advocates for the implementation of Computerized Maintenance Management Systems (CMMS) in the management of medical equipment [12]. Aligned with WHO's emphasis on effective maintenance practices, the ISO 55000 standard provides a comprehensive framework for asset management across various industries. It outlines principles and guidelines for optimizing the management of assets, including physical equipment, financial resources, intangible assets, and human capital. By adhering to ISO 55000 standards, organizations can enhance operational efficiency, mitigate risks, and maximize the value derived from their assets, ensuring long-term sustainability and success [13].

B. Use of Google Forms for management

Google Forms is defined as a tool that allows managing event registrations, creating quick opinion surveys, quizzes, and more. With this application, users can create surveys and quizzes directly from their web browser or mobile device, without the need for additional software. Additionally, it provides the ability to view results instantly as soon as they are submitted, and organize them into charts for easy reference and understanding [14].

Google Forms is primarily utilized as a tool for gathering information online for a wide range of purposes. From its basic use as a simple way to collect responses to surveys and questionnaires, to more advanced applications in research environments. For instance, it was employed in a specific case to assess the impact of COVID-19 on agriculture in India and the allied sectors [15].

Within the education environment, Google Forms is widely used for various purposes, including assessing students' knowledge, planning events, collecting contact information, organizing quick surveys, gathering email addresses for newsletters, and more. Its versatility and ease of use make it a valuable tool for teachers, administrators, and students alike. In educational settings, where efficiency and organization are crucial for academic and administrative success, Google Forms has become an indispensable solution [16].

Another use of Forms is to make informed decisions, as evidenced in the case of buying-selling-holding decisions in a stock market [17]. Given the wide range of functions and uses that this tool offers, there is considerable flexibility to adapt and customize it according to the specific needs of a CMMS.

With App Script, Google enables users to modify and add functions to their applications. By writing code in JavaScript, users gain access to built-in libraries for key Google Workspace applications such as Gmail, Calendar, and Drive, among others. One of its main advantages is that no installation is required; a code editor is provided directly in the browser, and the created scripts run efficiently on Google's servers. This platform makes developing and enhancing applications for specific needs more accessible and effective. According to Google, the following features can be added using App Script [18]:

- Automations: Code can be written to programmatically execute tasks across all Google products. These automations can be triggered through custom menus, buttons, user actions, or time-based scheduling.

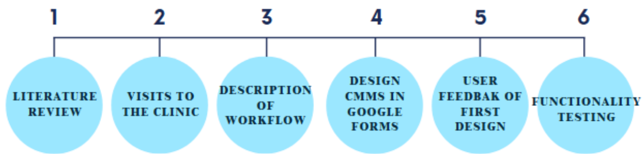

Fig. 1. Research Methodology

- Custom Functions: Specific functions can be created for Google Sheets using Apps Script and invoked from the spreadsheet just like built-in functions.
- Add-ons: Applications can be developed to automate tasks or connect to third-party services within Google Workspace. The resulting solution can be shared with others via the Google Workspace Marketplace.
- Chat Apps: A conversational interface can be built, allowing Google Chat users to interact with services as if they were communicating with a person.

Google Forms is a readily accessible tool compared to CMMS solutions offered as paid services by various companies. This led to the idea of adapting Forms' functionalities and transforming it into a CMMS tailored to the specific needs of clinics and hospitals. In the context of a Forms-based CMMS, automating certain processes is essential.

II. METHODOLOGY

Fig. 1 shows a diagram of how the research was conducted. Starting with a literature review was conducted to understand the general characteristics of CMMS (Computerized Maintenance Management Systems) in various settings. This review provided the theoretical foundation crucial for designing a CMMS adapted to specific clinical environments. A private clinic in Tegucigalpa was selected as the case study.

Visits to the clinic were made to conduct detailed interviews with the maintenance department staff and to observe their processes, covering both preventive and corrective maintenance activities. This provided an in-depth understanding of the clinic's workflow, yielding valuable information for the next phase of the research.

Based on the information gathered during these visits, a description of the workflow associated with medical equipment maintenance at the clinic was developed. Special emphasis was placed on detailing the processes involved in equipment repairs, establishing a comprehensive framework for the subsequent design.

The design of the CMMS was then carried out, modeling its structure based on the identified workflow. The system was conceptualized to be coherent and efficient, aligning closely with the clinic's specific maintenance practices. It was designed to maintain an individual record for each medical device in the clinic, tracking the maintenance performed on each device along with its corresponding work order. Furthermore, notifications for the start and end of each work order were implemented.

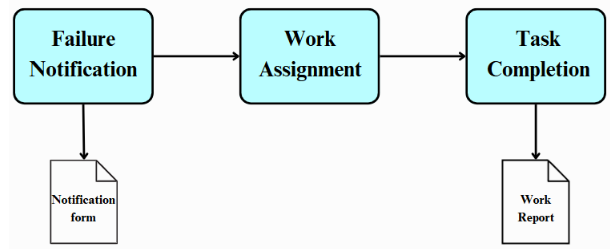

Fig. 2. Maintenance department workflow

Preliminary functionality testing of the CMMS was conducted at the clinic, where the system based on Google Forms was provided. This allowed maintenance records to be monitored from the computers or phones of the relevant staff. Additionally, the App Script code was transferred to the Google account used by the clinic's staff, where the CMMS was implemented, enabling them to manage the necessary tasks when performing preventive or corrective maintenance on equipment using their Google account.

The functionality testing process exposed the system to practical situations, including potential issues with the clinic's internet network that could affect its performance. As a result, possible design errors were identified, and it was ensured that the CMMS effectively met the clinic's needs.

To validate the effectiveness of the customized CMMS implemented at the clinic, a two-phase methodology was followed. First, tests were carried out to assess the functionality and usability of the system. Then, the results were compared with previous work related to the implementation of CMMS in similar clinical environments, providing an overall evaluation of its effectiveness and usefulness in the specific context of the medical institution. Previous work by [8], in which a CMMS was implemented in a clinical setting at a private hospital in Tegucigalpa, was used as a reference.

III. RESULTS AND DISCUSSION

As part of the analysis phase, a workflow assessment was conducted at a private clinic in Tegucigalpa, who were open to try this option of CMMS. The workflow of the maintenance department in regard to medical devices, as seen in Fig. 2, could be divided into three sections: failure notification, work assignment, and task completion.

In the first section of failure notification, the process begins when personnel, such as nurses or doctors from different areas, identify a problem in one of their equipment. They fill out a paper form to report the affected equipment and identified issues, which is then delivered to the maintenance office.

The second section involves work assignment. Once the failure notification form reaches the hands of the maintenance manager, they assign technical personnel based on the priority of the equipment in the area where it is needed. It is possible for the maintenance manager to assign the task to himself. It is important to note that not only corrective maintenance tasks are assigned, but also preventive maintenance and analysis tasks for equipment from various areas.

The last section is task completion. Once the task is assigned to various maintenance personnel, they are responsible for completing it and subsequently notifying the stakeholders of the task's completion. Personal notification is provided to the area personnel, and a brief form is drafted to file the maintenance in the maintenance office.

To emulate a CMMS with the defined workflow, two different forms were created: one form for reporting perceived failures in the area, and another form for completing work orders, whether corrective, preventive, or for analysis.

The modifications made in App Script are as follows:

- The code was modified to send an email to the person who reported the failure, informing them of the completion of maintenance on the equipment related to the failure.
- A new section was added to the maintenance form, allowing the selection of the personnel performing the maintenance.
- A new section was added to collect the code or serial number of the equipment being serviced.
- A new question was added to the maintenance form to document the personnel who performed the maintenance.
- A new section was implemented to categorize the areas of the two different clinics.

A. Data Security

Cybersecurity refers to the practices and measures designed to protect systems, networks, and data against attacks, damage, or unauthorized access. The human factor has often been dismissed as the weakest link in the cybersecurity industry [19]. To effectively strengthen cybersecurity defenses, organizations must recognize the crucial role of employees. A study reveals that training employees has a positive impact, reducing security incidents and fostering a culture of cybersecurity awareness [20].

During the development of the form structure, research was conducted on applicable security measures for the information collected in the forms. A two-factor authentication process was considered as a security measure; however, it was identified that the only security measure provided by Google is to protect the spreadsheet itself. While this prevents modifications, it does not prevent access or viewing of the sheet. Google's help pages warn that this should not be considered an effective security measure, as users can print, import, export, copy, and paste copies of a protected spreadsheet [21].

Alternatives were explored to apply a password that would restrict access to the spreadsheet. While Google Sheets does not offer this option, Excel allows password protection for spreadsheets in the cloud. However, since most of the work was carried out in Google Sheets, switching to Excel format would require significant modifications to the code to ensure proper functionality.

Despite the security limitations of Google Sheets, it is important to note that accessing the form data requires, at a minimum, that a person have access to the email used exclusively by the team responsible for performing the maintenance tasks. This restriction provides a basic level of security to the system, although further measures need to be explored to ensure the protection of sensitive information.

Therefore, a culture focused on cybersecurity is crucial in environments handling sensitive information. This involves not only the implementation of technical security measures but also the promotion of best practices among staff. Awareness of cyber risks and regular training on cybersecurity topics are essential to strengthening defenses against potential threats.

B. Functionality Tests

The tests were conducted in four steps, as seen in Fig. 3 from transferring the code to gathering feedback from the staff using the platform. In the first step of the testing, all the code and structures of both Google forms were transferred to the account used on the maintenance staff's computers. Afterward, a verification was conducted to ensure that the entire structure was functioning correctly.

In the second step, access to the forms was provided by distributing the links through QR codes to expedite staff access. These printed QR codes were used for preliminary testing.

As the next step, a visit to the clinic was scheduled to install the system on the computers available in their respective browsers. The purpose was to demonstrate the CMMS to the clinic staff and conduct the relevant functionality tests, during which quick access to the form was established. It is worth noting that, during this visit, training was also provided to staff not directly involved in the maintenance department, such as doctors working in the operating rooms and specialists who would need to use the system. In areas without computers to implement the system, training on the use of QR codes for form access was conducted. The clinic was provided with info graphics explaining how to use QR codes to report failures in areas without computers.

Finally, in the last step, the staff was asked to use the system and provide feedback on whether they found the form intuitive to use, in order to identify potential areas for improvement. A wide range of employees was consulted, including those from clinics, sales, reception, administration, and operating rooms. One of the few points mentioned by the staff was the need to include an electrical section in the failure notifications, such as for plugs or lights. The majority of the staff who used the system expressed satisfaction with its preliminary performance.

C. Modifications to the Current Process

Before the system implementation, the clinic's process required staff to submit notifications physically on paper, causing delays in assigning tasks. This also created the possibility that the staff who found and attempted to report a failure could not find maintenance personnel. Additionally, there was the risk of the failure notification form being damaged or lost, resulting in maintenance personnel being unaware of the issue for an extended period, hindering prompt maintenance and delaying services that required the use of the faulty equipment.

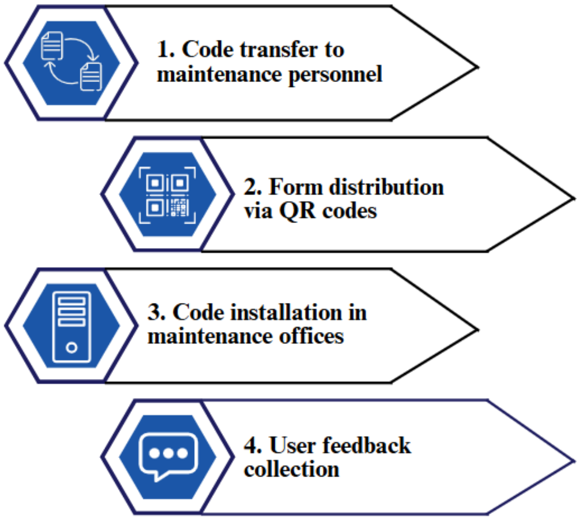

Fig. 3. Process for testing the system

After the implementation of the CMMS, part of the workflow involved in the failure and maintenance notification was modified. Notifications are no longer made on paper and are now automated by the program, preventing issues of being unable to submit notifications because the relevant personnel are unavailable or hard to find. This has improved the maintenance service, which in turn positively impacts patient care.

D. Issues Encountered

Several problems were encountered during the development of the system's code, as well as challenges in adapting it from Google Forms.

First, it was identified that users could select a work order and perform a preventive analysis, which was not included in the planned workflow. To address this issue, the order of the questions in the form was reorganized to avoid conflicts with the code.

An error was observed when attempting to update work orders due to the presence of two identical active orders simultaneously. This situation should not have occurred as it would have been redundant to address the same issue twice at the same time. To resolve this, a code was developed to automatically delete active duplicate records, and the code would issue a message informing about the duplication of active orders.

Another issue occurred outside of direct control, related to a delay in the automatic activation of App Script triggers. This inconvenience temporarily affected the system's proper functioning, requiring a wait until the issue was resolved by the service provider. Initially, it was thought that the problem might be due to an erroneous line of code or a syntax error. However, after testing the code, no issues were found. Further investigation in Google's official sources revealed that, on rare occasions, automatic triggers in Google App Script may experience failures. These problems typically resolve automatically over time. To confirm this, the issue was monitored for several hours, during which the triggers remained inactive. However, they later activated simultaneously in large numbers, suggesting that the issue resolved on its own. Therefore, it was concluded that the problem with trigger activation is beyond our direct control and is more dependent on the services provided by Google.

During code testing, an issue was identified with short answers in the form, specifically in the section that allowed entering the equipment name. It was observed that an extra space could be added at the end of the name, leading to discrepancies in data interpretation by the code. To address this, the code was modified to prevent these discrepancies when interpreting the responses, ensuring proper matching between failure notifications and the corresponding maintenance records.

IV. Conclusions

A structure based on Google Forms was designed, which fully met the clinic's needs. This structure includes two forms: one for reporting failures and another for documenting maintenance. Both forms are equipped with the ability to attach photographs for later verification of the work performed, and they integrate an automatic notification function upon completion. The system proved to be intuitive and easy to use for the staff responsible for reporting failures or performing maintenance tasks.

The implementation of the CMMS in the clinic has significantly optimized communication between the maintenance department and medical staff. Through automatic notifications, rapid information transmission has been achieved, facilitating task coordination and response to maintenance issues. Moreover, the system ensures that all failure notifications and maintenance performed are properly recorded and archived in the corresponding form data, effectively reducing the time and effort spent documenting the processes.

It was determined that implementing additional security measures is not feasible without making significant changes to the code to make it work with Excel instead of Google Sheets. Overall, it is considered that the information is adequately protected, as accessing it requires authorization to use computers with the exclusive maintenance staff email account or to access the digital file through specific permissions.

A potential code improvement would be to make the equipment from different areas interactive or to automatically update based on a Google Sheets file, which could be modified according to needs. Additionally, each piece of equipment could be assigned a code similar to the one used in the institution's inventory, enabling each maintenance or failure notification to be linked to its corresponding equipment via this code. Another measure to consider in the future would be the creation of interactive areas, so that adding a new physical area and its associated equipment would simply require adding the corresponding information to the Google Sheets file.

Regarding security, one possibility would be to move all the information to an online Excel sheet, where access could be restricted by a password. However, this change would require significant modifications to the system to ensure its proper functioning.

Finally, it is recommended to consider conducting additional studies to evaluate the long-term impact of the system on operational efficiency and the maintenance of medical equipment in the clinic, as well as its applicability in other similar contexts.

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