

e-Maintenance Framework for Strategic Asset Management in Tertiary Institutions

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Abstract. Tertiary institutions require buildings such as its senate building, classrooms, laboratories, administrative rooms, hostels and other offices in order to function. Providing and maintaining these buildings require a lot of planning and capital investment. The study examined the prospects of using e-Maintenance platform for strategic asset management in tertiary institutions. This study noted that adequate maintenance of the building infrastructural base of tertiary institutions is crucial for sustainability in the face of dwindling funds in the education sector. In order to automate the e-Maintenance process for strategic maintenance of the institution's building maintenance, a use case diagram, system block diagram, sequence diagram and activity diagram were designed and presented in this study. Three (3) main users are essential in the sequence of operation of the e-Maintenance platform. These users represent the building occupants, the facility manager and the management personnel; for effective oversite and performance monitoring. The methodology of this research includes using the combination of HTML, CSS and the C-Sharp programming language for the interface design and server side scripting while MySQL was the database platform used for storing and retrieving the data used for the application. In conclusion, the study developed an e-Maintenance framework for strategic asset management in tertiary institutions.

Keywords: Asset management · Automation · Construction industry · e-Maintenance · Web-based systems

1 Introduction

Tertiary institutions require buildings such as its senate building, classrooms, laboratories, administrative rooms, hostels and other offices in order to function. Providing and maintaining these buildings require a lot of planning and capital investment. The dwindling funds available to tertiary institutions means that adequate attention is given to the available infrastructure within the university, as providing new ones may become difficult. The asset gathered by the tertiary institutions need to be strategically managed over the years through proper maintenance to ensure they are continually attractive and

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meet the competitive environment universities try to compete in. In the study by [1] strategic infrastructure asset management is defined as the process by which organization achieves its goals by ensuring that its asset meets the needs of its changing customers.

Crucial to asset management is operational improvement, satisfaction of the customer using the facilities, improved productivity, quality asset and positive environmental impact. To achieve this, maintenance is at the centre of strategic asset management. Maintenance cost on the other hand continues to increase. The study by [2] stated that maintenance cost can account for up to 40% of the total operating cost of an organization. To think that the maintenance cost of a conglomerate increased from 200 billion dollars to 600 billion dollars in the space of 10 years [3]. This means that without adequate planning for maintenance, it can break or ruin a business [4]. As tertiary institutions continue to increase its capacity and asset base to cater for the needs of its students, there is need for adequate maintenance of its asset. Tertiary institutions have embraced the use of information and communication technologies. This can be applicable for maintenance monitoring and feedback mechanism. Other e-technologies adopted by tertiary institutions can be seen in works by [5–8].

An easy definition of the term e-Maintenance is put forward by [9] as the process of integrating existing traditional maintenance strategies with the innovation of information and communication technologies (ICTs). From this definition, [10] asserted that e-Maintenance is able to provide the necessary maintenance support in terms of information on resources needed for the maintenance works, services needed to be carried out and the personnel allocation in order to take proactive and informed decision. The process of e-Maintenance helps users to log in from anywhere in the world to take remote actions. In this, maintenance operations can be setup, controlled and the performance of the maintenance personnel monitored and evaluated [11]. The study by [12] added that e-Maintenance technologies ensures transparency and efficiency by integrating the business process of an organization with a collaborative maintenance environment. The maintenance process becomes lean and downtime is minimized as much as possible. The use of the internet-based network ensures data and information flow for easy decision making in maintenance of university's asset. With the prospects of e-Maintenance, the study developed an e-Maintenance framework for strategic asset management in tertiary institutions.

2 Review of Related Literature

Different definitions exist for e-Maintenance in diverse studies [9, 10, 13]. A major similarity in the description of e-Maintenance is the use of ICTs within a firm's maintenance strategy or plan. The study by [13] stated that different types of e-Maintenance platforms exist and in different capacities as used in diverse industries. In the study by [4], their e-Maintenance system was a condition monitoring module that receives data from sensors attached on the device needing maintenance services. With the emergence of artificial intelligence (AI), predictive maintenance can be detected through condition monitoring/prognosis of equipment and buildings [13]. The prospects of this remote sensing in e-Maintenance has been heavily utilized in the

automobile industry, aerospace industry, power and other manufacturing industries. Examples of the e-Maintenance systems in operation include, Condition Monitoring Multi Agent System (COMMAS) was designed for a smart electrical plant [14] and a chemical processing plant [15], an expert system using vibration analysis to identify faults in the manufacturing industry [16], the use of Radio Frequency Identification (RFID) technology with microchips and antenna in many other industries [17] and instant email notification as used by computer or gadget manufacturing companies [18]. In the aerospace industry, [19] reported that a communication platform was developed to remotely fix their aircraft's computers.

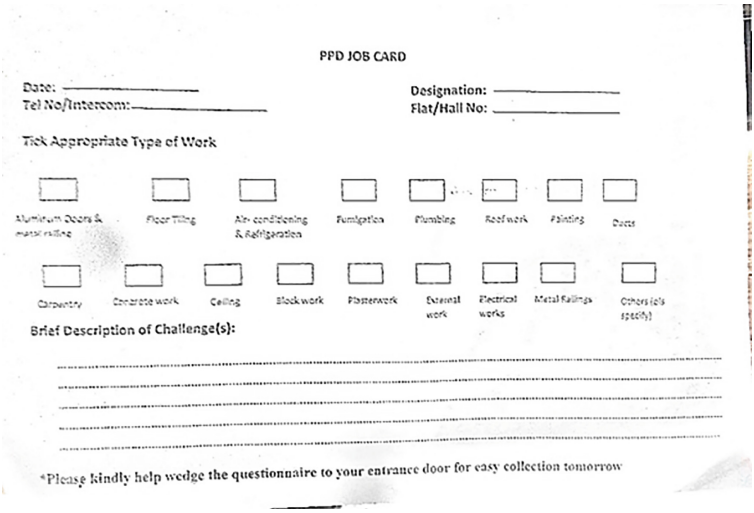
The study by [10] examined the advantages and barriers to an efficient use of e-Maintenance. Their study showed that e-Maintenance offers the opportunity to develop new maintenance systems within an organization, improve support systems and help define new maintenance activities. Additionally, [13] argued that firms are able to increase their competitive advantage over their counterparts through a well-managed e-Maintenance platform. The article by [20] opined that smart companies are able to optimize the performance of their asset base through process reliability. In that, [13] pointed out the advantage of a 24-hour feedback system and centralization of data. A major challenge to the maintenance feedback mechanism is the need to provide an easy to manage database due to the high volume of information it has to store and process [10]. The study by [4] asserted that people management is key while planning for maintenance works. e-Maintenance helps to create a collaborative environment among the building occupants, facility managers, technicians and the management. By this economic goals are realized by companies that implement e-Maintenance systems through reduced maintenance process cost by increasing maintenance identification time and duration of maintenance intervention and preventing downtime [4]. They referred to it as an enhancer of zero downtime performance in business operations.

3 System Design

According to [10], for e-Maintenance to succeed, the existing maintenance system within an organization needs to be studied for efficient models and process to be drafted in e-Maintenance technologies. In tertiary institutions in Nigeria, due to the enormous investment in building infrastructure, there is a dedicated department that handles maintenance services within the institution. In some places, they are referred to as the Works Department while in the area under study, it is referred to as the Physical Planning Department (PPD). Every maintenance unit in each tertiary institution has its own mode of carrying out its maintenance works in terms of sourcing for maintenance resources, delegation of personnel and carrying out of the maintenance activity. The similarity amongst the tertiary institution is the goal of maintaining its asset at a minimum cost. The e-Maintenance framework designed in this study is for a private institution in South-West Nigeria.

The existing maintenance complaint technique used in the tertiary institution chosen is a paper-based method using a job card for asset management. The study posit that the process can be automated thereby ensuring speed, easy data storage and retrieval, process monitoring and evaluation. A sample of the job card is presented in

Fig. 1. In Fig. 1, essential components are highlighted such as date, location, type of work required and a brief description of the maintenance challenge. This was designed by the Physical Planning Department within the private tertiary institution.


PPD JOB CARD

Date: _____ Designation: _____

Tel No/Intercom: _____ Flat/Hall No: _____

Tick Appropriate Type of Work

Aluminum Doors & metal railing | Floor Tiling | Air conditioning & Refrigeration | Fumigation | Plumbing | Roof work | Painting | Ducts

Carpentry | Concrete work | Ceiling | Block work | Plasterwork | External work | Electrical works | Metal Railings | Others (pls specify)

Brief Description of Challenge(s):

*Please kindly help wedge the questionnaire to your entrance door for easy collection tomorrow

Fig. 1. Sample of Job Card used for Maintenance purposes (sourced from the private institution)

In order to automate the e-Maintenance process for strategic maintenance of the institution's building maintenance, a use case diagram, system block diagram, sequence diagram and activity diagram were designed and presented in this study. From Fig. 2, there are three (3) main users of the system. The first user is the building occupant, either in a Fig. 2 showed the use case diagram for the e-Maintenance portal in strategic asset management. Office space, residential apartment, hostel or other administrative building including the health centre. The other users are the Facility Manager and the Management personnel in charge of the Physical Planning Department (PPD) or a Personnel in the Senate either the Registrar or any other authorized person.

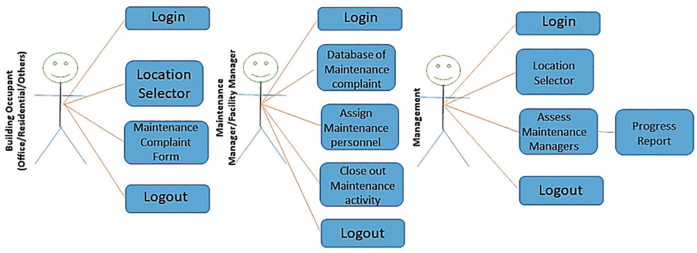


Fig. 2. Use case diagram for e-Maintenance portal in strategic asset management

Figure 3 showed the system block diagram for the e-Maintenance portal. Essentially, the e-Maintenance system is a web-based system that receives information from the building occupants who lodges maintenance issues required within their space. The Facility Manager is able to access the system from anywhere. The Facility Manager attached to each building asset accesses teach complaint from the building occupants and assigns them to the appropriate job personnel. The maintenance activity would be close out as soon as the job has been completed. The final user of the system; the Management team is able to monitor and evaluate the activities and output of the facility manager from their computers. All information are stored and archived on the e-Maintenance platform.

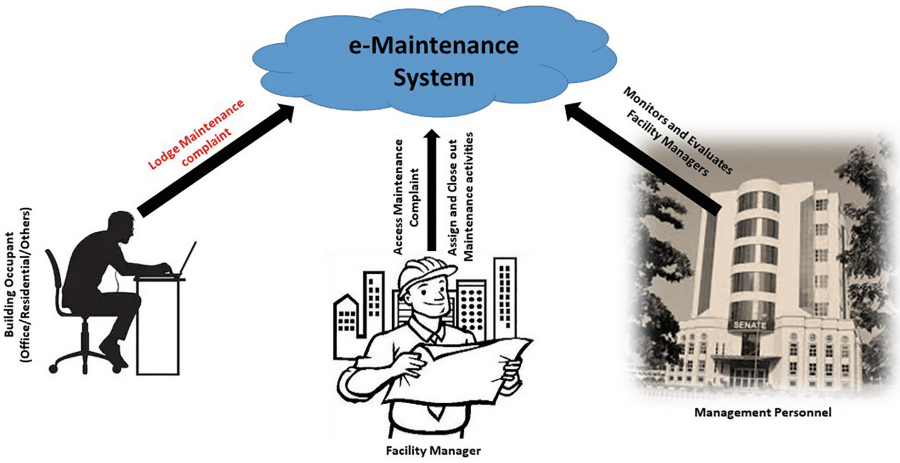


Fig. 3. System block diagram for the e-Maintenance portal

Figure 4 showed the sequence diagram of the flow of information. In the sequence diagram, there are 3 phases through the 8-point step from initiation of the e-Maintenance compliant to the evaluation process.

Figure 5 showed the activity diagram of the e-Maintenance system for strategic asset management. From the activity diagram in Fig. 5, an e-Maintenance URL is provided on the homepage of the tertiary institution webpage. From here, building occupants can select the buildings where maintenance work is needed and complete the maintenance complaint forms i.e. the job card that exist in the traditional maintenance process within the institution. The e-Maintenance complaint form has details of the Description of the complaint, the type of work, Date the complaint is been made, exact location within the area selected and the status of the maintenance work either open or closed out. The Maintenance manager or Facility Manager (FM) is able to login via the same URL and view the maintenance work which is broken down into Type of work, the description of the complaint, location, date, status and assign. The assign section helps the Maintenance manager or FM to allocate jobs to the appropriate quarters of skilled labour required. Once the job is completed, the Maintenance Manager or FM is

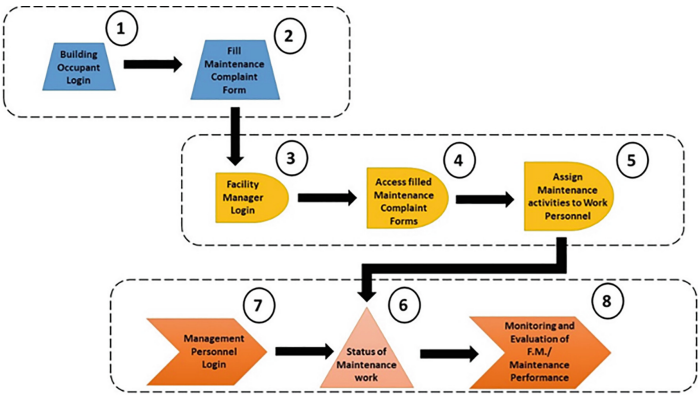


Fig. 4. Sequence diagram of the flow of information

able to close out the maintenance activity on the e-Maintenance portal. The Management or Personnel appointed to serve as an oversite function to monitor and evaluate the activities of the Maintenance manager or FM. The Management function is able to view activities that are still pending and closed out. The contact details in terms of email and contact number of the Maintenance manager or FM is made available on the platform for easy communication to sort out pending maintenance issues.

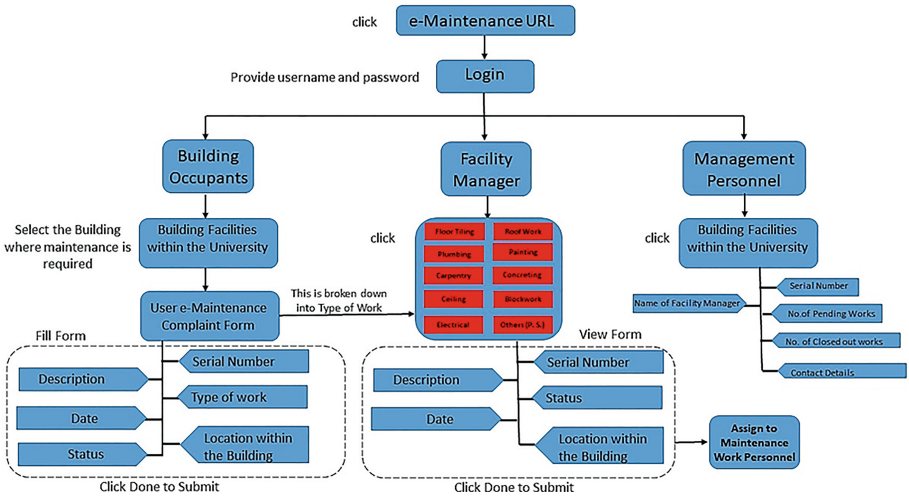


Fig. 5. Activity diagram of the e-Maintenance system for strategic asset management

4 System Implementation

This section gives a brief overview of the tools used in the coding of the application software. The various tools used in the development of the system are as follows:

4.1 Hyper Text Mark-up Language (HTML)

HTML is a markup language used in the development of web pages. Markup languages are usually written with angled brackets and tags such as <p> which means paragraph, <br> which means break, <body> which means the main contents that will be viewed on the browser and so on. HTML codes can be written with any text editor and are saved using the file extensions ".htm or .html". Once they have been saved any web browser can be used to view it. HTML for this application was written using sublime text as the text editor.

4.2 Cascading Style Sheet (CSS)

CSS is used to add some styling to HTML tags. The particular framework used was Bootstrap. The extension for css file is.css and external style sheets can be added using the html <link> tags. It helped to enforce the behavior of several of the entities of the application.

4.3 MySQL

In order to design the database management system (DBMS) for the e-maintenance system, MySQL (Structured Query Language) was used. Using MySQL helped to store the data in separate tables rather than putting each of them in a large warehouse. This is organized for speed, scalability, reliability and easy-to use. A database is a collection of related data. This is a free and open source software and runs on all platforms. MySQL also performs several functions. This was used in this application to store the data.

4.4 C-Sharp(#) Programming Language

The programming language used for controlling the system was C-Sharp (#). A C# program can contain managed or unmanaged parts. The managed code is fussed over by the system which runs it. C# programming language is able to maximize possible performance, and enable direct access to parts of the underlying computer system. C# programming belongs to the family of languages in the visual studio. It can be used for various types of application programming some of which include web programming, windows programing, animation and graphics and so on.

The methodology of this research includes using the combination of HTML, CSS and the C-Sharp programming language for the interface design and server side scripting while MySQL was the database platform used for storing and retrieving the data used for the application.

In the implementation of the e-Maintenance system, Figs. 6, 7, 8, 9, 10, 11, 12 and 13 showed the screenshots of the developed e-Maintenance platform. The users of the platforms follows the activity diagram described in Fig. 5.



Fig. 6. Portal Homepage for e-Maintenance system

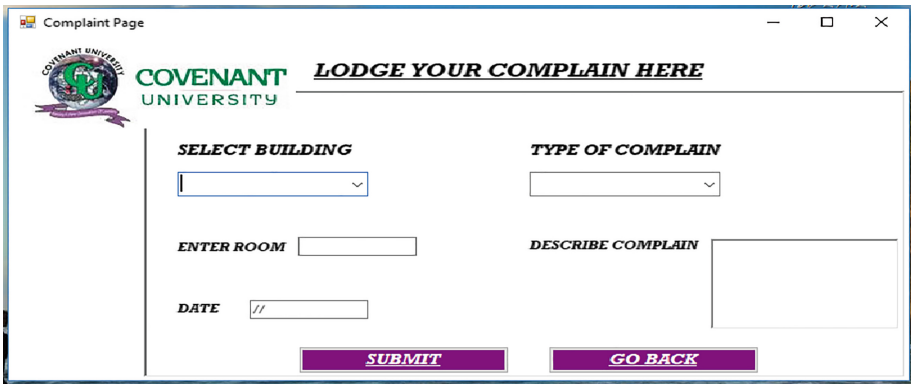


Fig. 7. User complaint page for e-Maintenance system

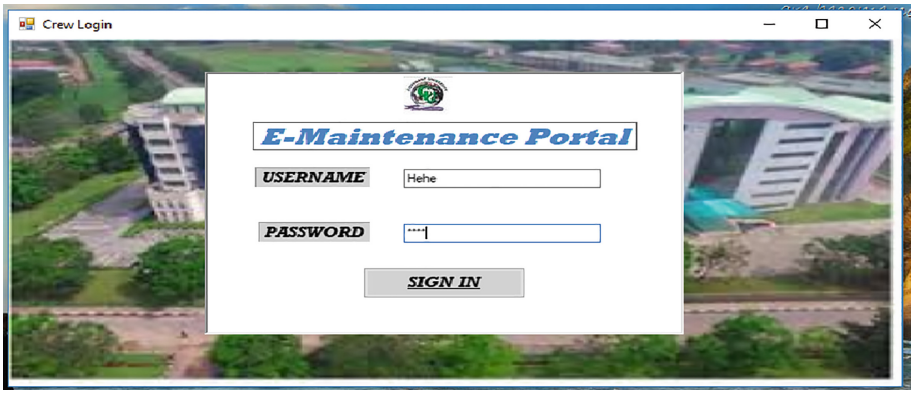


Fig. 8. Facility Manager Login page for e-Maintenance system

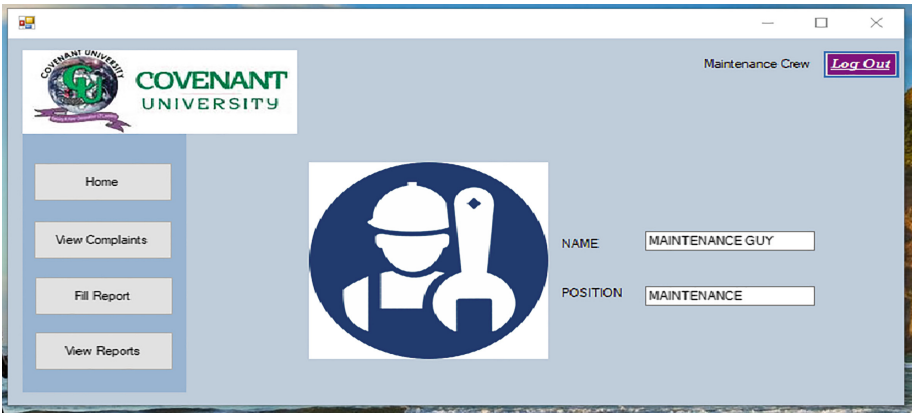


Fig. 9. Facility Manager Interface for e-Maintenance system

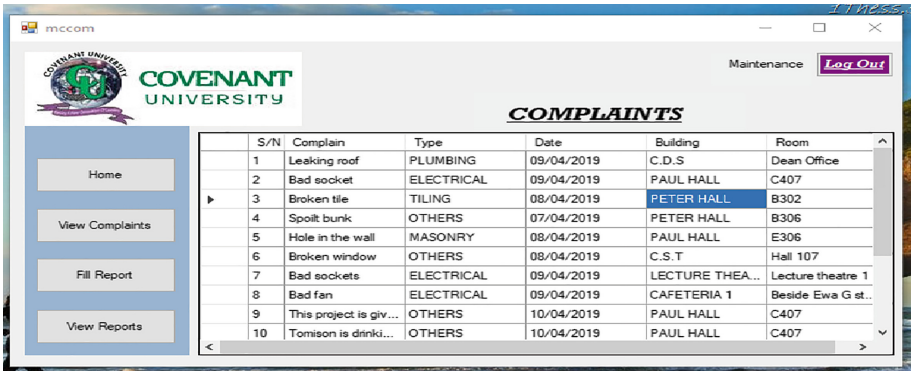


Fig. 10. Summary Complaint Interface for e-Maintenance system

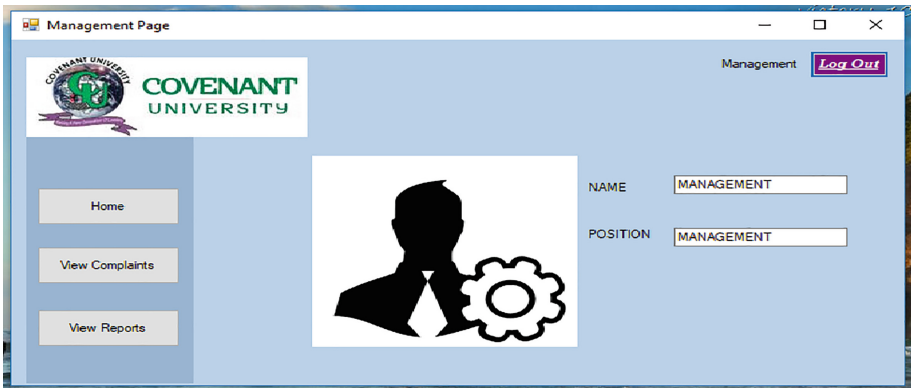


Fig. 11. Management Interface for e-Maintenance system

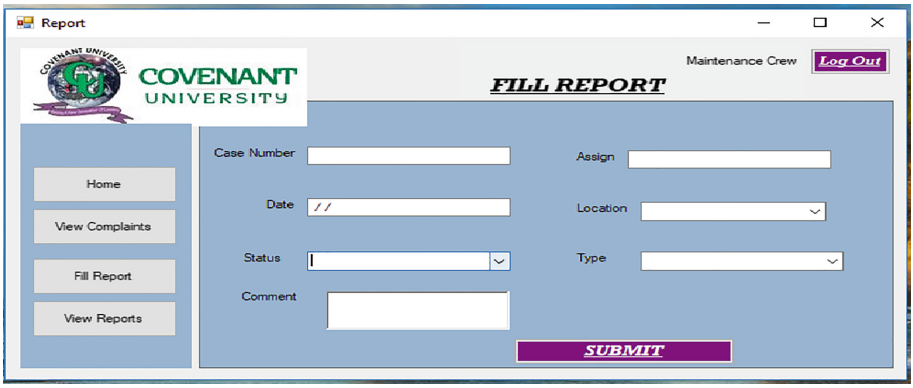


Fig. 12. Fill Report Interface for e-Maintenance system

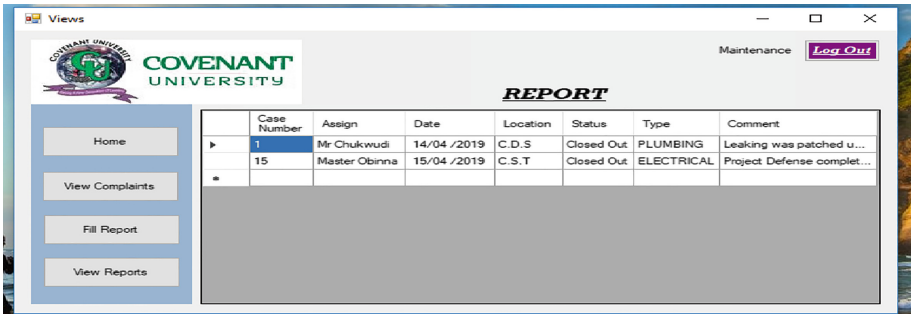


Fig. 13. View Report Interface for e-Maintenance system

5 Conclusion

The study examined the prospects of using e-Maintenance platform for strategic asset management in tertiary institutions. This study noted that adequate maintenance of the building infrastructural base of tertiary institutions is crucial for sustainability in the face of dwindling funds in the education sector. In order to automate the e-Maintenance process for strategic maintenance of the institution's building maintenance, a use case diagram, system block diagram, sequence diagram and activity diagram were designed and presented in this study. Three (3) main users are essential in the sequence of operation of the e-Maintenance platform. These users represent the building occupants, the facility manager and the management personnel; for effective oversite and performance monitoring. For future study, the e-Maintenance platform should be developed, having an interactive interface and a database. The effectiveness should also be measured against the existing tradition method of obtaining maintenance feedback within the institution.

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