Development Of a Framework for A Locally Designed Computerized Maintenance Management System for General and Military Aviation In Zimbabwe

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Abstract

The research aims to develop a framework for a locally designed computerized maintenance management system for general and military aviation in Zimbabwe with the aim to bolster the meandering engineering management artifacts in the country's aviation industry. The observation came about after a series of aircraft incidents and accidents that are claiming lives due to a series of cheese model errors being brought about by the current paper-based approach. The Paper-based approach lacks track of events due to the cumbersome work an individual is exposed to whenever a task has to be fulfilled. The research modelled a software prototype as proof of concept, capable of tracking and monitoring events, generate observations into reports, link management to tradesman thereby improving communication across the board and account for each event among other activities. The system will be generating real time reports taking advantage of emerging technologies such as Artificial Intelligence and Cloud Computing among others. The results were noted and analyzed giving desired outputs in response to input data and the system performance satisfied the objectives set on the onset of the research. Conclusions, recommendations were made and indications on where the system needs improvement for future engineering and technical developments.

Keywords
Aviation, maintenance, computer, job tracking and accidents.

Introduction
Industry 4.0, often known as the fourth industrial revolution, has resulted in a faster integration of technical advancements and industrial activities. The fourth industrial revolution's growing technologies and characteristics have had a massive impact on current industrial manufacturing and maintenance systems. The chosen maintenance management components and integrated core function of industry 4.0 technologies are focused on predictive maintenance Technological innovation has resulted in the emergence of various new concepts such as cyber-physical systems (CPSs), the Internet of Things (IoT), artificial intelligence (AI), big data, and cloud computing. These new technologies have cleared the path for new inventive opportunities and greater socioeconomic development. The driving force was intensified competition by leading industrial economies like the first world countries, which increased market demand for standards around the world. The competition gave an impetus fair share of trouble, the human factors which contribute to the majority of aviation incidents and accidents (Karunakaran, Babu and Sheriff 2020). The research aims to reduce human errors and thus improve maintenance reliability, as human errors, rather than mechanical errors, are the primary causes of most aviation incidents and accidents. Safety and security in aviation cannot be overstated because they are critical and mandatory requirements. Aircraft maintenance is critical for any airline, crew, passengers, and cargo to prevent and minimize system faults and failures, which are the main causes of devastating incidents and accidents. Aside from aircraft incidents and accidents, errors can be the cause of unnecessary flight cancellations and delays, which have a significant impact on the airline's financial benefits. Zimbabwe's aviation sector has a nightmare of maintenance management due to paper-based management throughout the entire system.

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This results in most maintenance activities becoming an independent function rather than process sub-function due to lack of reference. For a long period of time, operations, safety and security of aviation in Zimbabwe have been affected by aviation maintenance personnel, making grave mistakes. The inherent development in technology together with the industrial sectors, aircraft maintenance should be flexible and easy to survive the dynamic business environments present. For such proactive world-class maintenance practice to be achieved there is need for computer-based support.

1.1 Objectives

The objective of the study was to develop a framework for a locally designed computerised maintenance management system for general and military aviation in Zimbabwe. This was achieved by first determining the scope of the current maintenance management systems for military and general aviation, followed by the determination of features required for automation in maintenance management subgroups. The final step was the development and testing of a general all-encompassing CMMS framework as proof of concept. (10 font)

Literature Review

The aviation sector boasts of several sectors with three distinct pillars of the industry and these are commercial aviation, general aviation and military aviation. Commercial aviation has money or funds incorporated enhancing importation and exportation of goods and services whilst general aviation involves non-scheduled operations of airlines and examples include medical evacuations. Military aviation involves the country's military or army and dedicated force establishments set up units which include light weight aircraft and helicopters mainly used for aerial combat and other military missions which safeguard a nation.

2.1 Maintenance Strategies

The maintenance programs in the aviation industry are similarly to those of the other industry which constitute reactive and proactive maintenance strategies. These strategies are being integrated with computer management systems to create what is now termed Computer Maintenance Management System. Examples of these strategies are:

Scheduled maintenance: Scheduled maintenance is a maintenance strategy that involves performing maintenance tasks at regular intervals to prevent equipment failure and ensure optimal performance. Scheduled maintenance can help prolong equipment lifespan, reduce maintenance costs, and improve safety. This is particularly important in aviation, where equipment failure can lead to accidents and loss of life. In military aviation, scheduled maintenance is even more critical as equipment is often used in extreme conditions and must be kept in peak condition to ensure optimal performance. The CMMS framework should include features that cater to the unique needs of military aviation, such as tracking maintenance tasks based on mission requirements. A study by Iorga, Chindris and Rusu (2021) found that scheduled maintenance was the most common maintenance strategy used in aviation, with 84% of aviation organizations reporting the use of scheduled maintenance. The study also found that organizations using scheduled maintenance reported lower maintenance costs and higher equipment reliability compared to those using reactive maintenance.

Preventive maintenance: According to Al-Rashdan, Al-Rabab'ah and Al-Shyyab (2019), preventive maintenance is a proactive maintenance strategy aimed at reducing the likelihood of equipment or system failure. This approach involves regular inspections, lubrication, cleaning, and calibration activities aimed at ensuring that equipment remains in optimal condition.

Corrective maintenance: According to Fayaz, Kamaruddin and Tawi (2019), corrective maintenance is a reactive maintenance strategy that involves repairing or replacing equipment after it has failed. Corrective maintenance is a reactive maintenance strategy aimed at addressing equipment or system failures after they have occurred. While, proactive maintenance strategies such as preventive and predictive maintenance should be the primary focus of a maintenance management system, corrective maintenance is still an essential component of any maintenance program.

Reliability Centred Maintenance (RCM): Shafiee, Shariati and Keyvani (2019), defined RCM as a proactive maintenance strategy that aims to ensure that maintenance activities are focused on critical equipment or systems.

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This approach involves identifying potential failure modes and the consequences of failure, assessing the likelihood of failure, and identifying appropriate maintenance strategies to mitigate the risk of failure. RCM focuses on optimizing maintenance activities to improve the reliability of equipment or systems.

Total Productive Maintenance (TPM): In the year 2020, Gao, Li and Xu defined TPM as a maintenance strategy that aims to create a production/operating environment where maintenance activities are integrated into the production/operating process. This approach involves identifying and eliminating sources of inefficiencies, such as equipment breakdowns, unplanned downtime, and quality defects.

2.2 Emerging Technologies

Digital technology has led to the revolutionization of maintenance strategies across industries through the use of automation tools and simplified work flow management. This has led to the development of a new strategy known as of computerised maintenance management systems. This strategy make use of these emerging technologies together with the concepts adopted from the old one to build a more holistic system which is more efficient and effective. Examples of these technologies which have found application in maintenance are:

Artificial Intelligence (AI):
AI can be used in CMMS to improve the accuracy of equipment failure predictions. This approach involves using machine learning algorithms to analyse data from various sensors and other monitoring devices to predict equipment failure. The integration of AI with CMMS can enable maintenance personnel to identify potential issues early and take corrective action before they become critical. Liu, Zhao and Zhu (2020) investigated the use of AI in CMMS for maintenance planning. The study proposed an AI-based maintenance planning model that uses machine learning algorithms to predict the optimal maintenance schedule. The model considers various factors, including equipment criticality, maintenance costs, and downtime, to generate an optimal maintenance schedule. The proposed model can help maintenance personnel to detect issues early and take corrective action before they become critical.

Augmented Reliability (AR):
AR refers to the enhancement of the reliability of a system through the use of modern technologies, including Computerised Maintenance Management Systems (CMMS). CMMS are software applications used to manage maintenance operations, including scheduling, work order management, asset tracking, and inventory management (Mokhtar, Lashin and Fathy 2020). By integrating CMMS into maintenance operations, organizations can improve the reliability of their systems and reduce maintenance costs. According to a study by Mokhtar, Lashin and Fathy (2020), CMMS has been shown to improve equipment reliability by reducing breakdowns and downtime. The study found that organizations that implemented CMMS experienced a 23% reduction in maintenance costs and a 14% increase in equipment reliability.

Virtual reality (VR):
VR technology has become a popular tool in many industries, including computerised maintenance management systems (CMMS). VR technology can be used to create immersive training and simulation experiences for maintenance personnel, as well as assist in the design and planning phases of maintenance projects. One study conducted by Shi, Zhang and Jiang (2020) examined the use of VR technology in CMMS for maintenance decision-making. The study found that VR technology can provide a more intuitive and immersive way to visualize maintenance data, which can help maintenance personnel make more informed decisions.

Other technologies worth mentioning are Building Information Modelling (BIM), whose application in CMMS is applicable, the Smart Wear Detection Technologies where by Gao and Jia (2019) covered their application in CMMS and finally Nanotechnology.

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2.3 Computerized Maintenance Management Systems (CMMS) In Aviation Industry

CMMS play a critical role in the aviation and military industries. CMMS can help improve maintenance practices, reduce downtime, and improve safety by providing real-time data and automating maintenance processes. One study by Fan, Li and Zhang (2019) explored the use of CMMS in the aviation industry for improving aircraft maintenance. The study found that CMMS can help improve maintenance planning and scheduling, as well as reduce maintenance costs and improve aircraft reliability. Another study by Ilie, Meier and Gheorghiu (2018) focused on the use of CMMS in the military for improving maintenance practices. The study found that CMMS can help improve the accuracy and timeliness of maintenance data, as well as improve maintenance decision-making and reduce downtime.

Current CMMS (computerized maintenance management system) practices assessment is an important process for organizations to evaluate their maintenance management software and identify areas for improvement. To conduct an effective assessment, a set of questions need to be addressed to evaluate various aspects of the system, such as user-friendliness, data integration, and utilization of system features. One study by Gao and Jia (2018) emphasizes the importance of CMMS data integration with other systems, such as inventory management, to improve the accuracy of maintenance data and reduce maintenance costs. The study found that integrating CMMS with inventory management systems improved the accuracy of maintenance data, which in turn resulted in cost savings by reducing inventory levels and minimizing equipment downtime. Therefore, assessing the integration of CMMS with other systems is another important aspect of the evaluation process.

Methods

3.1 Literature Review

Using credible online sources, textbooks, articles, and previous research on the topic of Computer Maintenance Management System, the researcher conducted a theoretical study to gain a better understanding of the topic, in order to understand the current system being used, learn its benefits, and be able to improve it by using authentic articles online and from the library. The various aspects and components of CMMS were studied and analyzed together with the existing CMMS frameworks and software. With the use of reputable articles on the internet and library visit, that is how the information was obtained to aid in the best way to combine the two systems.

3.2 Design Procedure

The assessment phase of the project underwent a series of steps in the quest to identify CMMS. requirements, its capabilities and most of all the existing gaps in the implementation of the aviation CMMS system. The initial survey of the Zimbabwe aviation sector was conducted as summarised in figure 1 below.
The design of the CMMS framework needs to take into consideration the technical requirements among other important aspects. Of major concern are: The Network Server Platform (e.g. Server: Microsoft windows virtualised by XAMPP and Database), Consumer Platform(s), (Client Workstation These are the various receivers with several features, makes and models and Mobile – The various handsets in their variety of makes.)

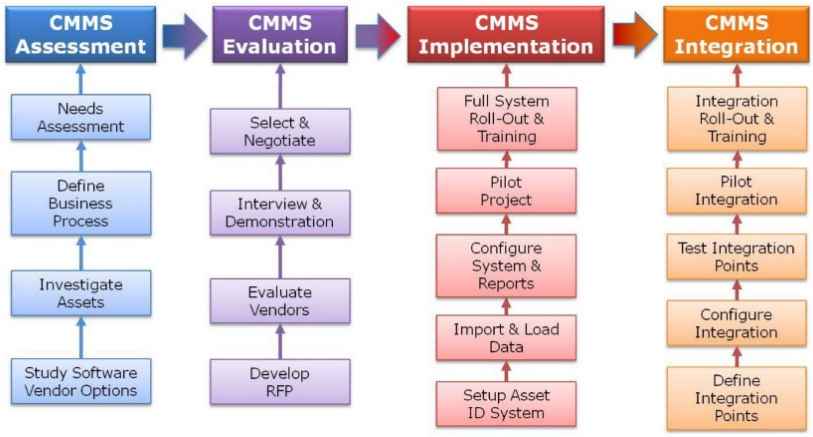

Figure 1. Database Creation and Implementation.

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Data was collected from some aviation companies/sites who will remain anonymous due to confidential reasons and analysis was done with the aid of existing models.

3.3 Expansion of The Concept

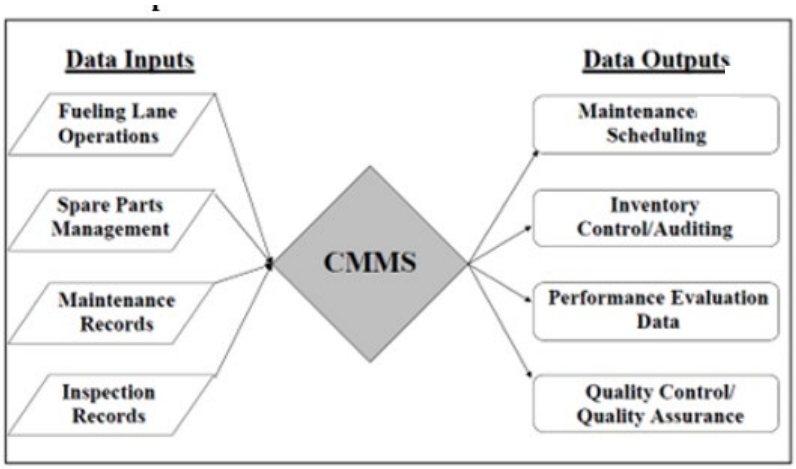

Figure 2. Inputs and Outputs of the CMMS Framework Concept.

The above Figure. 2 highlights the data inputs and data outputs for the CMMS framework. The design concept for the chosen CMMS framework took into consideration the following factors:

Table 1. Considered Factors.

General Specifications	Architecture of the Software	Architecture of the Hardware
◆ Universal language ◆ Simplified user interface ◆ Generate variety of reports at given intervals ◆ Simple error identification ◆ High level of security features ◆ Local technical support.	◆ Software system control module. ◆ Aircraft inventory module. ◆ Tradesman module. ◆ Management module. ◆ Aircraft Spares module ◆ Several maintenance strategies module	◆ Suitable Server requirements ◆ Workstation requirements ◆ Monitors ◆ Reliable Local Area Network (LAN)

3.2 Development of Chosen Solution

The design concept then brings the research to the framework which is the locally designed computerized maintenance management system for general and military aviation in Zimbabwe.

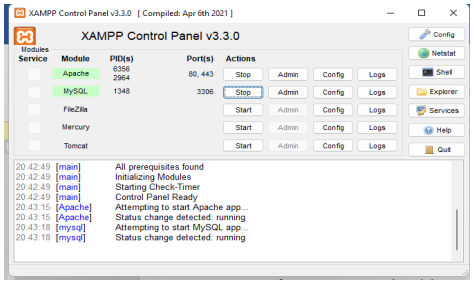

Figure 3. XAMPP Control panel

<u>The XAMMP window</u> provide support for creating and manipulating database as well as facilitating a local host to connect like a remote host. XAMPP is a web-based application developed using php programming language. The programming language is inbuilt such that connectivity and displays are quicker and easier. The MySQL facility available inside the system is the database management tool. Apache is a webserver software responsible for receiving raw information then process the request and send it back in the form of web pages. The host application facilitated the design of the maintenance management system through the CMD facility used.

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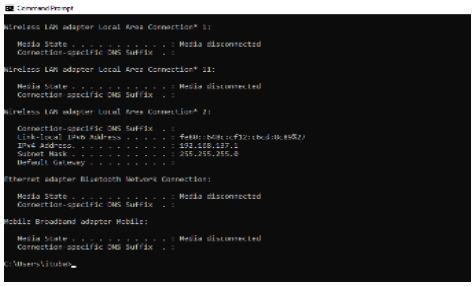

Figure 4. Command Prompt Display Page.

The Command Prompt Display
creates the IPv4 address which promotes the tradesmen to interlink with the server which beams instructions for arising tasks. The IPv4 sets the Local Area Network and in so doing it gives any person who is in the database authority to communicate any instruction back and forth.

Figure 5. Available Browser for Choice.

Logging in to the system.
When the IP address has been created the user in the database may then choose any available browser in the gadget that person uses be it a mobile cellphone, tablet, desktop or a laptop to then access the maintenance management system. The browser which can be google chrome, opera mini among others enables the gadget to retrieve files that were created in the webserver.

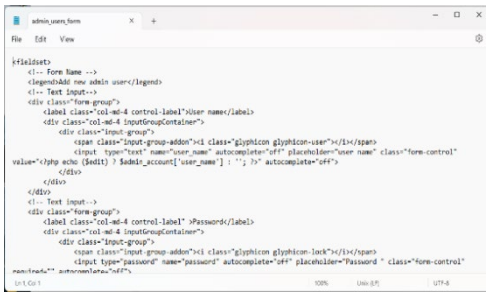

Figure 6. Sample Program.

The Administration Program when it is run in the browser it leads to the log-in page

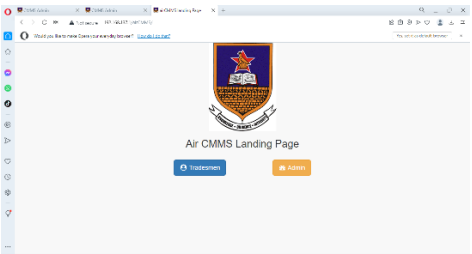

Figure 7. Landing Page.

The landing page.
When the Command prompt creates the IP address it brings all the host to this page where they have to click on their respective designation.

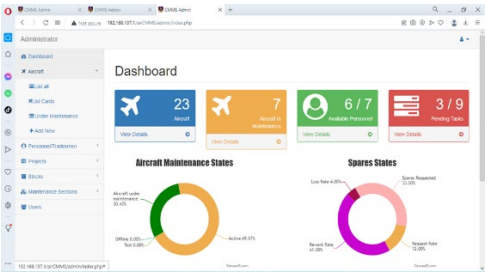

Figure 8. Dashboard.

This figure is displaying the key page of the CMMS which directs the user to various platforms within the system. The directing page was created by the incubator program language. Different programs were written for the various platforms including:

The Aircraft module which displays all the available properties that are useful in the maintenance practices of the aircraft.
The personnel module has all the available personnel project form enables the CMMS to display all pending projects within the system and it captures all the data

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The task module warrants the user and the administrator to access duties assigned by management

3.3 . CONCLUSION

The parameters were modelled using XAMPP tool such that the displays were all giving desirable output. The algorithm from XAMPP tool using PHP programming language was used to create the model.

Results and Discussion

4.1 Chapter Preview

The researcher managed to develop the CMMS module which was then tested. The results of these tests are discussed in this chapter. The concept interlinked emerging technologies and integrated the software to the hardware and as proof of concept the outcome is discussed as the modules are used one after the other with several inputs for certain desired output.

4.2 Maintenance Management Scheduling System

The noticed benefit of this design is its ability to assist the aircraft maintenance team adhere to adopted preventive maintenance procedures. When the aircraft return from a sort, relevant personnel (pilot in this case) uses the CMMS to account for the hours, fuel consumed, distance covered by each flight and if the aircraft developed any fault during flight. Electronic records allow the aircraft performance to determine the next maintenance procedure needed. The aviation computerised maintenance management systems are a real time reminder to the maintenance team when the aircraft is due for its next service to prepare them for the service. The system flexibility ability notifies scheduling data couple of days or several weeks before the service date arrives, this permits the maintenance to maximise on operational efficiency. Due to the fact that the maintenance management system is new, there is a tendency to be biased and concentration is on the system and not the work hence overloading the personnel with multitude of tasks including new technology and procedure. To reduce the overload, a gradual process to the maintenance personnel has to be employed as they assimilate and adopt the system for, their day-to-day use. The computer personnel will ensure the gradual process is smoothened by restricting computer output interface to paper-based reporting approach as the computer literate programs are rolled out to the personnel. The introduction of the system to an extend will slow down the maintenance if the gradual approach is not employed or employed simultaneously with the training of personnel.

4.3 Maintenance Data Collection

The designed aviation CMMS enact mandatory filing procedures by automatically generating reports (as shown on figure 9 below) for each aircraft in the system. With such procedures, CMMS reminds relevant maintenance stakeholders that regular checks and inspection is compulsory, serving as a repository on inspection reports which ensuring evidence that inspections have been completed. The reporting structure evidenced on the system is vital for tracing any information that may be required of the leading particulars which comply to their warranty regulations. Problems arising from manufacturer can be easily identified and the available information provided by the system then expedite situation handling if any arises. The aviation CMMS have notable benefits which include the ease with which the aviation sector can implement an aircraft performance monitoring system. The engineering department of both general and military aviation is able to determine performance of each and every vessel in the fleet.

4.4 Maintenance Scheduling

The designed CMMS generates useful maintenance scheduling reports by using the aircraft leading particulars and out of phase spares. These reports (shown above) account for each and every aircraft performance, for each specific type it performed, in order to predict when a specific aircraft is due for its next maintenance. Data collected can be processed instantly, daily, or even in advance to allow for more efficient vessel scheduling.

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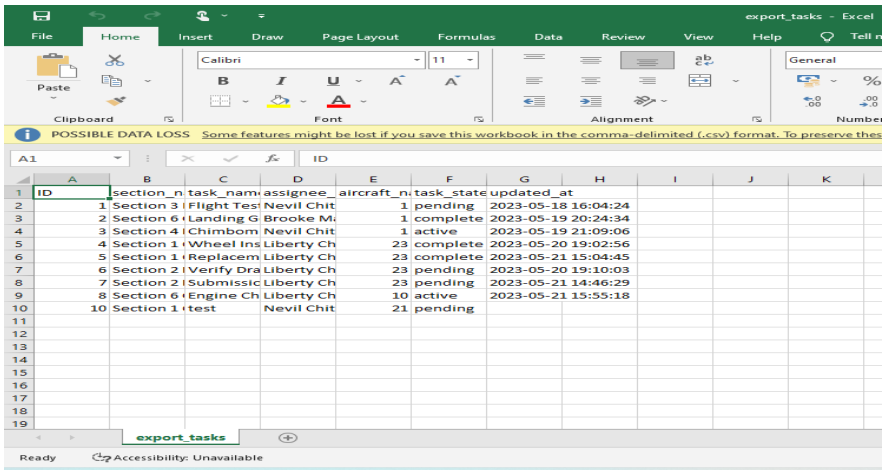

ID	section_n	task_nam	assignee_	aircraft_n	task_state	updated_at
1	Section 3	Flight Tes	Nevil Chit	1	pending	2023-05-18 16:04:24
2	Section 6	Landing G	Brooke M	1	complete	2023-05-19 20:24:34
3	Section 4	Chimbom	Nevil Chit	1	active	2023-05-19 21:09:06
4	Section 1	Wheel Ins	Liberty Ch	23	complete	2023-05-20 19:02:56
5	Section 1	Replacem	Liberty Ch	23	complete	2023-05-21 15:04:45
6	Section 2	Verify Dra	Liberty Ch	23	pending	2023-05-20 19:10:03
7	Section 2	Submissic	Liberty Ch	23	pending	2023-05-21 14:46:29
8	Section 6	Engine Ch	Liberty Ch	10	active	2023-05-21 15:55:18
10	Section 1	test	Nevil Chit	21	pending	

Figure 9. Excel report generated by the system.

4.5 Performance Monitoring System

The computerised maintenance management systems will be employed to record and trace each aspect in the performance of aircraft vessels. It will also be harnessed to monitor and account for the labour force, aircraft spares, the daily supplies and other related resources together with scheduling corrective maintenance and preventive maintenance. Generated reports and analysis availed by CMMS furnish indispensable feedback and elementary quality dimensions for a continuous qualitative improvement program. Information on performance of each aircraft, each engineering team performance to even each individual is availed on continuous basis. Amongst monitored types of data and statistical information by CMMS are the following reflected features:

4.5.1 The Access Page

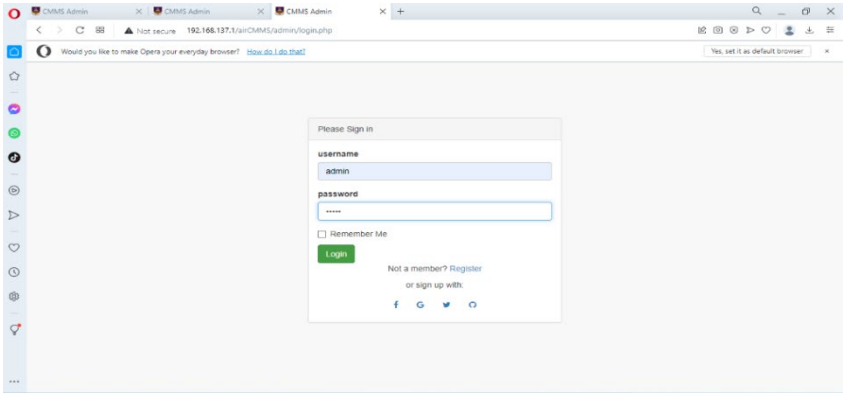

Figure 10. Access Page.

The access page allows the user to enter required details in this case, it is the administrator who enters the password. Upon entering the password, the individual responsible clicks the login key which give access to the dashboard.

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4.5.2 The Splash-screen

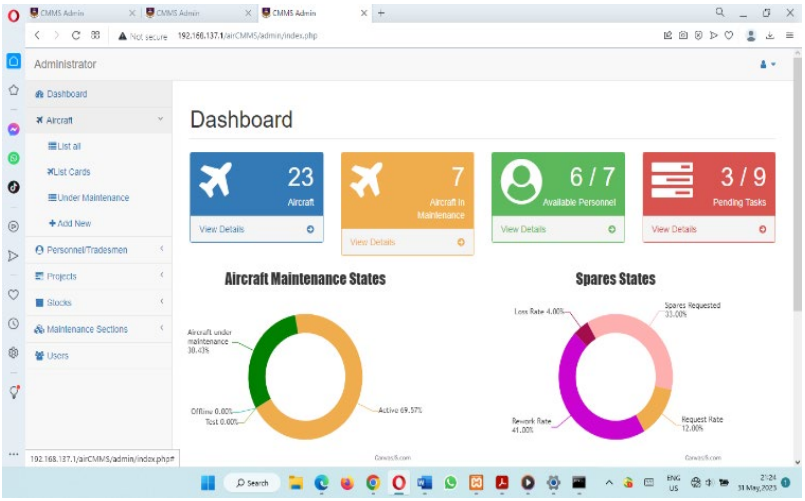

Figure 11. Splash-Screen Platform.

The splash-screen displays the aircraft state, spares state the menu to navigate the system with.

4.5.3 Aircraft Platform

The aircraft platform navigates an individual to the full aircraft list which have the aircraft serial number, type of aircraft, name and make, year of manufacture, whether it's a rotor type of aircraft or it's a fixed wing and the category.

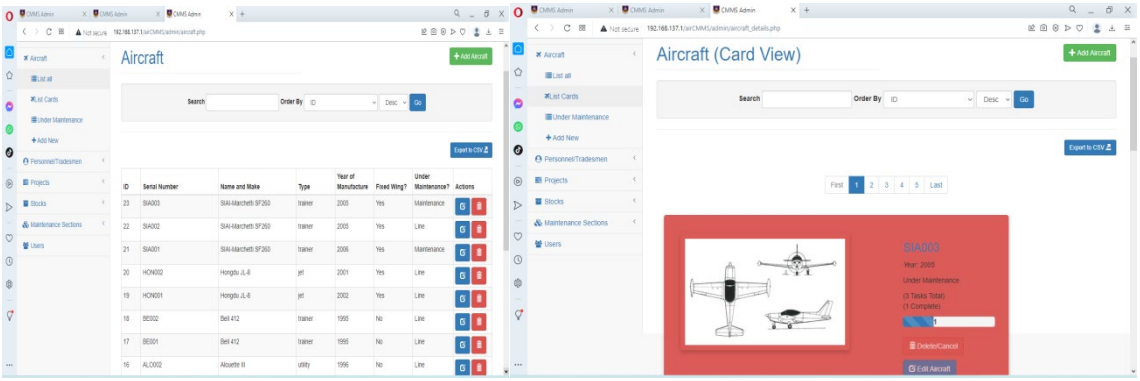

Figure 12. Aircraft Platform and Card View.

When one clicks on the selection they open the aircraft card view window which reflect in colour the category the aircraft is in (shown in figure 12 right hand side above), if under maintenance it will be red. Inside there will be information on the percentage of activity carried out.

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4.5.4 Personnel/ Tradesman Platform

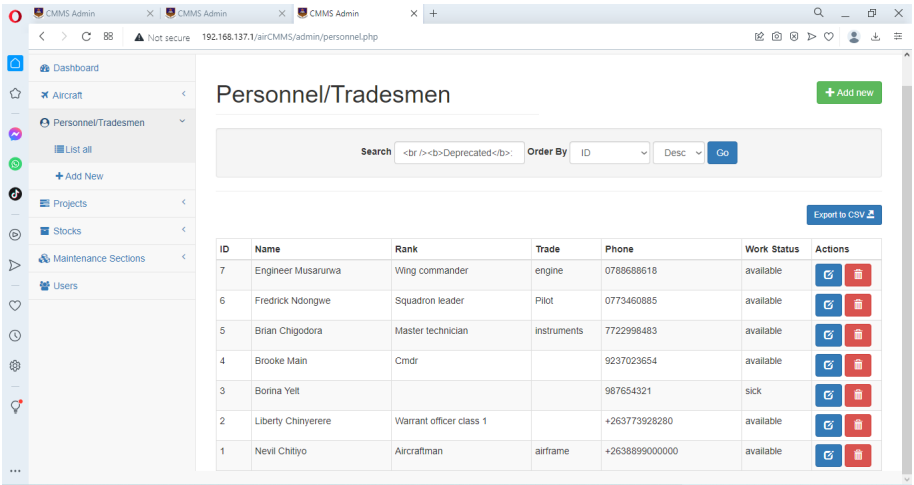

Figure 13. Manpower Disposition.

The platform displayed in figure 13 above is a manpower disposition where details of each individual are captured so there is the serial number denoted ID, name, rank, trade, contact phone details and work status. So, the work status will enable the supervisor to detail individuals with duties since it displays those present and those on leave as well as those feeling sick. If there is a new member who has been employed, the details of the individual are added to the Add new platform displayed below.

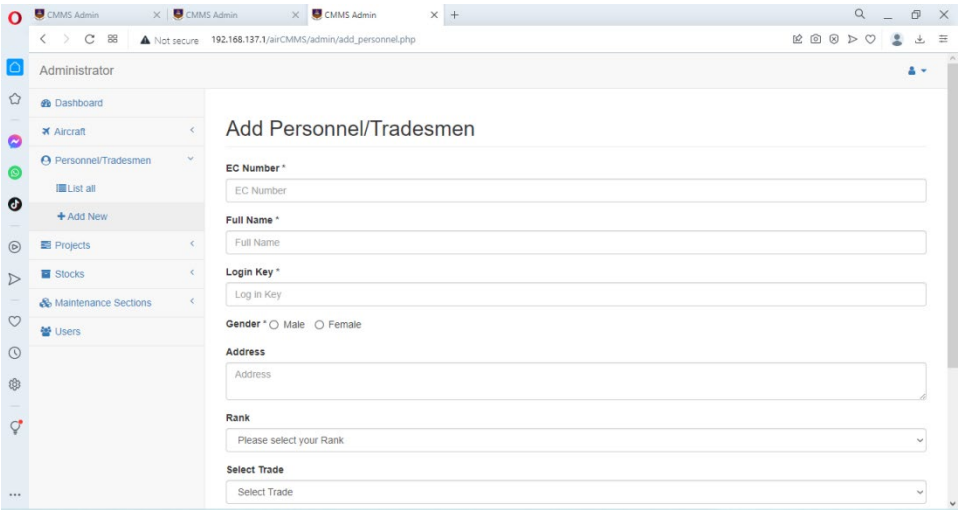

Figure 14. Add New Platform.

The EC number is entered, full name and an initial login password is also supplied. The gender is also important, place of residence for ease of locating the person whenever duties require attending outside working hours. The rank, trade and base column has a pre-input detail where the administrator just select the appointment, respective trade and the workstation/ base.

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Conclusion

Introduction

After the results shown from the previous chapter, there were certain challenges faced and quick solutions to them are discussed in this Chapter. The challenges which were not solved within the timeline are put as recommendations.

Challenges, Strategies and Solutions

Organizational Readiness: Every entity wants the best and newest tools for its growth but there are ways to introduce new tools. The organizational hierarchy has to be notified that a new system is being implemented to improve the already in place system such that increased benefits results.

Inadequate IT Facilities: To ensure IT infrastructure is availed; need must be stressed with available facilities assessed accordingly. Personnel has to be assured of a seamless, fast and reliable performing internet and intranet connections. The server structure has to always have latest versions available to support the input of the personnel.

Failure to Point out Benefits: The well-polished CMMS will immediately show results. The organizational hierarchy should quickly embrace the new system as it, analyses faults and assist with solutions which improve performance. Substantial benefits have to be indicated to the management as they occur especially established shorter periods in projects being undertaken.

Lack of Understanding of Well-designed Processes: An abrupt change is always resisted, but if the personnel are involved from the initial phases of the process, the change will be swift since there is enormous understanding of the whole process. Training, communication and acceptance are important factors to consider when major changes in an entity are to be successful.

Lack of Resources: Whenever there is an implementation of a new system, certain factors have to be met and properly budgeted for in the initial stages of planning. External resourcing usually aids the already available systems hence such considerations have to be made to support the already existing facilities. New technologies, connectivity are capable factors in enhancing resource availability and allocation.

Recommendations

The research recommends that:

- Wider local network be considered.
- CMMS be implemented.
- CMMS users regularly change passwords.
- Improve security measures
- Improve on the number and type of reports that can be generated
- Commercial Aviation adopt the system

Conclusion

The designed CMMS placed an emphasis on technology adoption and the elimination of the time-consuming paper-based approach in order to maximize available resource allocation. The logic used in the model derivation aimed at creating a system that was simple to use, eliminating counterfeits, and reduced the causes of frequent aircraft failures, resulting in less downtime. The model presented formalizes a decision analysis approach that analyzes and identifies numerous criteria in operational frequency, aircraft downtime, bottleneck status, and aircraft spares quality.

The research revealed a lack of conventional aircraft maintenance management systems. This clearly demonstrated why Zimbabwe has become a victim of counterfeit spare parts, resulting in catastrophic aircraft incidents and accidents. The implementation of the CMMS will eliminate the problems which were caused he technical by manual handling, also helps in identification in training gaps among team.

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Biographies

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