

**Maintenance Management System**  
**for**  
**Packwell Lanka (Pvt) Ltd**

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**Maintenance Management System  
for  
Packwell Lanka (Pvt) Ltd**

**A thesis submitted for the Degree of Master of  
Information Technology**

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University of Colombo School of Computing  
2021**



# Declaration

The thesis is my original work and has not been submitted previously for a degree at this or any other university/institute.

To the best of my knowledge it does not contain any material published or written by another person, except as acknowledged in the text.

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Signature

Date: 04.09.2021

This is to certify that this thesis is based on the work of Ms. S. I. D Jayamaha under my supervision. The thesis has been prepared according to the format stipulated and is of acceptable standard.

Certified by:  
Supervisor Name: Dr. H. A. Caldera



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Signature

Date: 05.09.2021

# Abstract

Packwell Lanka (Pvt) Ltd is a private company that specializes in the manufacturing of customized corrugated boxes and all other packaging solutions for more than 35 years and is leading the industry in providing a variety of packaging solutions to both domestic and international clientele. The company's main aim is to provide their customers with high quality products on time. In order to do so, they need to ensure that their equipment and machinery are maintained efficiently.

They currently employ a manual procedure for carrying out their maintenance, both preventive and corrective. The solution that is developed helps them to automate these processes with functionalities such as Equipment Management, Preventive Maintenance, Work Order Management, Predictive Maintenance, Vendor Management, Inventory & Procurement and Report Generation.

The Maintenance Management System was developed based on the Rational Unified process. PHP was the main programming language used along with NetBeans 12.0 as the Integration Development Environment (IDE). The database server used was MariaDB 10.1.19, which is a fork of the MySQL database server. Apart from PHP, HTML and CSS were used in the development of interfaces based on a Bootstrap theme.

The developed maintenance management system is implemented in the company with it being used to track breakdowns and assets. They are currently in the process of phasing out their old processes. All components of the system were tested comprehensively prior to implementation. The final outcome satisfies all customer requirements and has eased their day to day process.

# Acknowledgements

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# Chapter 1: Introduction

## 1.1 Project Overview

Packwell Lanka (Pvt) Ltd is a private company that specializes in the manufacturing of customized corrugated boxes and all other packaging solutions for more than 35 years and is leading the industry in providing a variety of packaging solutions to both domestic and international clientele. The company's main aim is to provide their customers with high quality products on time.

In order to achieve the said target, it is essential the machines are run at their peak efficiencies with no unplanned breakdowns. The process employed to achieve this involves maintaining the production machinery with planned and preventive maintenance programs to control the quality of the product and ensure that it always remains within the accepted quality levels specified by the client.

Maintenance management systems are software that help companies manage their assets, track breakdowns and schedule maintenance. They are intended to assist the company in ensuring that production proceeds hassle free whilst increasing profitability as well as reducing downtime of machinery.

## 1.2 Motivation

Presently, the maintenance activities adopted by the company are all manual and paper based. The company current performs 2 different types of maintenance: preventive and corrective.

The maintenance department maintains files on each of their individual equipment. The process they currently employ to conduct preventive maintenance is by maintaining a paper-based document of when maintenance for a particular equipment is due. Every month, the maintenance executive makes a note of equipment with maintenance due that month and manually assigns them to a technician. In the case of corrective maintenance, when an equipment failure is reported to the maintenance department, it is assigned to a technician to attend to it. Once the maintenance is done, it is reported back to the department head who then makes a note of the work carried out.

There are some scenarios where maintenance needs to be escalated to higher levels of authority. These include situations where large payments are involved for the maintenance

process. These approvals consume a time and significant paper wastage. Also, the entire process is not made transparent with other departments who have the need for a working equipment. They have to keep contacting the maintenance department to know the current status.

Considering all of the above aspects, the company wants to have a maintenance management solution which includes recording of all activities from unplanned breakdowns to planned maintenance on a computer database for viewing historical records at any given time and analyzing trend patterns that could forecast the breakdowns before they occur. This also helps to optimize the inventory by keeping only the required spares and thereby reducing the carry of unwanted stock.

### **1.3 Objectives**

The main aim of the project is to automate the maintenance management process thus increasing the maintenance department's productivity and efficiency. The efficiency of the machines also increases. Upon automation the following objectives shall be achieved:

- The work order placement and handling process will be entirely automated eliminating the need for manual paperwork.
- The commanding order will be automated with those involved being notified when assigned a work order, thereby increasing the efficiency of the management process.
- Information of equipment will be managed centrally, and relevant data will be accessible to all parties involved.
- Maintenance completion can be tracked by both managers and breakdown reporters (originators).
- Implementation of a reporting mechanism to download reports when and where required (as and when required by authorized personnel).
- Develop a mechanism to restrict areas in which a user may place work orders.
- Calculation of standard KPIs, such as the following, to be automated thereby improving their accuracy.
  - Overall Equipment Effectiveness (OEE)
  - Mean Time To Repair (MTTR)
  - Mean Time Between Failure (MTBF)
  - Planned Maintenance Percentage (PMP)

- Management of preventive maintenance schedules and notifications when maintenance is due.
- User management facility involving technical staff and those authenticated to use the system.
- Equipment Traceability (when an equipment is moved from one location to another)
- Enable facility to allow users to customize KPIs.
- Reduction of human error in the process.
- Reduction of equipment downtime.
- Development of a user-friendly system.
- Notifications to stakeholders via Emails and SMS

## 1.4 Background Study

A background study was conducted on the other similar systems available in the industry, and this is elaborated on in Chapter 2 of the dissertation. There are existing off-the-shelf software that can be used for the automation of this manual process. However, using the off-the-shelf software do not generally cater to all the requirements of the company. Also, if any customizations are required, they incur a large cost. Another option considered was reengineering the existing manual process.

There are also several alternative methods that may be used for the implementation of this solution. They are also discussed in Chapter 2 of the dissertation. These methods include using a standalone system, choice of development model and choice of programming language.

## 1.5 Scope

### 1. Dashboard

*The main dashboard of the system to be designed to provide all main indexes (statistics) of the system with regards to work orders, and preventive maintenance.*

### 2. Work Order Management

*This module is designed to store and retrieve details in relation to all work orders that have been entered into the system. The user is to be able to view details such as the work order no, related equipment, originator, costs, current status and take action where necessary (e.g.: elevation to higher authority).*

### 3. Equipment Management

*The Equipment Management module is proposed to store all information regarding equipment and facilitates objectives such as equipment traceability. This is also designed to allow the company to maintain a repository of the equipment available and ease the tedious process of accessing information.*

#### 4. Preventive Maintenance

*Preventive maintenance involves the systematic inspection of equipment where potential problems are detected and corrected in order to prevent equipment failure. In practice, a preventive maintenance schedule may include things such as cleaning, lubrication, oil changes, adjustments, repairs, inspecting and replacing parts, and partial or complete overhauls that are regularly scheduled. This module is to allow the user to store in the system a planned maintenance schedule. The system will then accordingly notify the users when maintenance is due and allow the same to be tracked.*

#### 5. Predictive Maintenance

*Predictive maintenance uses the data collected during monitoring to determine when performance degradation or failure is likely to occur, and the severity of the decline. This allows maintenance tasks to be performed in a more accurate and cost-effective manner based on real time equipment assessment.*

#### 6. Vendor Management

*The management of equipment and other spares requires the company to interact with external vendors. This module is designed to store a list of such vendors and manage them.*

#### 7. Inventory and Procurement Management

*The maintenance of work equipment requires spares and tools. This module is to be used to maintain an inventory of such items within the company. This will also facilitate the generation of purchase orders for procurement of stock.*

#### 8. Report Generation

*The report generation module allows users to download predesigned reports based on parameters when and where required.*

#### 9. User and Access Management

*This module deals with the security of the system. This is where new users can be created and granted access to the system. Additionally, it also allows for specific features of the software to be accessible only to certain user levels which can be customized by the administrative user of the organization.*

## **1.6 Feasibility Study**

In order to assess if or not the proposed system is viable, a feasibility study was carried out on the technical, economical and operational feasibility. The technical feasibility of a project discusses whether or not the proposed solution is practical and if or not sufficient technical resource and expertise are available within the organization post implementation. (PadaKuu, n.d.) Considering the fact that the final solution is web based, the existing technical equipment within the company should be sufficient for the implementation.

The economic feasibility of a solution is a measure of its cost effectiveness. (PadaKuu, n.d.) In order to assess the economic feasibility, all costs, direct and indirect are taken into account. Generally, these include costs for the infrastructure of the proposed solution, additional costs for human resource and cost of training the existing staff. Evaluation of these aspects make it clear that the benefits of implementation of the solution outweigh the costs. Since the main users of the system would be staff of executive grades and above, they currently have the competency to use a computerized system. Hence additional cost would be incurred to train the staff. With migration of the manual process to an automated one, the large cost of paper being used by the company would be reduced immensely.

Operational feasibility is a study of how well the solution will work within the organization. Implementation of this solution poses no added risk to the current operation, neither does it affect any staff member's job security since they can continue to do their daily jobs. It does however, reduce the effort to be made on documenting and maintaining files on maintenance tasks that are carried out.

## **1.7 Structure of the Dissertation**

The Background chapter provides an outline of the requirement analysis and background study conducted prior to the development of the solution. This includes a review of similar systems, related technologies and design strategies. This is followed by a chapter on Design Architecture of which the purpose is to highlight the structure of the system being implemented. All design documentation for the system will be provided here. The Implementation & Methodology chapter includes the tools used in the development of the project along with all major code segments and re-used components of other authors.

The Evaluation chapter provides a critical assessment of the system. This includes the testing that was carried out along with a detailed test plan and results. It will also discuss the

response to the system by the users and a discussion of whether or not all initial objectives of the system were met. The final chapter of the dissertation is the Conclusion including a summarized result of the project. It shall also discuss any drawbacks with the implemented and system and suggest future room for improvement.



# Chapter 2: Background

This chapter contains an analysis of the requirements of the company, a review of the existing similar systems in the market and other alternative solutions.

## 2.1 Requirement Analysis

The main technique used to gather information was interviewing the staff at the maintenance department of the company. The interviews proved to be very helpful as it enabled to get a wide area of understanding about the entire process as a whole.

The observation technique was also used to collect information on the system. The process was observed so that the points where the system needed to take over functions could be identified. The other main method used was reviewing of current documents such as purchase orders, invoices and equipment records. This allowed to gain information on the information that needs to be stored and the layout of reports and invoices and other documents.

Using all of the above techniques, the following problems were identified with the existing workflow in the company.

- A lot of paperwork is involved. This includes the recording of a breakdown, maintenance schedules, work order assignments, etc.
- Management of technical staff, identifying their availability and also managing external vendors.
- Risk of work orders being ignored as a result of being misplaced in approval processes.
- Keeping track of an equipment inventory and repairs is a tedious task.
- Conduction of preventive maintenance and monitoring KPIs for equipment requires a significant amount of manpower.
- Unable to predict when maintenance is due since documentation is done manually.
- In order to provide a checklist of what to do in the event of a breakdown, multiple copies need to be made resulting in redundancy and wastage of paper.
- No mechanism for the auto generation of reports in the manual process.
- There is no transparency between the maintenance and external departments.
- Searching for information is time consuming.
- Updating details regarding a single equipment requires changing information stored in multiple locations

- Maintaining a history of equipment requires large files.
- Data redundancy

The above highlighted problems were analyzed and used to arrive at the objectives and scope outlined in Chapter 1.

### **2.1.1 Functional Requirements**

- Any staff member at executive grade or above to be able to report a breakdown.
- The breakdown to be notified to the maintenance department and maintenance executive to be able to do one or many of the following tasks:
  - Assign the work order to a technician
  - Escalate to higher levels
  - Purchase spare parts
- Technician to be notified of assigned work order
- Any staff member at executive grade or above, involved in the work order, to be able to track its status from origination to completion.
- Dashboard depicting the values of standard KPIs.
- Maintenance department to be able to manage preventive maintenance by scheduling in advance.
- Notifications to be received by the department when maintenance is due.
- Maintenance executive to be able record details on equipment.
- Maintenance Manager to be able to define customized KPIs.
- A standard set of reports to be available for download.
- The maintenance department needs to be able maintain a record of the suppliers

### **2.1.2 Non-Functional Requirements**

- Maintain a high level of security with only authorized users being able to access it.
- Always sustain accuracy with regard to its data.
- Have a user friendly interface and be accessible to all.
- Always be available and reliable to the company.
- Display maintainability.

## **2.2 Review of Similar Systems**

Similar systems, available for purchase to be used in the industry, were studied to get an idea of the system being developed and how the functions needed to be presented. Considering the

role of maintenance managers in a company, a CMMS (Computerized Maintenance Management System) needs to have several essential features in order to prove itself valuable. According to DPSI (DPSI, n.d.), the following are five key features for maintenance managers:

1. Work order tracking
2. Reusable task templates
3. Share statistics with upper management
4. Generate equipment breakdown reports
5. Give maintenance technicians quick and easy access to work orders

Also, systems generally have a set of non-functional features that need to be addressed such as:

- Security – Only authenticated users need to be able to login to the system
- Accuracy – Calculations done within the system must be accurate and not have any error
- Availability – The system must be available at least 95% of the time
- Connectivity time must not exceed 5 seconds (FBTR India, n.d.)

The industry currently has many maintenance management systems which include but are not limited to the following:

- GP MaTe (Anon., n.d.)

*User-friendly maintenance and material management system that facilitates maintenance planning and inventory control. Product has many optional modules that support Safety (PSM, MOC and LOTO), Budgeting, Multi plant information sharing, and Operator Tours and Data Collection. The system is available in many languages and supports vendor currency conversions.*

- EZOfficeInventory

*This is a leading CMMS software that enables you to track maintenance costs, schedule services, manage vendors, and customize alerts for greater control. This software includes a mobile app to scan QR Code and Barcode labels and manage service tickets on the go. It also provides full maintenance histories and actionable service reports.*

Table 2.1 below shows a comparison of the above software that was done by Capterra. (Capterra, n.d.) Both of the below have high starting prices, with additional costs for inclusion of extra features and functionalities.

	<b>GP MaTe</b>	<b>EzOfficeInventory</b>
<b>Starting Price</b>	\$2,000.00/single user license	\$35.00/month
<b>Best For</b>	Large facilities including manufacturing, power production and processing	Caters to needs of different industries
<b>Users</b>	1000+	1000+
<b>Features</b>	<ul style="list-style-type: none"> <li>• Billing &amp; Invoicing</li> <li>• Calibration Management</li> <li>• Inventory Management</li> <li>• Key &amp; Lock Management</li> <li>• Mobile Access</li> <li>• Preventive Maintenance</li> <li>• Service History Tracking</li> <li>• Technician Management</li> </ul>	<ul style="list-style-type: none"> <li>• Billing &amp; Invoicing</li> <li>• Calibration Management</li> <li>• Inventory Management</li> <li>• Mobile Access</li> <li>• Preventive Maintenance</li> <li>• Service History Tracking</li> <li>• Technician Management</li> </ul>
<b>Platform</b>	Web/Installed/Mobile	Web/Installed/Mobile

*Table 2.1 Comparison of GP MaTe vs EzOfficeInventory*

All of the features listed in Table 2.1 above are characteristics associated with Computerized Maintenance Management Systems (CMMS). Apart from these, the solution developed will also provide dashboards and equipment traceability with allowance for customization.

### **2.3 Related Implementation Methods**

Standalone systems can be tailor-made or off-the-shelf. However, they are not networked to other systems or to the internet. Such systems have a high level of security as the only way of entry to the system is by user authorization. Nevertheless, it has its drawbacks such as, data redundancy and remote file access made difficult.

An alternative to the above method is the implementation of a web-based solution. Web-based solutions can be hosted in house or publicly. They also allow for platform independence since the system is built for access via a web browser. Table 2.2 below gives a comparison of the features available in Web and Standalone applications.

<b>Web Applications</b>	<b>Standalone Applications</b>
Deployment is carried out on a server.	Deployment is carried out on individual client machines separately.
Web applications can be accessed from anywhere, so there is no location constraint.	As desktop are confined to a standalone machine, so they can be only accessed from the machines they are deployed in.
Web applications are platform-independent, they can work in different types of platforms with the only requirement of a web browser.	Desktop applications need to be developed separately for different platform machines.
Web applications are at higher security risks as they are inherently designed to increase accessibility.	Desktop applications, on the other hand, have better authorization and administrators have better control, hence more secure.
Web applications rely heavily on internet connectivity, for there operation.	Desktop applications don't require the internet for their operations.

*Table 2.2: Standalone vs Web-based Solutions (ArtOfTesting, n.d.)*

The system being developed will provide a “web-based solution” to the company’s problems. The main reason for selecting a web based solution is because it provides the facility for employees in the company to interact with the system irrespective of their location. Also cost for peripheral devices within the company is reduced as it provides the ability to share devices via networking.

## **2.4 Related Technologies**

The implementation of software such as this requires several technologies to be used. These include:

- Programming Language
- Database Management System
- Architecture

There are a variety of coding languages that are available for use with web based systems, such as HTML, CSS, Java, JavaScript, Python, Php, .Net and Angular. (Spinx, n.d.) Each of these languages have different purposes and cater to different needs. The following languages will be used in the development of this solution,

- HTML – Development of the base layout, structure and static pages

- CSS – Styling of all web pages
- JavaScript – User interactions and form input validation
- Php – used for the management and manipulation of data which includes storage in the database and retrieval for presentation to the user.

The purpose of the database server is for the maintenance of a central location for storage of the entered data. The most appropriate database management system for web based solutions is MySQL. It is commonly used because of its flexibility, speed and reliability. Another key advantage of using MySQL is that is open source and hence free to use.

“Software architecture refers to the fundamental structures of a software system and the discipline of creating such structures and systems. Each structure comprises software elements, relations among them, and properties of both elements and relations. It functions as a blueprint for the system and the developing project, laying out the tasks necessary to be executed by the design teams.” (Wikipedia, n.d.) Advantages of using development frameworks are they create a solid base in the development of a software solution. It also allows for reusing of code hence reducing code duplicity. The architecture used in the development of this solution is the Model-View-Controller (MVC). This is an architecture that separates a solution into three sections:

- Model – which contains the business logic
- View – which contains the user interfaces and views
- Controller – the layer that coordinates between the model and view

There are other architectures available such as Client-Server, Data-centric and monolithic. However, the advantage of using MVC is that it allows for faster web development, offers multiple views within a single model, modifications generally do not affect the entire model and also this architecture allows to return data without the need for formatting.

## **2.4 Related Design Strategies**

“The systems development life cycle (SDLC) is a term used in systems engineering, information systems and software engineering to describe a process for planning, creating, testing, and deploying an information system.” (Wikipedia, n.d.) Process models are the techniques available for the development of the system depending on the systems objectives. Different process models used today include the Waterfall Model, Prototype Model, Agile Method and the Rational Unified Process (RUP).

The first widely used software life cycle model is referred to as the waterfall model. It is generally considered the conventional or "classical" software lifecycle. The waterfall model is an idealized process model in which each phase is completed before the next phase is started, and a project moves from one phase to the next without iteration or overlap. (Gomaa, 2011)

“The prototyping model suggests that before carrying out the development of the actual software, a working prototype of the system should be built. A prototype is a toy implementation of the system.” (Mall, 2004) This is a model where a solution is built, tested, presented and rebuilt until accepted by the system users. It is a commonly used trial and error method and is mostly used in scenarios where the requirements of the user are vague and unclear. However, the drawback with using this model is that it consumes a large amount of time building prototypes while incurring a high cost. This method also encourages users to frequently change their requirements.

The process model being used for the development of this system is the Rational Unified Process (RUP). The Rational Unified Process is an object-oriented and web-enabled program development methodology. (TechTarget, n.d.) RUP consists of four phases namely, Inception, Elaboration, Construction and Transition. The Inception phase is where the idea for the solution is stated and feasibility of the project is determined. During the Elaboration phase, the resources are further evaluated and other cost factors that need to be considered in the development. The development of the solution is completed in the Construction phase of the model. Once the development is done, the testing cycles are also carried out in this phase. The Transition phase is when the solution is released to the company with room for final adjustments that are received from the users.

Reasons for the selection of this process include the fact that it is able to keep up with the client's changing requirements. The process of integration also goes on throughout the life cycle and hence reduces the time. Also, since components are reused, the development time is greatly reduced.

## **2.5 Summary**

In conclusion, considering the requirements analyzed in this chapter, the following implementations and technologies were selected. The system is to be a web based solution, following a client – server architecture. The solution development is to be based on PHP using the RUP design approach.

# Chapter 3: Design Architecture

This chapter focuses on the overall structure of the system. Design documentation with regards to the system such as Use Case diagrams, Sequence diagrams will be provided here. In order to provide an overall understanding of the database structure, the Entity Relationship Diagram (ERD) will also be elaborated on in this chapter.

## 3.1 Overall System Structure

The main purpose of a component diagram is to demonstrate how the various modules of a system interact with each other.

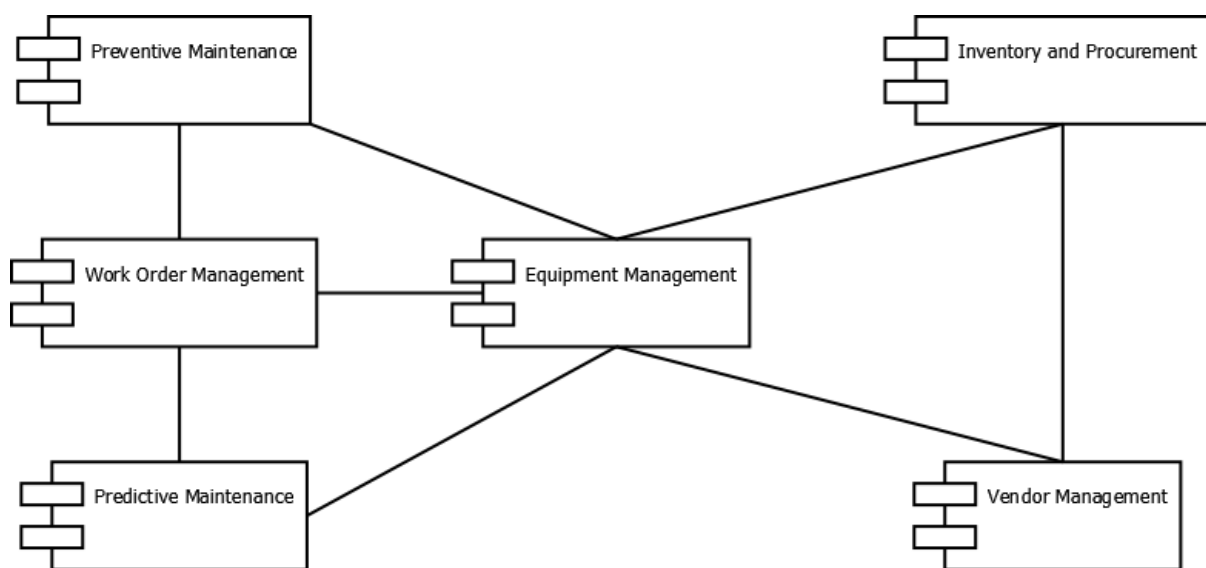


Figure 3.1: Component Diagram

Figure 3.1 above shows the component diagram of the developed system. The key modules relevant to the maintenance process are as follows:

- **Equipment Management**  
*This module is responsible for the maintenance of equipment information. It also handles information on spares.*
- **Preventive Maintenance**  
*Handling of preventive maintenance that have been pre planned by the maintenance department.*
- **Predictive Maintenance**  
*Handling of predictive maintenance that are generated by the system based on individual KPIs for each equipment.*



- Work Order Management

*This module is concerned with the management of all work orders that are created for maintenance starting from the initiation to the completion.*

- Vendor Management

*The information regarding vendors that are supplying or have supplied equipment to the company are managed using this module.*

- Inventory and Procurement Management

*The procurement of spares and maintenance of the inventory is done using this module.*

The Work Order Management module operates on its own and is also related to the Predictive and Preventive Maintenance modules. This is because, whenever predictive or preventive maintenance is carried out, a new work order needs to be created. The predictive and preventive maintenance also needs to interact with the Equipment Management module. This module is concerned with the storage of information regarding machinery within the company as well as other spares related to them. Hence, these modules have to be consistent and integrated together in order for the system to function smoothly. The Equipment Management module is in turn linked to the Vendor Management and Inventory and Procurement modules. These modules are used for the management of Vendor information and purchasing of spare part stock respectively.

Apart from the key modules listed in the diagram above, the User Management module is used for the maintenance of user information. This includes those that have access to the system as well as information regarding the staff of the Maintenance department.

## **3.2 Use Case Diagrams**

A use case diagram is the primary form of system/software requirements for a new software program underdeveloped. (Visual Paradigm, n.d.) They are able to provide a graphical view of what the system is supposed to do. The use case diagram in Figure 3.2 below gives an overall idea of how all the stakeholders of the company interact with the system.

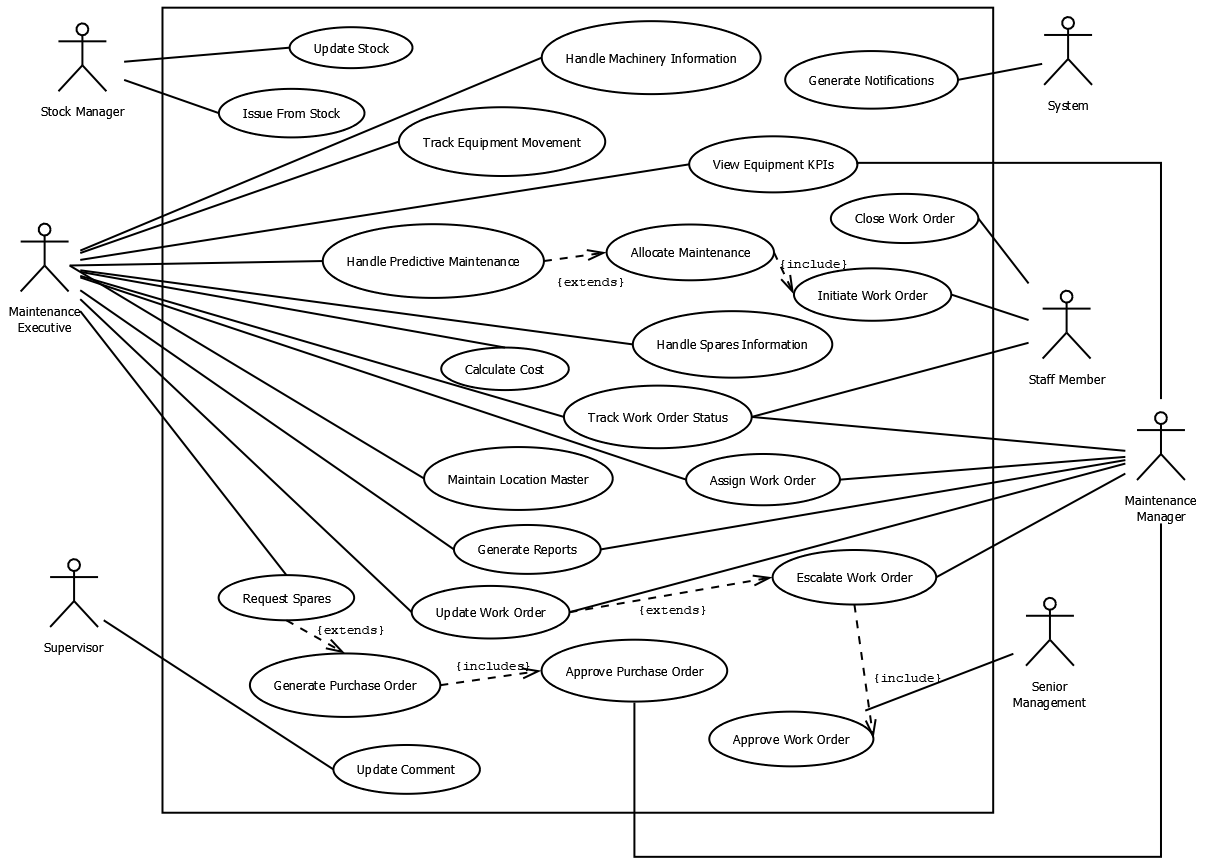


Figure 3.2: Overall Use Case Diagram

### 3.2.1 Equipment Management

The Equipment Management modules is mainly used for the maintenance of a record of all equipment within the company. Figure 3.3 below shows the use case diagram for the equipment management module.

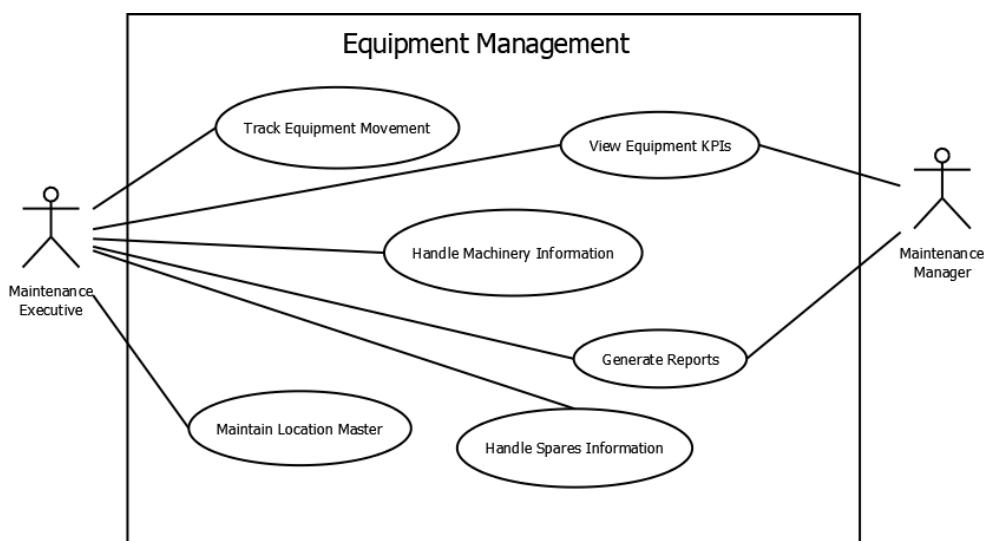


Figure 3.3: Use Case Diagram for the Equipment Management Module

The Maintenance Executive is able to register new equipment in the system. The company required for the system to include the ability of maintaining equipment in several geographical locations. For this purpose, a functionality has been included which allows the maintenance department to manage a location master. These locations are then classified into sub locations. Equipment may be moved across these locations and the functionality has been provided for users to track the same. This module also allows visibility into the Key Performance Indicators of each equipment.

### 3.2.2 Preventive Maintenance

Preventive Maintenance is referred to as maintenance that is carried out before a breakdown occurs.

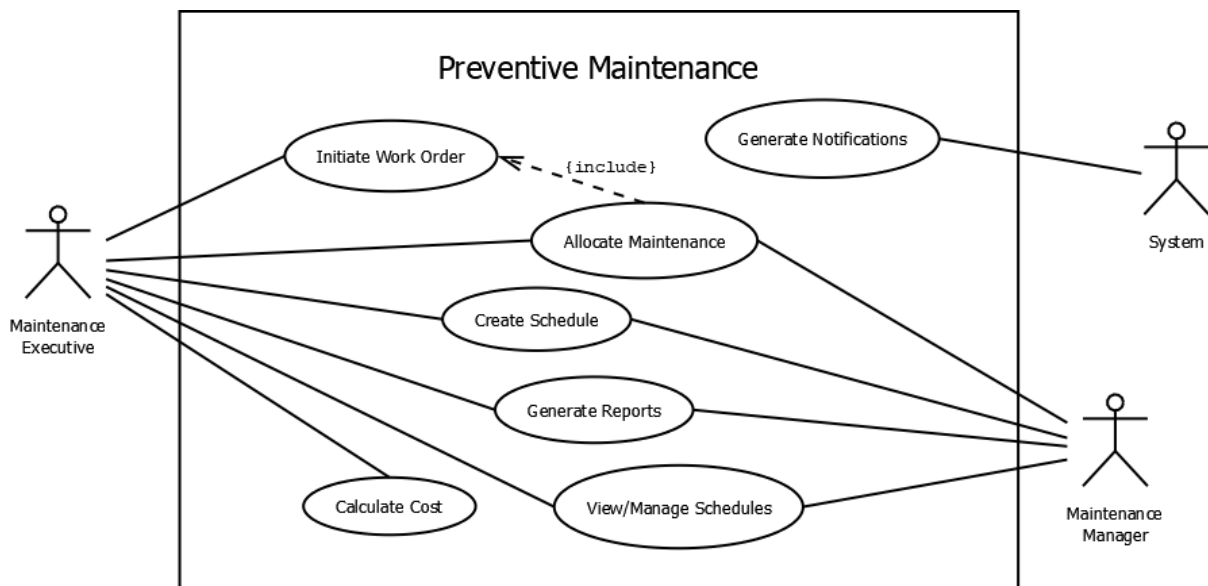


Figure 3.4: Use Case Diagram for the Preventive Maintenance Module

Figure 3.4 above shows the use case diagram for the module that handles preventive maintenance. In order to carry this out successfully, users of the maintenance department are able create a schedule for each equipment. They can do this either manually, or they could assign a maintenance frequency. Based on the schedule that is entered into the system, the system will generate notifications to the users whenever maintenance is due. The maintenance department can then create a work order for completing the scheduled maintenance. For maintenance tasks that involve replacing parts, an approximate cost is also calculated prior to completion.

### 3.2.3 Predictive Maintenance

The predictive maintenance module is mainly based on data that has been input into the system. The standard KPIs that are generated for each equipment, such as Mean Time Between Failure are used to analyze and predict the probability of a breakdown before it happens.

Figure 3.5 below shows the interactions of the users with the module. When the users are notified of a probable breakdown, they are able to analyze it and then decide whether to dismiss it or initiate a work order to check on the same.

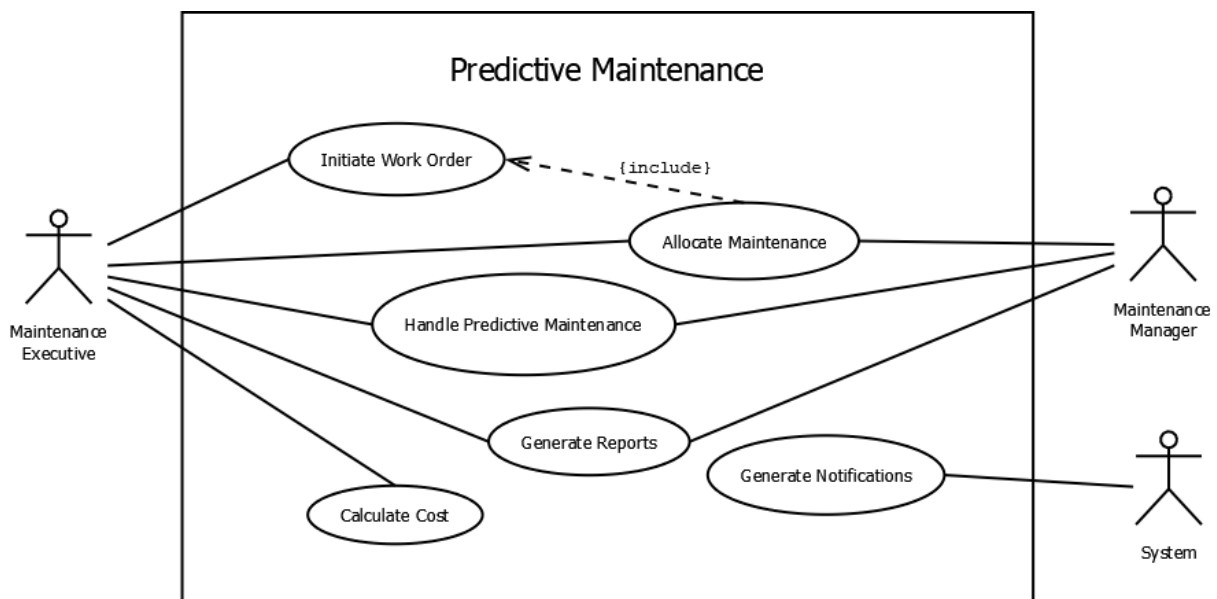


Figure 3.5: Use Case Diagram for the Predictive Maintenance Module

### 3.2.4 Work Order Management

This module is the most important in the system. It interacts with all other modules and focuses on being able to complete a work order in time. Whenever predictive or preventive maintenance is carried out, a work order is created. Apart from this, this module is responsible for handling all forms of corrective maintenance.

Figure 3.6 below depicts the interactions between the key stakeholders of the Work Order Management module. Any authorized staff member is able to raise a work order. This work order is then assigned to the maintenance department who assess it and assign it to a technical staff member to carry it out. While the maintenance process is being carried out, the technical personnel are able to update the status and comments against the work order through their supervising staff. Sometimes, scenarios may occur where the actions to be taken need be to escalated to higher authority. This is also enabled where the maintenance manager is able to raise the work order for approval from the senior management. All changes to work order status

are notified to the actioner via email. Once the maintenance is complete, the initiator is notified, and they are able to close the work order.

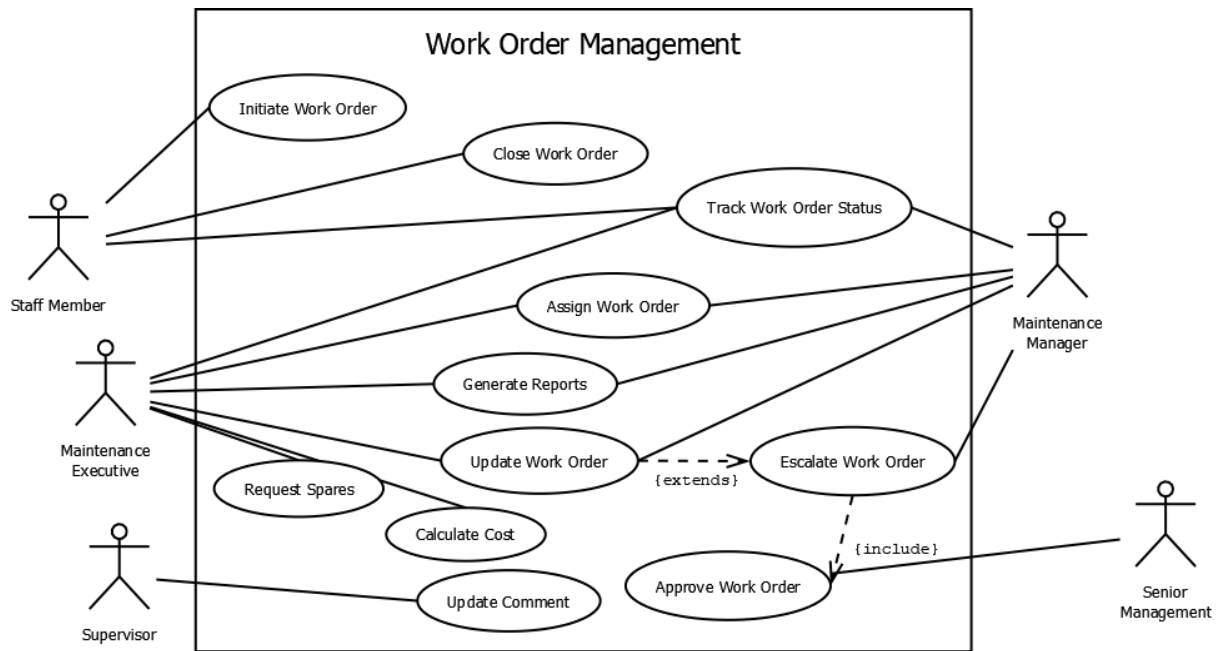


Figure 3.6: Use Case Diagram for the Work Order Management Module

### 3.2.5 Vendor Management

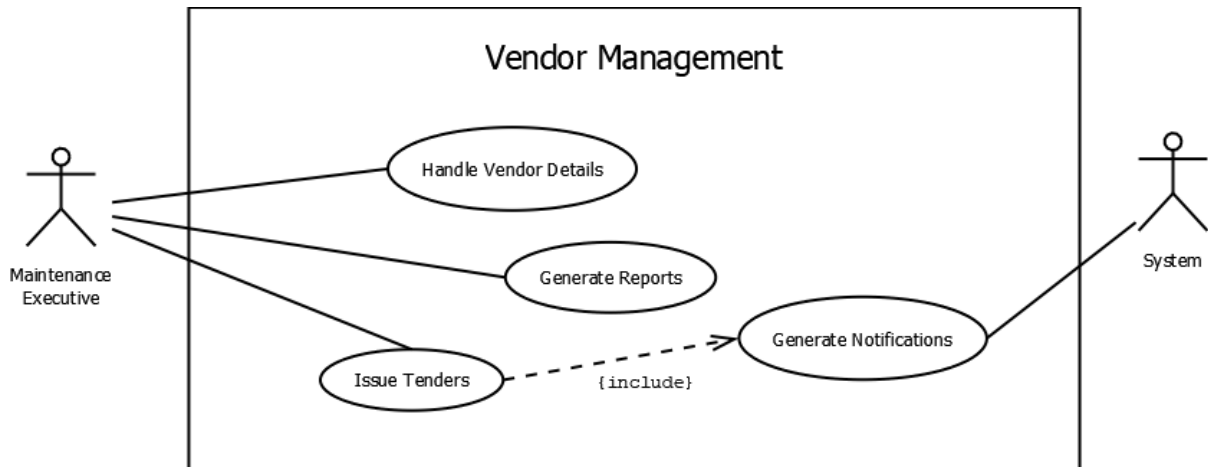


Figure 3.7: Use Case Diagram for the Vendor Management Module

Figure 3.7 above is the Use Case Diagram for the Vendor Management Module. This module is used for the storage of Vendor information relevant to existing equipment in the company. The Maintenance executive is able to add and modify vendor information. Functionality is also provided to notify existing vendors of the company whenever tenders are called for new equipment.

### 3.2.6 Inventory and Procurement

The purpose of the inventory and procurement module is keeping track of the spares for the equipment and also for ordering of same when required. Figure 3.8 below shows the use case diagram for this module. The stock manager is also a key stake holder in this module and is responsible for adding the items to and issuing them from stock. Reorder levels are maintained and the system generates notifications when this level has been reached. The maintenance executive is able to generate purchase orders for the procurement of equipment. This is then sent for approval by the maintenance manager.

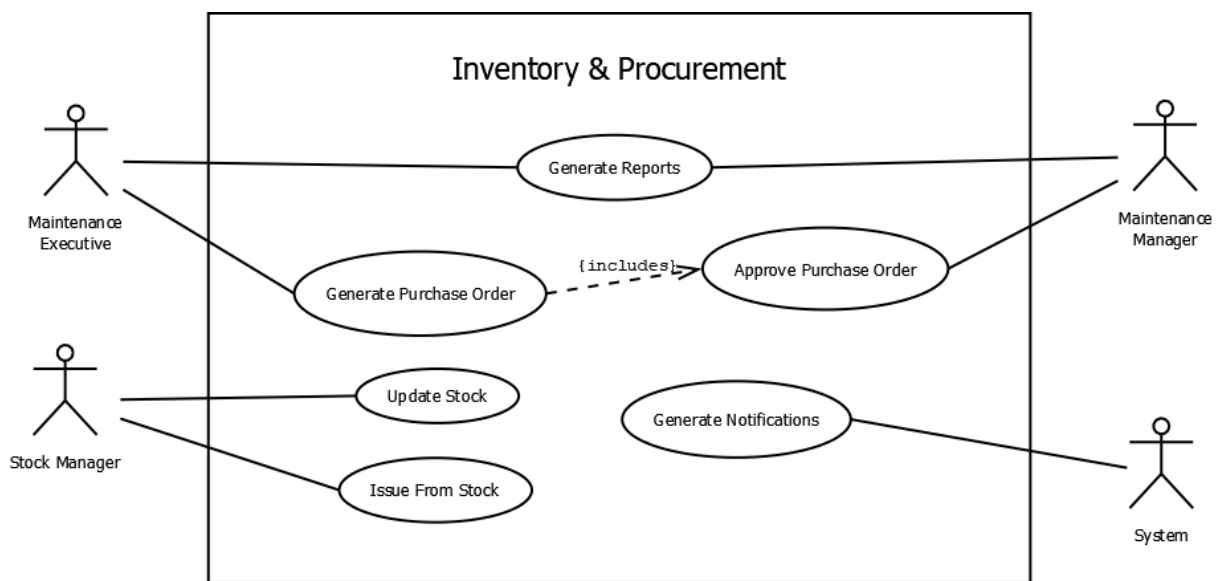


Figure 3.8: Use Case Diagram for the Inventory and Procurement Module

### 3.2.7 Administration Module

The administration module is concerned with the aspects of the system such as user management and master data management. Figure 3.9 below is the use case diagram for this module. In this use case, the actors have been classified as administrator and user.

General users are able to login and change their password if required. Administrators are able to add new users or restrict existing users. The system also has an array of user roles to which users can be mapped. The permissions for these user roles can also be set by the administrators of the system. Apart from this, even though the technical staff is not given access to the system, their details need to be maintained for the purpose of assigning them work orders to carry out.

Capability has also been given to the administrators to customize the KPIs that they want to monitor. They are able to do so by customizing the calculations for other KPIs that they may want to monitor down the line.

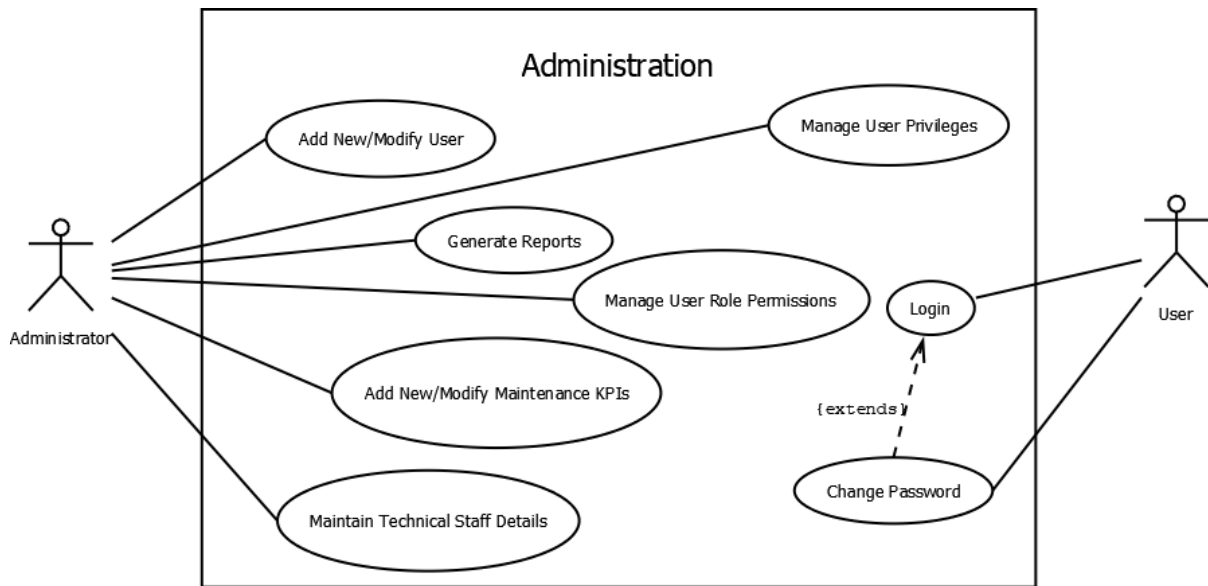


Figure 3.9: Use Case Diagram for the Administration Module

### 3.3 Sequence Diagrams

The purpose of sequence diagrams is to display the interactions between objects in order to carry out a function. Figure 3.10 below shows the sequence of functions being called when a user attempts to login to the system. Initially, the user enters their username and password into the login form. This data is validated against the list of authenticated users in the database. If a match is found for the username and password pair, the login successful message is displayed and user is able to login to the system.

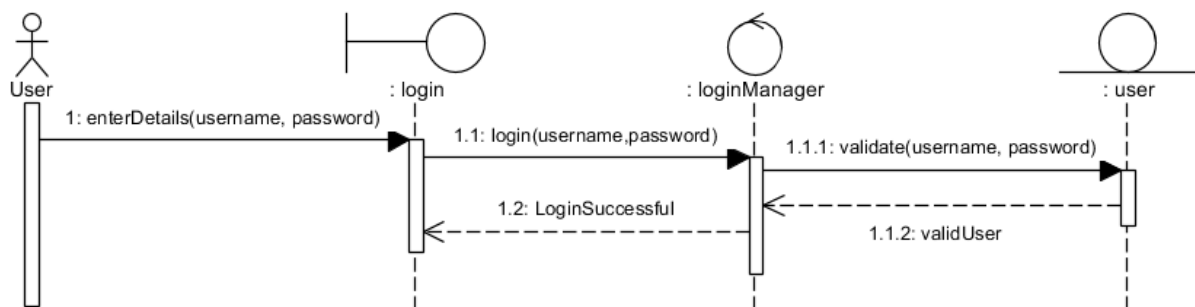


Figure 3.10: Sequence Diagram for Successful User Login

Figure 3.11 below is a diagram that shows the flow of information during the initiation of a work order. First, the user navigates to the ‘Create Work Order’ page and enters the details

of the breakdown. These details are then used by the control module to insert data into the database. Once the data is successfully inserted, a reference to the work order is generated and displayed to the initiator. Finally, the maintenance department is notified via email that a new work order has been initiated.

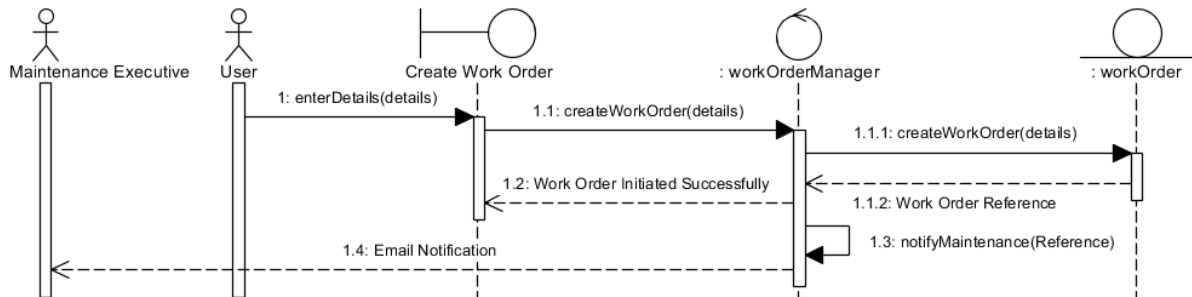


Figure 3.11: Sequence Diagram for Successful Work Order Initiation

### 3.4 Entity Relationship Diagram

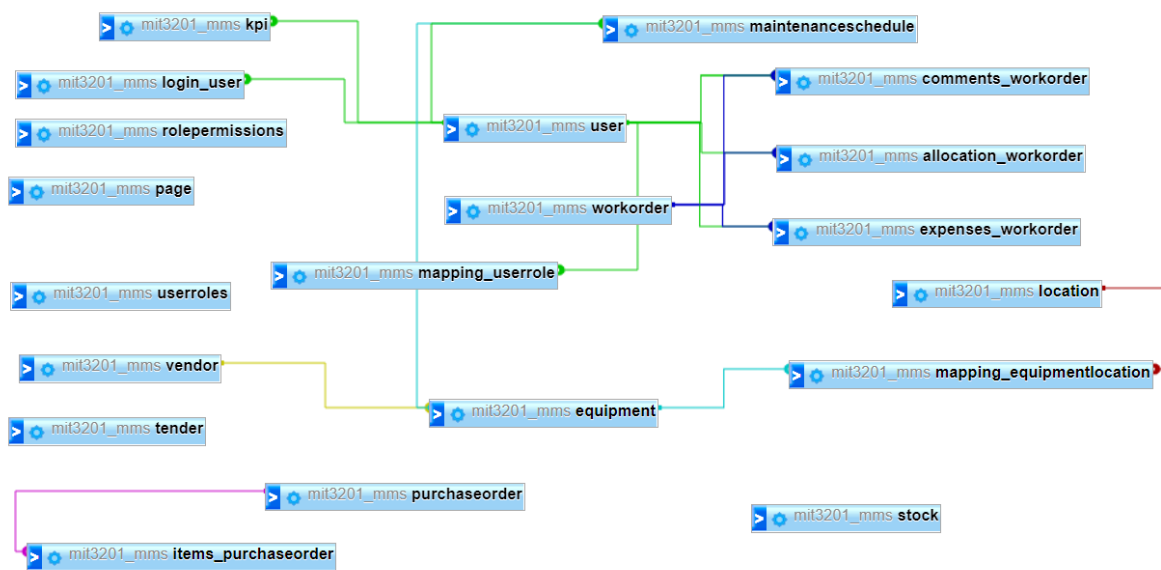


Figure 3.12: Summarized Entity Relationship Diagram

An ERD shows the relationships between entities stored in the database. The diagram in Figure 3.12 above has been generated using the database manager and shows the relationships between the various tables in the database.



### 3.5 Class Diagram

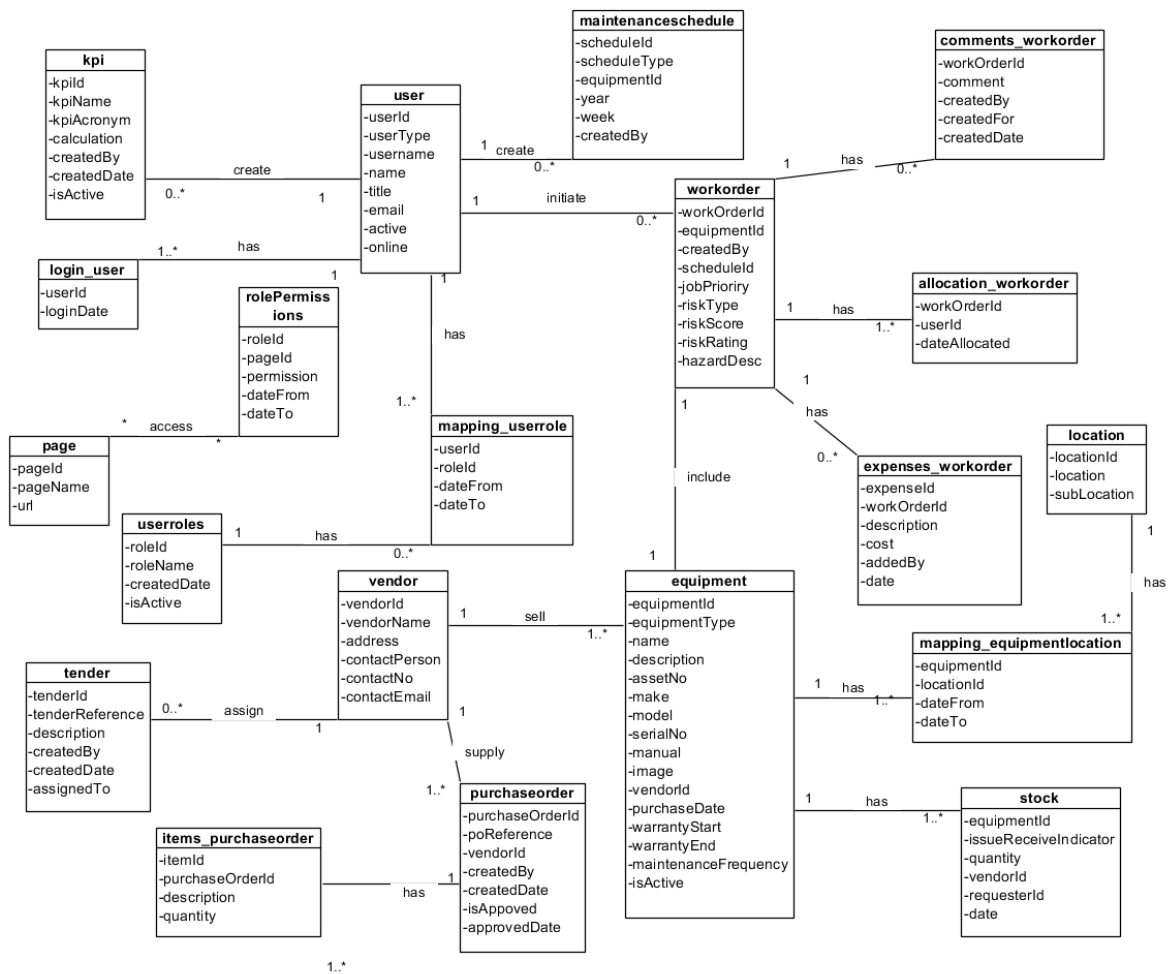


Figure 3.13: Class Diagram

The class diagram is the main building block of object-oriented modeling. It is used for general conceptual modeling of the structure of the application, and for detailed modeling translating the models into programming code. Class diagrams can also be used for data modeling. (Wikipedia, 2009) Figure 3.13 above is the class diagram that was designed for the Maintenance Management System. It clear shows the entities along with their attributes as well as the relationships that they have with each other.

### 3.6 Activity Diagram

The main purpose of an activity diagram is to capture and portray the dynamic aspects of a system. It is quite similar to the sequence diagram differing only in the fact that the sequence diagram shows the flow of messages between objects whereas the activity diagram illustrates the flow of messages between activities. Figure 3.14 below shows the activity diagram for the process that occurs from the initiation to the closure of a work order.

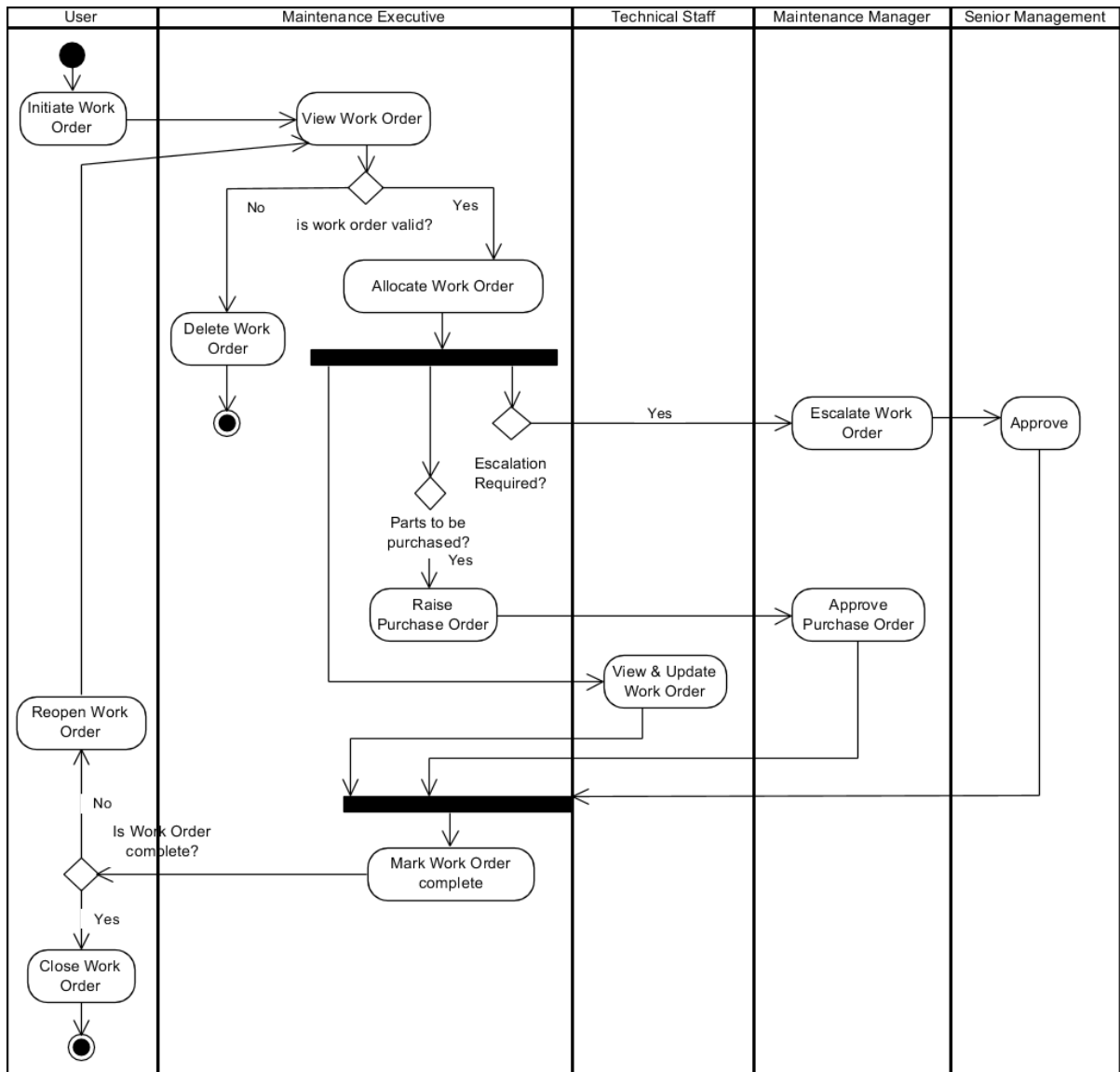


Figure 3.14: Activity Diagram for the Work Order completion process.

### 3.7 User Interface Designs

The user interface design is a critical part of a software system. It has to be ensured that the design is consistent throughout and appears user friendly. For the purpose of developing the interfaces, a readily available Bootstrap theme was used, Admin LTE. The following are samples of interfaces designed for some of the key functions.

#### 3.7.1 Login Page

Figure 3.15 below shows the design of the login page. This is the first location that a user lands on upon attempting to access the system. Once the username and password are entered and authenticated, the user is logged into the system and redirected to the main

dashboard. If invalid credentials are entered, an error message is displayed and user is redirected to the same page.

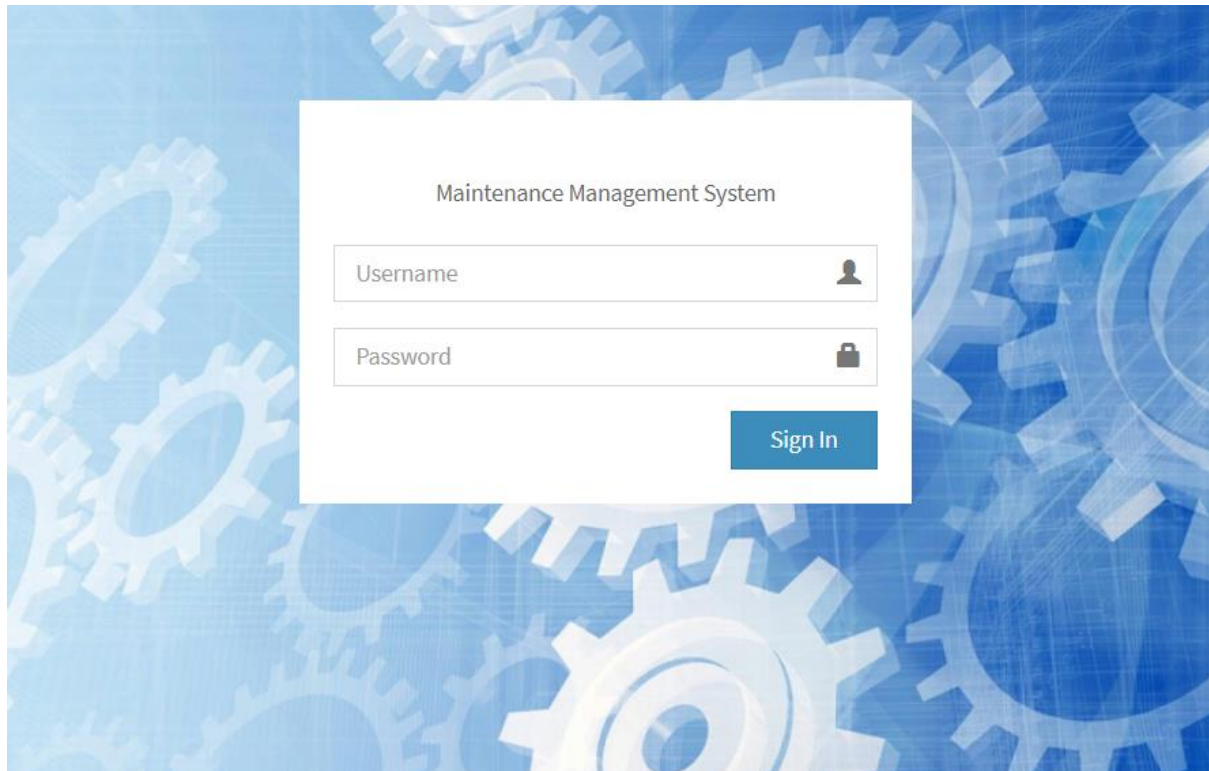


Figure 3.15: Login Page Interface

### 3.7.2 Navigation Menu

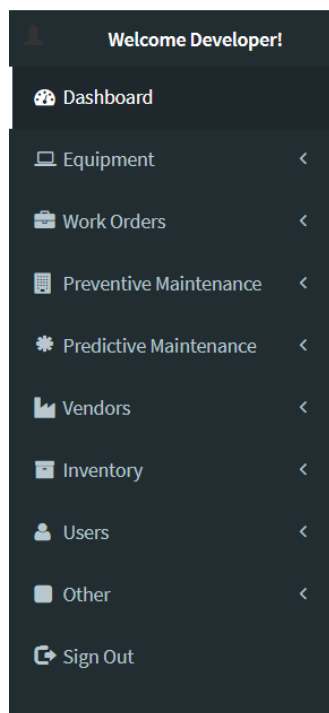


Figure 3.16: Main Navigation Panel

The main navigation panel in Figure 3.16 above is visible on all interfaces to the left. This enables and enhances navigation between all pages in the system. The main tabs are classified into the key sections of the Maintenance Management System, with each have sub links.

### 3.7.3 Data Entry Forms

The screenshot shows a web interface for adding equipment. At the top, there is a header 'Add Equipment' and a breadcrumb trail 'MMS > Equipment > Add Equipment'. Below this, there are three input fields: 'Equipment No:' with a text input field containing 'Enter equipment number', 'Asset No:' with a text input field containing 'Enter Asset number', and 'Location:' with a dropdown menu containing 'Select Location' and a downward arrow.

*Figure 3.17: Data Entry Interface*

Forms have been used for the purpose of capturing data in the system. Figure 3.17 above is a sample form that has been created to collect information on the equipment within the company.

## 3.8 Summary

Considering the use cases discussed in this chapter, the structure of the database required for the implementation was determined. The design of the class diagram also played a key role in this to identify the relationships between entities. Upon completion of the system design, the implementation of the solution was commenced.

# Chapter 4: Implementation & Methodology

This chapter gives an overall idea of the methods that have been utilized in the implementation of the Maintenance Management System. All major code segments used in the system are listed in this chapter, along with hardware and software implementation environments, development tools and reusable components. Reusable components are those that have already been developed and are available for use on the internet.

## 4.1 Implementation Environment

The implementation environment plays a key role in the performance of the developed system. This includes both hardware and software. Table 4.1 below shows the hardware resources used in the current implementation of the system. This ensures smooth operation of the developed system.

<b>Processor</b>	Intel(R) Core(TM) i5-7200U CPU @ 2.50GHz 2.71 GHz
<b>RAM</b>	16 GB
<b>Hard Disk</b>	500 GB

*Table 4.1: Hardware for Implementation*

Table 4.2 below gives an overview of the software that are required for the implementation of the solution.

<b>Operating System</b>	Windows 10 Home
<b>Programming Language</b>	PHP 7.0.13
<b>Web Server</b>	2.4.23
<b>Database Server</b>	MariaDB 10.1.19

*Table 4.2: Software for Implementation*

## 4.2 System Development Tools and Technologies

The following tools and technologies were those used in the development of the Maintenance Management System.

- **NetBeans 12.0** – This was the IDE used for the development of code of the system.

- **PHP 7.0.13** – The main programming language used for the development of the system. This is a server-side scripting language.
- **HTML** – This is a standard mark-up language and was used for the maintenance of format of the webpages.
- **CSS** – Styling language used to add design and style to webpages.
- **jQuery** and **JavaScript** – They were used for the client side validation of forms.
- **AJAX** – This language was used to trigger events that loaded information without the webpage being refreshed.
- **MySQL** – This was the language used to implement the database structure and also to interact with the database.
- **Dia 0.97.2** – This software was used for the development of use case diagrams in the initial stage of development.
- **Visual Paradigm 15.1** – This software was used for the development of sequence, activity and class diagrams during the design stage of the system.

### 4.3 Reused Components

The software was built on a bootstrap theme. Components such as the following were reused from those that were part of the theme:

- **DatePicker** – This allows to select date from displayed calendar component.
- **Data Tables** – This is a plug-in that uses jQuery to display data such that it can be instantaneously in or sorted as desired.
- **Modal** – This searched JavaScript component displays a styled alert box (modal) to act as an intermediate form between two pages.

Apart from the above, the below component were also reused to generate reports.

- **Dompdf** – This component uses PHP to convert the content written in HTML into pdf that can be printed or downloaded directly by the user.

### 4.4 Implementation and Major Code Segments

The system was implemented using the MVC (Model – View – Controller) architecture.

The **View** contains all the files that the user interacts with. The **Model** contains all the code that is used to interact with the database such as functions for inserting, selecting, deleting and updating records. The **Controller** acts as the intermediate between the Model and View

by doing any calculations or other operations that need to be performed before the data is sent into the database.

#### 4.4.1 Code for connecting to the database

The following code is used to connect to the database. Before any query is to be executed by the model, it is required to first establish the connection to the database. The “`die()`” statement is used to display any errors in the process and the “`mysqli_error()`” is used to display the specific error generated. Two functions have been initialized for querying the database. The first function ‘`query()`’ is used to returns a ‘`mysqli_result`’ object that can then be extracted into an array. The second function, ‘`affectedRows()`’, is used in scenarios where the number of rows that were inserted, updated or deleted needs to be identified.

```
<?php
//Create Database Connection
class Connection {

    function query($sql) {
        //Connect to the database or display error if connection
        unsuccessful
        $conn = mysqli_connect('localhost', 'root', '', 'mit3201_mms') or
        die("Cannot connect to the server");
        //Execute query or display error with query syntax if execution
        unsuccessful
        $result = mysqli_query($conn, $sql) or die("Cannot execute the
        query. " . $sql . ". " . mysqli_error($conn));
        return $result;
    }

    function affectedRows($sql) {
        $conn = mysqli_connect('localhost', 'root', '', 'mit3201_mms')
        or die("Cannot connect to the server");
        mysqli_query($conn, $sql) or die("Cannot execute the query. " .
        $sql . ". " . mysqli_error($conn));
        $result1 = mysqli_affected_rows($conn);
        return $result1;
    }
}
?>
```

#### 4.4.2 Code for Login Function

The login function is used for the purpose of authenticating and authorizing access to a user. The user is prompted for the username and password. Once they are entered, the database is checked for active users with matching username and password. If a match is found, the user is redirected to the main dashboard, else an error message is displayed as shown in Figure 4.1 below.

## Model

```
function login($username, $password, $link) {
    $conn = new Connection();
    $sql = "SELECT u.*, m.roleId "
        . "FROM user u "
        . "LEFT JOIN mapping_userrole m "
        . "WHERE u.username = '$username' AND u.password =
MD5('$password') AND u.active = 1 AND CURDATE() BETWEEN m.dateFrom AND
m.dateTo";
    $result = $conn->query($sql);
    if (mysqli_num_rows($result) == 1) {
        $array = mysqli_fetch_array($result);
        $sql1 = "UPDATE user SET online = '1' WHERE username LIKE
'".$array['username']."'";
        $conn->query($sql1);
        $timestamp = date('Y-m-d H:i:s');
        if (isset($_SERVER['HTTP_X_FORWARDED_FOR'])) {
            $ipAddress = $_SERVER['HTTP_X_FORWARDED_FOR'];
        } else {
            $ipAddress = $_SERVER['REMOTE_ADDR'];
        }
        $sql2 = "INSERT INTO login_user VALUES
('".$array['userId']."', '$timestamp', '$ipAddress')";
        $conn ->query($sql2);
        session_start();
        $_SESSION['level'] = $array['roleId'];
        $_SESSION['name'] = $array['name'];
        $_SESSION['username'] = $array['username'];
        $_SESSION['start'] = time();
        $_SESSION['expire'] = $_SESSION['start'] + (5 * 60);
        header("location:$link");
        return;
    } else {
        session_start();
        $_SESSION['err'] = 1;
        header("location:../index.php");
        return;
    }
}
```



**Access Denied! Unauthorized Access!**

*Figure 4.1: Error message displayed for Invalid Credentials*

### 4.4.3 Code for File Upload

The file upload function is used to keep track of images, manuals and other documents relevant to an equipment. The uploaded files are stored separately in the root folder. The below code is what is used for image uploading purposes.



```

function uploadImage(){
    $equipmentId = $_POST['equipmentId'];
    $mantarget_dir = "../uploads/manuals/";
    $pictarget_dir = "../uploads/images/";
    $mantarget_file = $mantarget_dir . $equipmentId . ".pdf";
    $pictarget_file = $pictarget_dir . $_FILES['image']['name'];
    $manuploadOk = 1;
    $picUploadOk = 1;
    $manualFileType = pathinfo($mantarget_file, PATHINFO_EXTENSION);
    $picFileType = pathinfo($pictarget_file, PATHINFO_EXTENSION);
    $pictarget_file = $pictarget_dir . $equipmentId . "." . $picFileType;
    //File Format check
    if ($manualFileType != 'pdf') {
        $manuploadOk = 0;
    }
    if ($picFileType != 'jpg' && $picFileType != 'png' && $picFileType !=
'jpeg' && $picFileType != 'gif') {
        $picUploadOk = 0;
    }
    if ($manuploadOk != 0) {
        $checkUpload = move_uploaded_file($_FILES['manual']['tmp_name'],
$mantarget_file);
        if ($checkUpload) {
            $manual = $equipmentId . ".pdf";
        } else {
            $manual = "";
        }
    } else {
        $manual = "";
    }
    if ($picUploadOk != 0) {
        $checkUpload = move_uploaded_file($_FILES['image']['tmp_name'],
$pictarget_file);
        if ($checkUpload) {
            $image = $equipmentId . "." . $picFileType;
        } else {
            $image = "";
        }
    } else {
        $image = "";
    }
    $obj = new Machine();
    $obj -> uploadImage($equipmentId, $image, $manual);
    header("location:../equipment.php");
}

```

#### 4.4.4 Code for Session Initiation

The authentication and passing of variables in the developed system have been achieved with the use of the SESSION variable. This ensures that variables are not transparently displayed in the url.

```

<?php
session_start();
//Check if user role is assigned and otherwise redirect to homepage

```

```

if (!isset($_SESSION['level'])) {
    $_SESSION['err'] = 2;
    $_SESSION['url'] = $_SERVER['PHP_SELF'];
    header("location:index.php");
    return;
}
include 'model/user.php';
$user = new User();
//Check if user has permission to access relevant page, otherwise
redirect to previous page
$res = $user->getPagePerm($_SESSION['username']);
$existing = array();
$i = 0;
while ($row = mysqli_fetch_array($res)) {
    $existing[$i] = $row['page'];
    $i++;
}
if (!in_array(basename($_SERVER['PHP_SELF']), $existing)) {
    $_SESSION['err'] = 10;
    header('Location: ' . $_SERVER['HTTP_REFERER']);
    return;
}
?>

```

## 4.5 Summary

With the completion of the implementation, the functionality of the solution is now accomplished. The next step to be carried out on the solution is testing which is to be discussed in the next chapter.

# Chapter 5: Testing and Evaluation

This chapter gives an overview of the testing that was carried out on the system. A detailed test plan is provided as well as the results of several test cases. This section also covers. The evaluation of the system by the users is also discussed in this chapter. The tools used to obtain their feedback and the feedback provided is given here.

## 5.1 Related Testing Types

Testing was carried out in four stages for the system.

### 1. Unit Testing

The system was tested, a single unit at a time. Unit testing was further divided into Black Box and White Box Testing. Black Box testing involves inputting information and checking if expected output is returned. White Box testing involves studying the codes to carry out testing.

### 2. Integration Testing

All units of the system were integrated together and tested to check if any errors arose.

### 3. System Testing

The system was tested in an environment similar to the real implementation environment and was carried out after the completion of Unit and Integration testing.

### 4. User Acceptance Testing

This testing was carried by the user and the results show how satisfied they are with the system.

## 5.2 Test Plan

This section covers the test cases used in the process of comprehensive testing of the system.

### 5.2.1 Test Cases for Login Function

Test Case ID	Description	Test Procedure	Expected Outcome
1	Validate User Login	Enter correct username and correct password.	Login to the system and load dashboard.
2	Validate User Login	Enter correct username and incorrect password.	Display error message "Access Denied! Unauthorized Access!".

3	Validate User Login	Enter incorrect username and correct password.	Display error message "Access Denied! Unauthorized Access!".
4	Validate User Login	Leave username and password blank.	Display error message "Access Denied! Unauthorized Access!".
5	Validate User Login	Attempt to access system pages without logging in.	Display error message "Access Denied! Please login to continue".

### 5.2.2 General Test Cases

Test Case ID	Description	Test Procedure	Expected Outcome
6	Validate User Level	Attempt to access pages with unauthorized user level.	Display error message "Sorry! You are not authorized to access the page"
7	Validate User Level	Attempt to access pages with authorized user level	Load page.
8	Validate Session Timeout	Attempt to access/navigate system after an idle time of 5 minutes	Redirect to login page and display error message "Session Timed Out! Please login to continue."
9	Validate Session Timeout	Attempt to access/navigate system within an idle time of 5 minutes	Load pages successfully
10	Validate Data Entry Forms	Leave blank details and submit form.	Focus first blank field and display message "Please fill out this field"

### 5.2.3 Test Cases for Equipment Management

Test Case ID	Description	Test Procedure	Expected Outcome
11	Validate 'Add Equipment' Form	Enter valid details and submit form.	Display message "Successfully added Equipment No: <Equipment No>"

12	Validate 'Add Equipment' Form	Enter asset no in invalid format.	Display error "Please enter valid Asset No".
13	Validate 'Add Equipment' Form	Enter details of existing equipment	Display error "Asset No <asset no> already exists".
14	Validate 'Add Equipment' Form	Input text into number fields	Display error "Field must be a number"
15	Validate 'Add Equipment' Form	Input number into text fields	Display error "Field cannot contain numbers"
16	Validate 'Add Location' Form	Enter valid details and submit form.	Display message "You have successfully added (a) new Location".
17	Validate 'Add Sub Location' Form	Enter valid details and submit form.	Display message "You have successfully added (a) new Sub Location".
18	Validate 'Add Category' Form	Enter valid details and submit form.	Display message "You have successfully added a new Category".

#### 5.2.4 Test Cases for Work Order Management

Test Case ID	Description	Test Procedure	Expected Outcome
19	Validate 'Add Work Order' Form	Enter valid details and submit form.	Display message "Job No <job no> added successfully!"
20	Validate 'Add Work Order' Form	Attempt to add more jobs than allocated to user	Display error "Sorry! You have already reached the maximum allowed number of jobs today!"
21	Validate 'Allocate Work Order' form	Enter valid details and submit form.	Display message "You have successfully allocated Job No <job id>!"
22	Validate 'Add Comment' form	Enter valid details and submit form	Display message "You have successfully added a comment!"

23	Validate 'Edit Comment' form	Enter valid details and submit form	Display message "You have successfully updated a comment!"
24	Validate 'Update Work Order Form' form	Enter valid details and submit form	Display message "You have successfully updated the description for work order <job id>"

### 5.2.5 Test Cases for Preventive Maintenance

Test Case ID	Description	Test Procedure	Expected Outcome
25	Validate 'Allocate Maintenance' Form	Enter valid details and submit form.	Display message "You have successfully allocated the maintenance"
26	Validate 'Edit Maintenance'	Enter valid details and submit form.	Display message "You have successfully edited the maintenance"

### 5.2.6 Test Cases for Inventory and Procurement

Test Case ID	Description	Test Procedure	Expected Outcome
27	Validate 'Generate MRN' Form	Enter valid details and submit.	Display message "Successfully generated MRN"
28	Validate 'Generate MRN' Form	Leave form fields empty and submit	Display error "Please fill out this field"
29	Validate 'Generate MRN' Form	Enter 'Quantity' exceeding 'In Stock' amount	Display error "Quantity exceeds in stock amount"
30	Validate 'Generate GRN' Form	Enter valid details and submit.	Display message "Successfully generated GRN"
31	Validate 'Generate GRN' Form	Leave form fields empty and submit	Display error "Please fill out this field"
32	Validate 'Generate Purchase Orders' Form	Enter valid details and submit.	Display message "Successfully generated purchase order"

33	Validate 'Generate Purchase Orders' Form	Leave form fields empty and submit	Display error "Please fill out this field"
34	Validate 'Generate Purchase Orders' Form	Enter as text 'Quantity'	Display error "Quantity cannot be text"
35	Validate 'Generate Tender Notices' Form	Enter valid details and submit.	Display message "Successfully generated purchase order"
36	Validate 'Generate Tender Notices' Form	Leave form fields empty and submit	Display error "Please fill out this field"
37	Validate 'Generate Tender Notices' Form	Enter as text 'Quantity'	Display error "Quantity cannot be text"

### 5.2.7 Test Cases for Administration Module

Test Case ID	Description	Testing Procedure	Expected Outcome
38	Validate "Add User" Form	Add valid details and submit	Display message "User added successfully"
39	Validate "Add User" Form	Leave empty field and submit	Display error "Please fill out field"
40	Validate "Add User" Form	Add existing username	Display "Username already exists"
41	Validate "Change Password" Form	Add valid details and submit	Display "Password change successful"
42	Validate "Change Password" Form	Leave empty field and submit	Display error "Please fill out field"
43	Validate "Change Password" Form	Enter incorrect 'Current Password'	Display "Invalid input"
44	Validate "Change Password" Form	Enter invalid password and repeat password	Display "Passwords do not match"
45	Validate "User Role Assignment" Form	Add valid details and submit	Display "User Roles updated successfully"

### 5.3 User Acceptance Testing

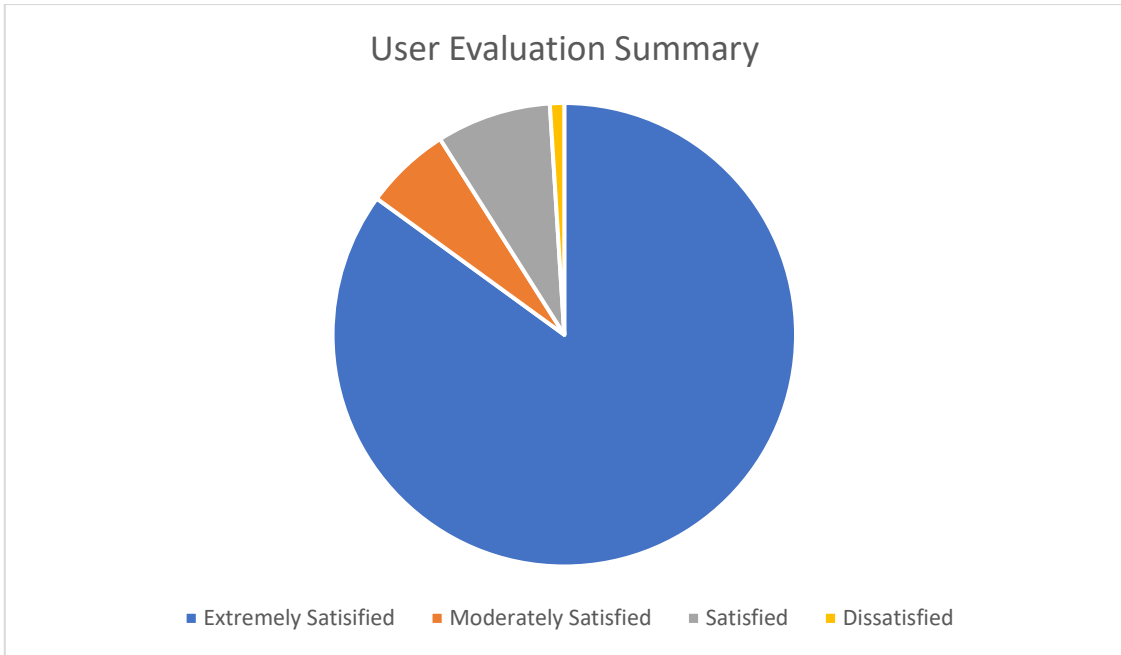
A questionnaire is to be used to obtain feedback from users in the User Acceptance Testing phase prior to the deployment of the live system. This will be used to further enhance the developed system. Figure 5.1 below shows the questionnaire used for feedback.

<u><b>User Feedback Questionnaire</b></u>				
Name of Employee: .....				
Designation: .....				
	<b>Good</b>	<b>Fair</b>	<b>Weak</b>	<b>Poor</b>
Overall Appearance of the System				
Color Scheme Used				
User Friendliness				
How well were the requirements met?				
Did you find it easy to enter data into the system?				
Were error messages appropriate?				
Performance of the System				
Appearance of Reports				
Appearance of Charts				
Comments: ..... ..... .....				
..... Signature		..... Date		

Figure 5.1: User Feedback Questionnaire

The results obtained from the questionnaire are summarized and available in Figure 5.2 below. On overall, the users are satisfied with the system.





*Figure 5.2: User Evaluation Summary*

# Chapter 6: Conclusion

Packwell Lanka (Pvt) Ltd is a leading company in the manufacturing of customized corrugated boxes and all other packaging solutions.

The maintenance management system designed provides a wide range of functionalities from initiation and completing work orders for breakdown to being able to alert the maintenance department of patterns in the breakdown timeline. It allows the maintenance department to assign work orders to technicians and monitor the work done on them there on. The system also has an integrated function to handle the calling of Tenders for purchase of equipment from their existing vendors. In order to streamline the process, stock management and cost calculation for the maintenance process are also included.

Several reports, charts and documents are generated at points throughout the system process. Documents generated include purchase orders, Goods Receiving Notes, receipts and maintenance cards. Reports generated include monthly and yearly expenses and information on equipment such as Mean Time Between Failure. Notifications in the form of emails are used to streamline communication within the system.

The developed system satisfies the clients requirement and they are currently in the process of phasing out their manual processes whilst implementing the Maintenance Management Solution.

## 6.1 Lessons learnt during the course of the Project

The development of this system provided me the ability to put into practice all the programming languages and tools learnt throughout the course of my career and also to learn to implement other languages and technologies. Since, the software is related to the maintenance industry, the development involved the study of various functionalities allowing me to gain a thorough insight into another field, outside my area of study.

Management of time effectively is another lesson learnt. The development of this system also helped to increase my communication skills when interacting with customers.

## 6.2 Future Improvements to the System

- Implementation of a payment gateway to support online payments to the company.

- Design of a mobile app to help enhance the interaction between the users of the system and allow them to access the system on-the-go.
- SMS notifications were not implemented in the system due to the high cost of the SMS gateway server. However, alternative solutions are being looked at locally to integrate this functionality into the system.

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# Appendix A – System Manual

This document contains all information regarding the minimum hardware and software requirements to run the software. It also gives directions on how to install the system.

## Hardware Requirements

Hardware	Minimum Requirements
Processor	Intel® Core™ i3 – 4010U CPU @1.70 GHz
RAM	4 GB
Hard Disk	500 GB

*Table A.1: Minimum Hardware Requirements*

Table A.1 above provides the minimum hardware needed in order to implement and run the software successfully.

## Software Requirements

Software	Minimum Requirements
Operating System	Microsoft Windows OS
Web Server	XAMPP v3.2.1 (Apache 2.4.16, PHP 5.6.12, MySQL 5.6.26)
Web Browser	Mozilla Firefox, Google Chrome
IDE for code modification	NetBeans

*Table A.2: Minimum Software Requirements*

Table A.2 above defines the software requirements for the effective functioning of the Maintenance Management System.

## Skills Required

<b>Programming Languages</b>	HTML, PHP, CSS, JavaScript, AJAX, jQuery
<b>Concept</b>	Object Oriented Programming using MVC Architecture
<b>Development Environment</b>	XAMPP Server

Table A.3: Skills Required

Table A.3 above defines the skills required to modify the code and functionality of the system.

## System Installation

### 1. Install required software

- Download and install XAMPP Server.
- Download and install a suitable web browser.

### 2. Extracting Files

- Copy the 'MMS' folder from the CD-ROM and paste it into the 'C:\xampp\htdocs' folder.

### 3. Database Installation

- Open XAMPP control panel and start the 'Apache' and 'MySQL' modules.
- Open web browser and type in the URL <http://localhost/phpmyadmin>
- Create new database with the name 'mms@packwell'.
- Go to the 'Import' tab, and click 'Browse...'
- Locate the 'mms\_packwell.sql' file on the CD-ROM and select it.
- Click 'Go' located at the bottom of the page to import database contents.

### 4. Launching the System

- In order to launch the system, open the web browser and visit the following URL: [http://localhost/mms\\_packwell](http://localhost/mms_packwell)
- Enter username and password to access the system.

# Appendix B – Design Documentation

This document gives an overview of the documentation used in the design phase of the software. The narratives for the use case diagrams in chapter 3 are provided here.

## Use Case Narratives

### Equipment Management

The use case diagram for this module is given in Figure 3.3 of Chapter 3. The use case narrative for the module is given in Table B.1 below.

Use Case	Equipment Management
Actors	Maintenance Manager, Maintenance Executive
Description	Update and maintain inventory of equipment in the company along with their locations.
Pre – conditions	
	All actors must have access to the module
Flow of events	
	<ol style="list-style-type: none"><li>1. Maintenance Executive updates equipment information</li><li>2. Maintenance Executive updated location master and spare part information</li><li>3. Users are able to view KPIs and track equipment movement</li></ol>
Post - conditions	
	All data needs to be stored accurately since it will be used for the generation of reports and calculation of KPIs.

*Table B.1: Use Case Narrative for Equipment Management Module*

### Preventive Maintenance

Figure 3.4 in Chapter 3 depicts the Use Case diagram for this module. Table B.2 describes the respective use case narrative.

Use Case	Preventive Maintenance
Actors	Maintenance Manager, Maintenance Executive, System
Description	Carry out and maintain a record of planned maintenance on equipment within the company.



<b>Pre – conditions</b>
All actors must have access to the module
<b>Flow of events</b>
<ol style="list-style-type: none"> <li>1. Maintenance department creates maintenance schedule.</li> <li>2. Maintenance department initiates work order to carry out maintenance.</li> <li>3. Maintenance department allocated maintenance to technician.</li> <li>4. System generates relevant notifications to users.</li> <li>5. Maintenance executive calculates costs.</li> </ol>
<b>Post - conditions</b>
All data needs to be stored accurately since it will be used for the generation of reports and also ensuring that timely maintenance is carried out. Notifications need to be delivered on time.

*Table B.2: Use Case Narrative for Preventive Maintenance Module*

## Work Order Management

The use case for the Work Order Management module is given in Figure 3.6 and Table B.3 describes the use case narrative for same.

<b>Use Case</b>	Work Order Management
<b>Actors</b>	Maintenance Manager, Maintenance Executive, Supervisor, Staff Member, Senior Management
<b>Description</b>	Initiate work orders in order to attend to break downs
<b>Pre – conditions</b>	
All actors must have access to the module	
<b>Flow of events</b>	
<ol style="list-style-type: none"> <li>1. Staff Member initiates work order</li> <li>2. Maintenance department assigned work order to technician</li> <li>3. Supervisor updates comments based on completed work</li> <li>4. Maintenance department may escalate work order to obtain approval from Senior Management</li> <li>5. Once complete, staff closes work order</li> </ol>	
<b>Post – conditions</b>	
All data needs to be stored accurately since it will be used for the generation of reports and calculation of KPIs.	

*Table B.3: Use Case Narrative for Work Order Management*

## Inventory and Procurement

The use case for this module is given in Figure 3.8. The use case narrative in Table B.4 describes the Inventory and Procurement module.

Use Case	Inventory and Procurement
Actors	Maintenance Manager, Maintenance Executive, Stock Manager, System
Description	Manage products, raw material. Issue in and out of stock. Generate purchase orders for re-orders.
Pre – conditions	
All actors must have access to the module	
Flow of events	
<ol style="list-style-type: none"> <li>1. Generate GRNs and MRNs to track stock in/out</li> <li>2. Check re-order levels</li> <li>3. Generate purchase orders to suppliers to re-order stock</li> <li>4. Approve purchase orders</li> </ol>	
Post – conditions	
All data needs to be stored accurately since it will be used for the generation of reports.	

*Table B.4: Use Case Narrative for Inventory and Procurement*

## Administration Module

Use Case	Administration
Actors	Administrator, User
Description	Add users, edit and delete them. Change login credentials. Manage permissions
Pre – conditions	
All actors must have access to the module	
Flow of events	
<ol style="list-style-type: none"> <li>1. Administrator adds/modifies users</li> <li>2. Administrator manages user roles</li> <li>3. Administrator manages maintenance KPIs</li> </ol>	
Post – conditions	
All data needs to be stored accurately since it controls access to the system.	

*Table B.5: User Case Narrative for Administration Module*

# Appendix C – User Manual

Only the users with defined privileges can access the system. User levels are set in order to prevent unauthorized access to modules. In order to access the system, open the web browser and visit the link [http://localhost/mms\\_packwell](http://localhost/mms_packwell).

## Logging in to the System

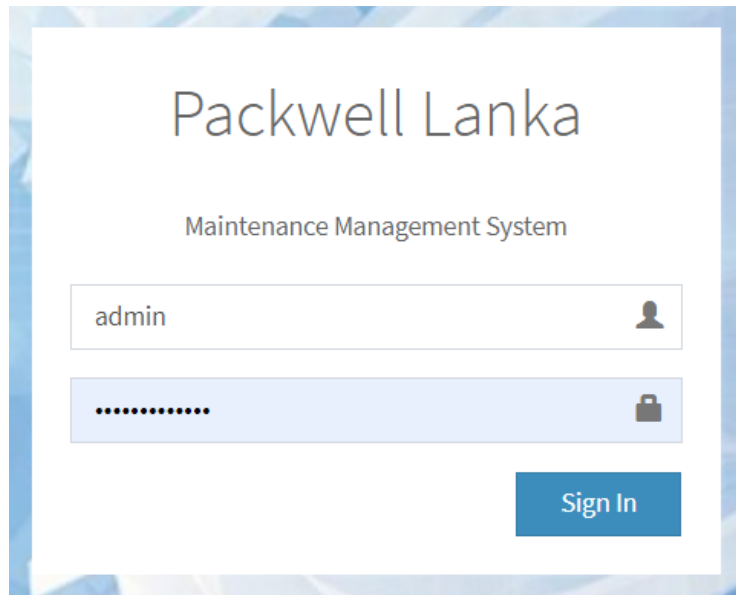


Figure C.1: Login Page

Users that are registered to access the system can login by enter their username and password. Figure C.1 refers to the login page of the system.

Upon login the user is directed to the main dashboard shown in Figure C.2.

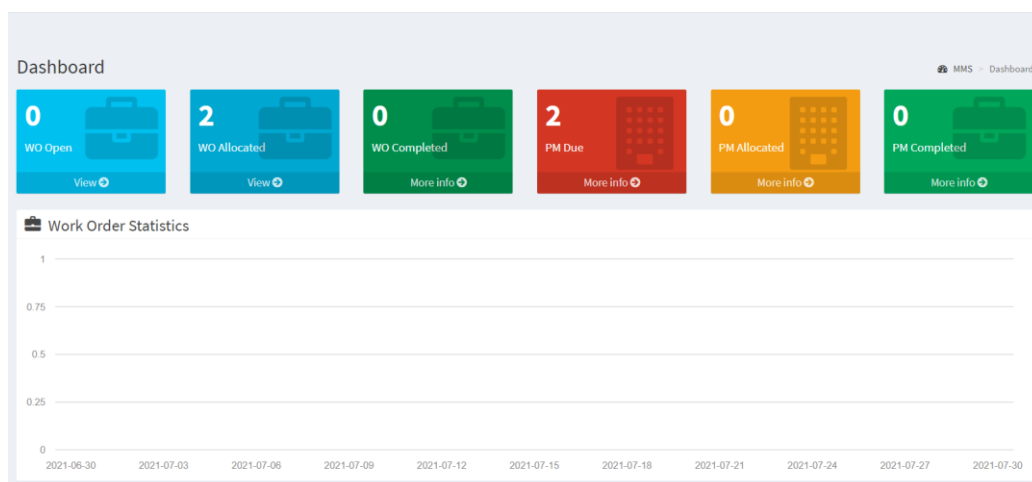


Figure C.2: Main Dashboard

## Location of Functions in the System

Equipment	Work Orders	Preventive Maintenance
Add New Equipment View All Equipment Equipment Overview Add Location Add Sub Location View All Locations Add New Category View All Categories	Add New Work Order Status Open Work Orders Allocated Work Orders Work Order Statistics All Work Orders Delete Work Orders	Add Schedule Edit Schedule View Allocation
Predictive Maintenance	Vendors	Inventory & Procurement
View Breakdown forecast Allocate maintenance Calculate Cost	Add New Vendor Update Vendor Details Issue Tenders	Generate GRN Generate MRN View GRNs and MRNs Re-order stock levels Generate Raw Material Purchase Orders
Users	Other	
Add User Manage User roles Assign user permissions	Manage KPIs Maintain Technical Staff Details	

Figure C. 3: System Functions classified by module

## Navigation

In order to navigate between modules, the navigation panel is to be used.. Figure C.4 is navigation bar used in the main interface of each module. The Sign Out function is provided as the last option in the Navigation panel

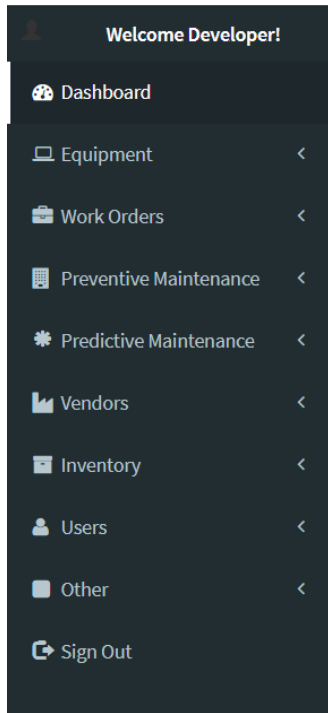


Figure C.4: Navigation Panel

## Data Tables

Data Tables have been used in most modules to view a list of all data such as employees, products, customers, raw material, etc. Figure C.5 shows one such data table with its components and their explanation follows.

All Equipment								
Equipment No	Name	Asset No	Category	Location	Make	Model	Serial Number	
1	Test Equipment	JL-BL-0000		Test - Test 1	Test Make	Test Model	098765432	
2	Test Equipment 2	JL-CC-0002	CCTV	Test - Test 1	Test Make	Test Model 2	98765	
3	Test Equipment	JL-BL-0001	BOILER	Test Location - Test Sub 2	Test Make	Test Model	0987	

Figure C.5: Data Table to view All Equipment

- **Show entries:** determines the number of entries visible per page and can be changed as required.
- **Search Bar:** enables the user to instantaneously search through the data in the table.
- **Previous/Next:** The user can see the next set of entries of the same data table.

- **Sorting:** By clicking on any of the table headers, the data can be sorted in ascending or descending order.
- **Click 'Information' button:** on the click of the 'i' button, the user is redirected to page with the specific row details and ability view further information. For example if the first row of the data table in Figure C.5 is clicked, Figure C.6 below is loaded.

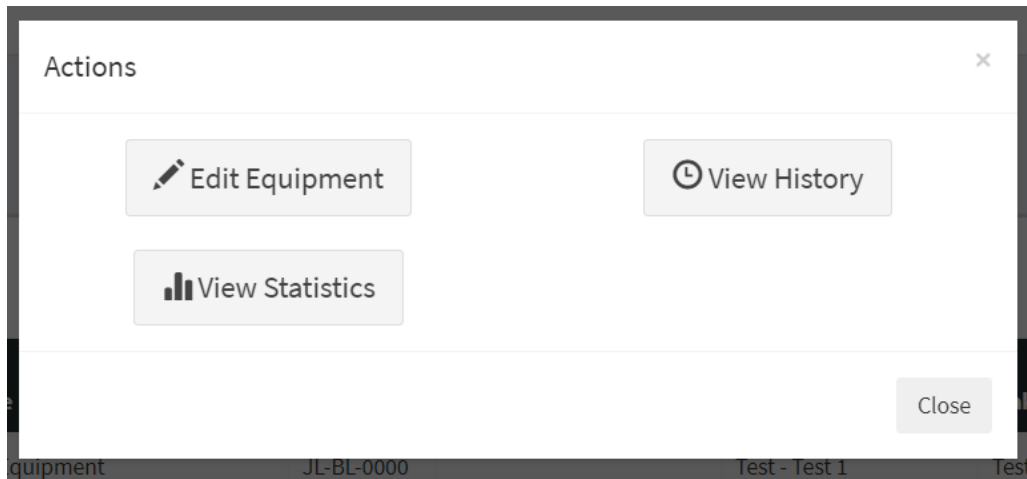


Figure C.6: Modal displaying further information for equipment

## Forms

In order to submit a form, fill in all the required fields and click on the green submit button. Figure C.7 shows a simple form. The green submit button is also visible here.

Figure C.7: Form to 'Add Work Order'

## Modals

At some points, when a button is clicked, a pop up is enabled to confirm form submission or to request more information for the completion of task. For example, referring to Figure C.5 above, when the ‘Information’ button is clicked a modal pops up prompting the user for further options. This modal is shown in Figure C.6.

## Date Picker

Date pickers have been used in several locations where it is required for the user to input a date into the form field. The appearance of a date picker is shown in Figure C.8. In order to input the date using this tool, the user has to only browse for the required date and click it.

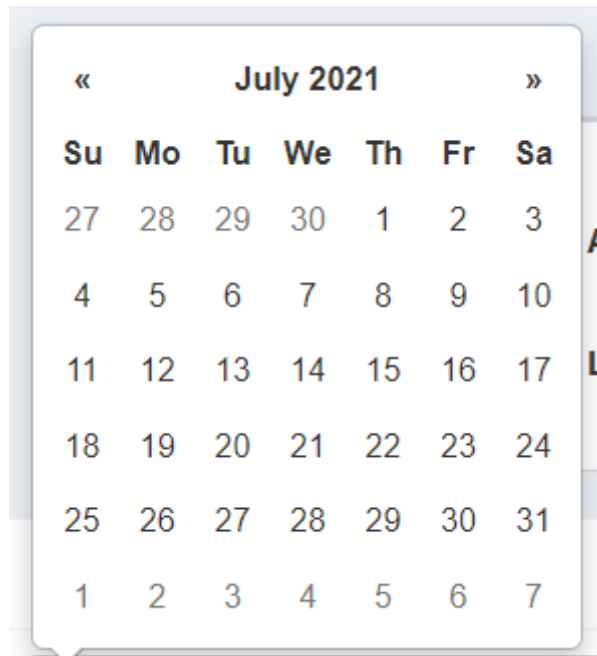


Figure C.8: Date Picker

## Errors

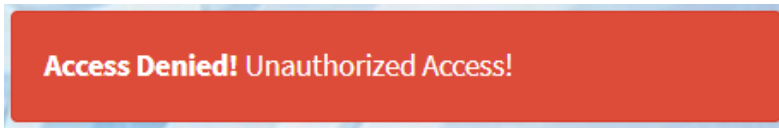
Errors are displayed before the form is submitted if form fields have incorrect data types and formats and also when the data in the form could not be entered into the database.

Asset No:

Invalid Asset No

Figure C. 9: Error message when invalid data format is input

Figure C. 9 gives the error message display when incorrect data format is entered in to a field. Figure C.10 below shows the error message displayed an unauthorized user attempts to access the system.



*Figure C.10: Error Message for Unauthorized Access*



# Appendix D – Management Reports

Management reports are one of the key outputs of this system. These reports are in the form of charts, pdfs and data tables. The generation of these reports helps the company to increase its productivity and efficiency.

## Work Order Statistics

This bar chart is available on the main dashboard page and gives an overview of how many work orders are created and completed on a daily basis. This chart is importance for the management to identify the performance of the Maintenance Team.

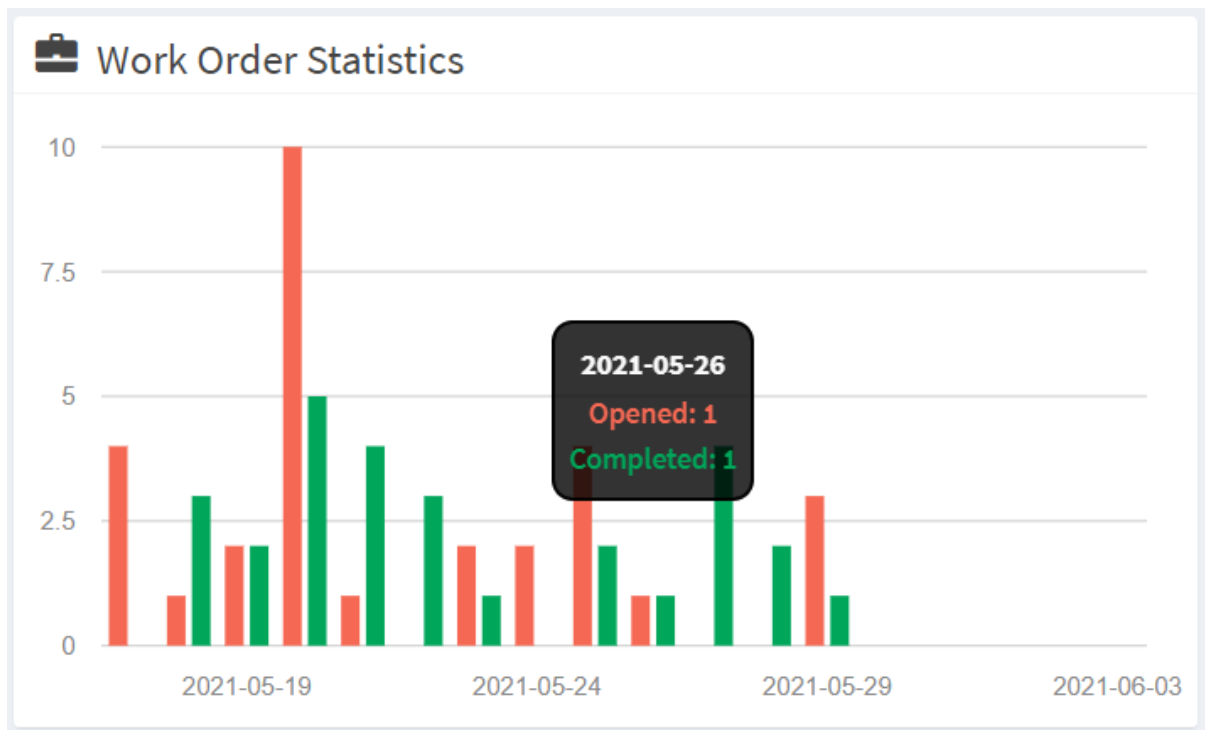


Figure D.1: Work Order Statistics Bar Chart

## Preventive Maintenance Statistics

The next chart available on the dashboard shows the amount of due preventive maintenance that is allocated and completed daily. Figure D.2 below is a sample of the developed chart for same.

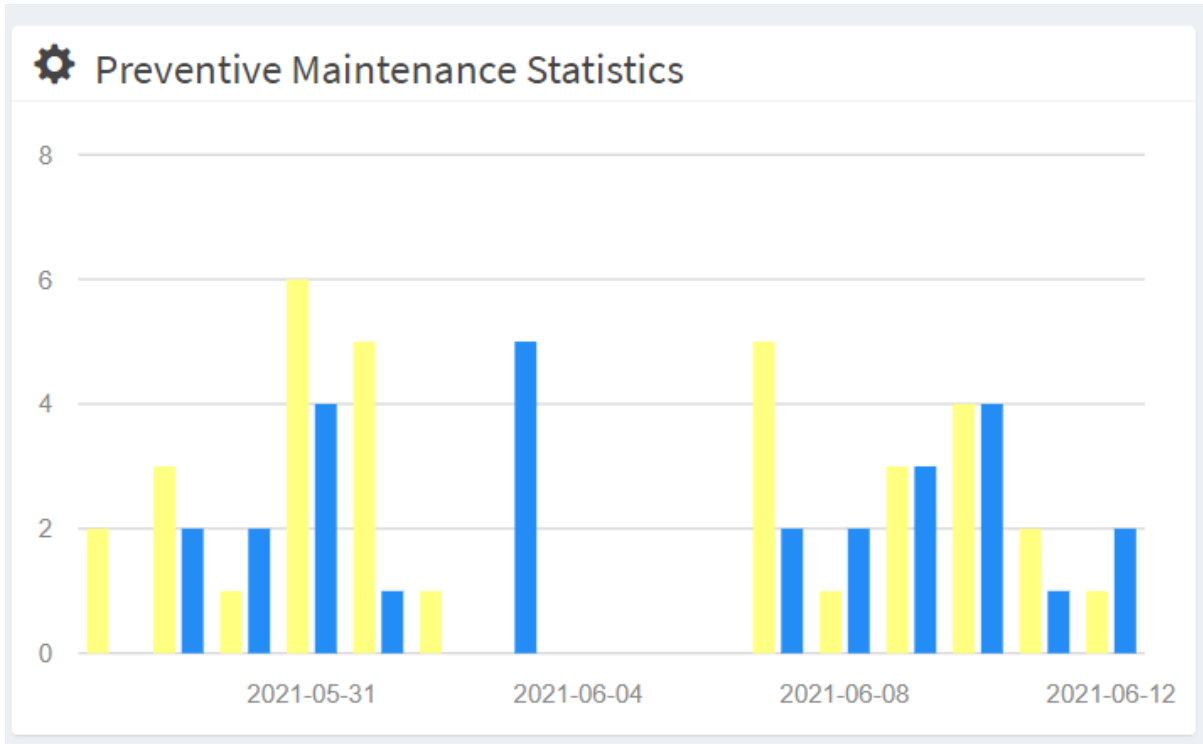


Figure D.2: Preventive Maintenance Statistics Bar Chart

## Equipment List as Data Table

Another form of report available in the system is through data tables. Figure D.3 below shows the data table used to list the equipment within the company. Data tables are interactive and allow the user to search for records dynamically and also sort them as required.

All Equipment								
Equipment No	Name	Asset No	Category	Location	Make	Model	Serial Number	
8	AC Plant	JL-AC-0001	Air Conditioning	-				
8	AC Plant	JL-AC-0001	Air Conditioning	-				
9	Fan Coil Unit	JL-AC-0002	Air Conditioning	-	Lark	LFP 68C		
9	Fan Coil Unit	JL-AC-0002	Air Conditioning	-	Lark	LFP 68C		
12	Fan Coil Unit	JL-AC-0005	Air Conditioning	-	Lark	LFP 136C		
12	Fan Coil Unit	JL-AC-0005	Air Conditioning	-	Lark	LFP 136C		

Figure D.3: Data Table for All Equipment

## Maintenance Expense Report

Figure D.4 below shows a sample format of a pdf report to be generated by the system for tracking of maintenance expenses.

<b>Packwell Lanka (Pvt) Ltd.</b>				
Maintenance Expenses for the Period <start date> to <end date>				
Generated By: <user> on <date>				
Work Order No	Asset No	Cost	Date	Staff No
Total Expenses = Rs. ....				

*Figure D.4: Maintenance Expense Report*

### Preventive Maintenance Cards

These cards are used by the company whenever they want to see an overview of the preventive maintenance carried out on an equipment. Figure D.5 shows a sample of the preventive maintenance card.

<b><u>EQUIPMENT PREVENTIVE MAINTENANCE CARD</u></b>			
<b>EQUIPMENT</b>		<b>ASSET NO</b>	
<b>MODEL</b>		<b>SERIAL NO</b>	
<b>LOCATION</b>		<b>SUPPLIER</b>	

*Figure D.5: Sample Preventive Maintenance Card*