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# Maintenance Management System for Upstream Operations in Oil and Gas Industry: Case Study

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***Abstract*—**This paper explores the plant maintenance management system that has been used by giant oil and gas company in Malaysia. The system also called as PMMS used to manage the upstream operations for more than 100 plants of the case study company. Moreover, from the observations, focus group discussion with PMMS personnel and application through simulation (SAP R/3), the paper reviews the step-by-step approach and the elements that required for the PMMS. The findings show that the PMMS integrates the overall business strategy in upstream operations that consist of asset management, work management and performance management. In addition, PMMS roles are to help operations personnel organize and plan their daily activities, to improve productivity and reduce equipment downtime and to help operations management analyze the facilities and create performance, and to provide and maintain the operational effectiveness of the facilities.

***Keywords*—**Maintenance, Oil and Gas Industry, Upstream Operations

## I. Introduction

MAINTENANCE is a combination of all technical, administrative, and managerial actions during the life cycle of an item intended to keep it in or restore it to a state in which it can perform the required function [1]. Previously, maintenance has been supposed as an expense account with performance measures developed to track direct costs or surrogates such as the headcount of tradesmen and the total duration of forced outages during a specified period. Fortunately, this perception is changing [2,3]. Nowadays, maintenance is acknowledged as a major contributor to the performance and profitability of business organizations [4,5]. Maintenance managers therefore explore every opportunity to improve on profitability and performance as well as achieve cost savings for the organization [6].

The maintenance organization is confronted with a wide range of challenges that include quality improvement, reduced lead times, set up time and cost reductions, capacity expansion, managing complex technology and innovation, improving the reliability of systems, and related environmental issues [7]. However, trends suggest that many maintenance organizations are adopting Total Productive Maintenance (TPM), which is aimed at the total participation of plant personnel in maintenance decisions and cost savings [8,9]. The challenges of intense international competition and market globalization have placed enormous pressure on maintenance system to improve efficiency and reduce operational costs. These challenges have forced maintenance managers to adopt tools, methods, and concepts that could stimulate performance growth and minimize errors, and to utilize resources effectively toward making the organization a "world-class manufacturing" or a "high-performance manufacturing" plant.

Industrial maintenance has two essential objectives which are a high availability of production equipment and low maintenance costs [1]. However, a strong factor militating against the achievement of these objectives is the nature and intensity of equipment failures in plants. Since system failure can lead to costly stoppages of an organization's operation, which may result in low human, material, and equipment utilization, the occurrence of failure must therefore be reduced or eliminated. An organization can have its customers build confidence in it by having uninterrupted flow in operations. Thus, maintenance ensures system sustenance by avoiding factors that can bother effective productivity, such as machine breakdown and its several attendant consequences.

In order to carry out effective maintenance activities, the team players must be dedicated, committed, unflagging, and focused on achieving good maintenance practices. Not only are engineers and technicians are involved, but also every other employee, especially those involved in production and having physical contact with equipment. Thus, maintenance is not only important for these reasons, but its successful implementation also leads to maximum capacity utilization, improved product quality, customer satisfaction, adequate equipment life span, among other benefits. Equipment does not have to finally breakdown before maintenance is carried out. Implementing a good maintenance policy prevents system failures and leads to high productivity [10].

To perform effectively, the maintenance manager normally should be well versed in performance measurement [3,11]. Measures such as productivity, efficiency, and effectiveness, quality, quality of working life, innovation, and profitability should be regularly used to assess the performance of the system and that of the subsystem within the maintenance function [12,13]. There exist several methods for maintenance performance [8,14].

Moreover, Labib [15] stated that the computerized maintenance management system (CMMS) is now a central component of many companies' maintenance departments, and it offers support on a variety of levels in the organizational

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hierarchy. Indeed, a CMMS is a means of achieving world-class maintenance, as it offers a platform for decision analysis and thereby acts as a guide to management [16].

CMMS are computer-based software programs used to control work activities and resources, as well as to monitor and report work execution. CMMS are tools for data capture and data analysis. The major features of CMMS include the processing of maintenance data to give in useful information on which management decisions are based. This information can be analyzed or evaluated with respect to previous results such that performance over a period of time can be assessed. Managers will therefore find it convenient in making use of the available data to plan for present and future goals. There is also the advantage of printing out this information in hard copy at any desired period. Other useful information, such as work done in the maintenance department and its total costs (TC), lists of jobs worked on during a period, and inventory taking, can be presented in a manner that will greatly ease both the technical and administrative task of maintenance. Through networking of the systems, information can be passed efficiently between the maintenance department and the organization's management.

The CMMS can be used to analyze budgets, downtime, supplies, screening of applicants, etc. The database programs in CMMS systems contain structured data on workers' names; job titles; daily; weekly or yearly schedules; etc. The data processed on CMMS can be stored permanently or retrieved much faster for future use or modifications. Also, CMMS can be used in maintenance planning and scheduling, coordinating people, and controlling resources and costs of maintenance functions. It can also be used in such areas as the analysis of a week's activity and budget proposals.

This paper is then to study the application of CMMS called PMMS in Petroliam Nasional Berhad (PETRONAS) which used to manage the upstream operations for over than 100 plants. The PMMS is also known as 'PETRONAS Maintenance Management System' is a computerised maintenance management system which has supported by the System Application Production (SAP R/3). The SAP system is an integrated suite of Order Entry, Scheduling, Manufacturing, Inventory and Financial software. In addition, it integrates Enterprise Resources Planning (ERP) system that consists of several modules, namely Plant Maintenance (PM), Finance (FI), Human Resources (HR), and Material Management (MM), which supported by many functions in the day-to-day operations. To organize this paper, section 1 explains the overview of maintenance management system for capturing the key issues. Section 2 classifies the research methodology. Section 3 briefs the case study at a selected oil and gas organisation. Section 4 explores the PMMS. Section 5 discusses the findings and the knowledge earned and the paper ends with some useful conclusions and thoughts for future research.

## II. Research Methods

An intensive case study was conducted in July 2008 and one of the authors recently undergone industrial attachment and spent almost 6 months focusing on productivity improvement activities at the case study company. Observation, focus group discussion and simulation application were used to collect the primary data that related to PMMS applications. The observation was focused on the upstream operations and PMMS meanwhile the focus group discussion were conducted among the MCS engineers. In addition, the discussion was conducted not only dwell on the past implementation, but also focus on the future plans and developments via telephone and internet conference. Then, to validate the PMMS, simulation of SAP software (SAP R/3) was performed with Master Data Team of PMO/PCSB. Secondary data was obtained from PCSB SAP R/3 Maintenance Control System (MCS) Guide, Carigali Maintenance Management Guide (CMMG), Carigali Inspection & Maintenance Guide (CIMG), and PETRONAS Electronic Performance Support Site (EPPS).

## III. Case Study

The case study was conducted at PETRONAS Carigali Sdn Bhd (PCSB). For history, on 11th May 1978, this Malaysian company, PCSB a wholly owned subsidiary of Petroliam Nasional Berhad (PETRONAS) was born as its exploration and production arm. PCSB's domestic operations are divided into three regions which are Peninsular Malaysia Operations (PMO), Sarawak Operations (SKO) and Sabah Operations (SBO). Effective 1st April 2002, these regional operations were put under PCSB's Division called Domestic and South East Asia Division (DOMSEA). This paper is only focus on PMO. PMO started its operation in April 1984 (the first production of division in PCSB) with the commencement of gas production from the Duyong field. Its main office is located at PETRONAS Office Complex in Kerteh about 110 km south of Kuala Terengganu. PMO is supported by Kemaman Supply Base (KSB) in terms of warehousing and logistics activities, Kerteh Helibase for helicopter services, Onshore Gas Terminal (OGT) at Paka for gas receiving facilities and Terengganu Crude Oil Terminal (TCOT) at Paka for crude receiving facilities. Nowadays, PMO operates sixteen producing fields namely Duyong, Dulang, Bekok, Kepong, Tiong, Tinggi, Pulai, Malong, Sotong, Anding, Resak, Abu-Cluster, Puteri and Angsi. There are a total of thirty three platforms, two Floating Storage and Offloading facilities (FSO), two Floating Production, Storage and Offloading facility (FPSO), and one Onshore Gas Terminal (OGT). There are 20,936 equipments under PCSB's maintenance. Effective maintenance is build-out and implementation of the process and systems. PCSB are transforming their maintenance into strategic, value-adding PMMS. PMMS is a maintenance strategy based on continual renewal so that plant and equipment are in good condition and hence free of age related defects.

## IV. PMMS

PCSB operates a number of complexes onshore and offshore installations, most of which are in the remote locations. The management and supervision of operational activities involves a flow of data, which can be most easily managed when consistent, meaningful information is readily available to all parties. This depends on the ready access to all information to design, construction, manufacturer, spare parts, skilled

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manpower resources and operating or maintenance histories. The PETRONAS Maintenance Management System (PMMS) which supported by System Application Production (SAP R/3) is implemented to achieve the management of such data. PMMS covers Asset Management, Work Management, and Performance Management.

### *A. Asset Management System*

In PMMS, Asset Management important to ensure that a complete maintenance master data is captured in the system, including plant asset structure, tag no, equipment master, Bill of Material, maintenance plans, and data consistency in master data. Asset Management covers two areas - Plant Asset Structure (PAS) and Planned Preventive Maintenance Plan (PPM). The first requirement for supported maintenance system is to represent its operational systems and their detailed structure.

#### *1) Plant Asset Structure*

The Plant Asset Structure allows the user to control system management according to functional location or process oriented criteria and to manage the individual inventory maintenance resources. This will enable the planning, execution and analysis of the maintenance works through the system. Fig.1 shows the example of a PAS for PSCB.

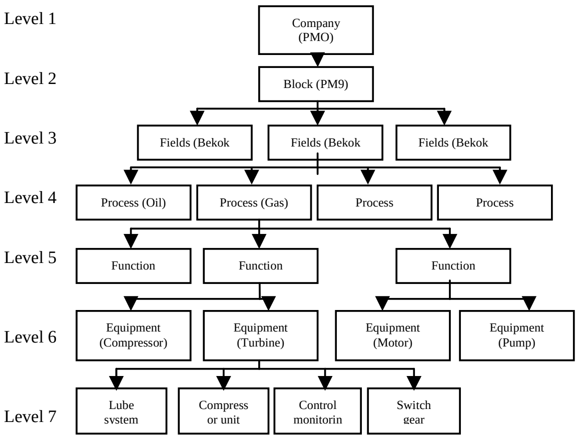


Fig.1 An example of Plant Asset Structure based on PCSB Level

The procedure of PAS is categorized by level. Level 1 until 3 is the selection process of the asset, investing the asset, making proper assessment of risks, and developing proper strategies to save the assets from exposure to risks. Level 4 is a process that execution of the Plant Maintenance System. At PETRONAS there have two different production platforms which are Oil or Associated Gas (AG) Platform and Gas or Non Associated Gas (NAG) Platform. The main processes on the platforms are oil production, gas production, gas dehydration, and gas compression. Level 5 is a Functional Location where a place in technical system. It used to capture information related to location, process or group of functions. Functional Location shall be used to structure or represent a plant relationship, between organizational set-up, process and maintenance functions. Under Functional Location has a Functional Location Boundary. The boundary is termed as a grouping of main and supporting equipment which provides one main function for delivering intended output from a maintenance perspective.

Level 6 is Equipment Master which is a uniquely identifiable physical asset, upon which all notifications and work order can be carried out where costs and history can be recorded. When an equipment master is dismantled and installed from one functional location to another, its equipment master historical data remains attached. Under Equipment Master have Equipment Classification and Equipment Characteristic. Equipment Classification mean is a group's equipment with the same functions to enable equipment performance analysis by class within an Operation Unit (OPU) or benchmarking among OPUs. For example, Equipment Classification can be used to filter out all maintenance orders created for an equipment class such as compressors. Using the classification system, pieces of equipment can be supplemented with technical characteristics, which provide further information on the equipment, including its technical and operational parameters. Equipment Characteristic means each class has a set of characteristics, which provides further information on the equipment, including its technical and operational parameters. The user can define characteristics freely and assign any number of them to the classes. The characteristics and their values can be inherited over several class levels in the case of hierarchically structured classes.. The failure analysis can be done for similar equipment in the same class in each OPU and be projected to a higher level since the classes used are standardized at client level.

Level 7 is refer to the bill of materials (BOM). BOM is the term used to describe the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture an end item (final product). BOM structures are included in system structuring in the overall structuring of individual operational systems, for example functional locations or pieces of equipment, enabling a unified and consistent structuring method. The objectives of BOM are to guide the structuring of the components to enable efficient work planning, to provide 'where-used' information of each spare part, to provide fast retrieval of stock material and identify parts to raise purchase requisition, and to reduce error in selecting and purchasing equipment parts. Maintenance BOM describes the structure of a technical object or assembly. Using maintenance BOM, the user can quickly select correct components for the maintenance tasks to be performed on the technical object. BOM when set up correctly would easily identify the number of the equipment installed with the same spare part, thus reduce duplicate stock material created in the system and help justify adjusting stock material minimum or maximum level based on the equipment criticality and its consumption rate. BOM can be extended to create multi level BOM.

#### *2) Planned Preventive Maintenance Plan*

Preventive maintenance is the generic term for planned inspections, preventive maintenance work and planned repairs.

In the maintenance management system, preventive maintenance plans are created to automatically generate preventive maintenance orders when the preventive maintenance work is due. The business objectives of preventive maintenance are to provide an effective planning of preventive maintenance schedule and to ensure good resource management which are performed on a recurring basis, to provide effective implementation of scheduled preventive maintenance will increase integrity and reliability of equipment and reduce unplanned breakdown of equipment, and to reduce maintenance costs by reducing uneconomic maintenance or overhaul schedules, wear and tear and human induced failures due to unnecessary equipment dismantling.

In the preventive maintenance plans, the following important details are specified:

- Maintenance Strategy and Functional Location - specifies the time interval when the preventive maintenance work is done. Once the preventive maintenance plan is finalized, maintenance strategies can be generated;
- Object List - specifies all the equipment where the preventive maintenance is to be carried out;
- General Task List (GTL) - a grouping on task list for work order. General task list used to describe the steps or operations of the preventive maintenance activities to be carried out. Spare parts, materials and tools may also be specified in the task list. The relevant Order Type can be performing on the GTL are Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), and Plant Statutory Inspection (PSI);
- Work Center - indicates which group in the maintenance department is responsible to carry out this job. Three functions in Work Center are for costing, scheduling and capacity planning. Work Center includes over two groups which are maintenance planner group mean the supervisor is responsible to carry out the plan of the job and Maintenance Work Center mean the group in the Maintenance department is responsible to carry out this job.

### *B. Work Management*

Work Management is a documented and tested step-by-step method aims to ensure the efficient work order is processed by standardizes maintenance business processes across all operation units. Moreover, it ensure that the implementation of proper control and various steps in work order process to minimize the amount of lost time during maintenance order planning with updated and complete master data. Work Management generally include detailed information on topics such as organizing an work, setting and implementing work order, and choosing employees to execute the work. The following explains the six main stages of work management.

#### *1) Work Identification*

Work Identification is used to complete and screen details in notification. To complete the Work Identification, users must use the correct notification type by determine whether it is an ad hoc or planned maintenance and functional to create notifications, use the correct equipment tag or functional location and do not use generic equipment tag, indicate the correct priority level, attach the relevant document if required, and screen the notification before converting to order. It requires to establish the nature of work carried out on the equipment so that maintenance can identify improvement areas in maintenance plan for the equipment, if necessary, to ensure that full equipment history is recorded in the system for future maintenance work, to help planner to better response to the urgency of the work request, to breakdown time period enable management to analyze reliability of the equipment and effectiveness of maintenance planning, and to attached document is critical in providing graphical view of the work scope or equipment condition.

(a) Notification Definition

There are three major groups of maintenance work for notification definition. TABLE 1 shows the detail of the notification types.

(b) Identify Maintenance Objects

For notification created against equipment, it is necessary for the requestor to input the equipment number. Similarly, for notification created against area or process unit/boundary, it is necessary to input the functional location number representing the area or process unit/functional boundary. In summary, the Functional Location field is mandatory when raising a notification. Users can identify the equipment number or functional location number through equipment by Technical ID number, OPU specific equipment by functional location (Technical ID), and equipment by functional location structure.

(c) Screening Process

Notifications should be screened to ensure that there is no duplication of work request, to verify that information such as equipment and/or tag number has been correctly entered before notification is being routed to Maintenance Department, to clarify the urgency of the notifications raised, and notification that has been screened will have its user status set to ‘SCRN’. Only these screened notifications can be converted into a maintenance order.

#### *2) Pre-planning*

Pre-planning and Planning is used to plan and approve the maintenance order. OPU will set up a team to screen the notification. The purpose of screening is verified that the information has been correctly entered into the notification. After screening (the notification will be set to ‘SCRN’, if approved), notifications with status ‘SCRN’ will be converted into maintenance orders. Created maintenance order defaulted with planning information. Create maintenance orders contains order type, used to determine mode of maintenance execution. Maintenance orders also contain Activity type depicting detailed job to be performed. This information is crucial for maintenance work reporting. TABLE 2 presents on overview of relationship between Notification Types and Maintenance Order types.

TABLE I
NOTIFICATION TYPE (NT)

| Maint. Group | NT | Description | When to use? |
|---|---|---|---|
| Reactive | (RM) Reactive Maintenance | Maintenance results from equipment breakdown, or equipment fails to perform/deliver its intended service. Reactive maintenance allows tracking of breakdown duration. | Work request that is in response to an equipment failure and ad-hoc situation |
| Proactive | (ProM) Proactive Maintenance | Maintenance to prevent damages or impending failure or to improve the equipment's reliability. Preventive, Predictive and Proactive work are collectively categorized under ProM notification type. | Notifications created for proactive rectification requests |
| | (IN) Inspection | Used to record any inspection activities particularly prior to maintenance work or routine static equipment inspection analysis. | Used by Inspection Team to record inspection result or report |
| Others | (PC) Plant Change | Used to register approved plant change request. | To record plant changes which are authorized for implementation |
| | (SM) Support Maintenance | Used to record work not related to core maintenance and supporting functions such as housekeeping, fabrication, repair of tools, and for other departments support request. | Work which is not directly related to core maintenance work. Support work for other departments |

*3) Planning*

The purpose of planning is to ensure prudent and cost effective maintenance work practices. The estimated and planned cost shall assist planner to improve maintenance work planning and serve as reference in future planning. General task lists for common maintenance can be adopted to specify operations of an order. Determine resources required to perform job (internal and external manpower, spare parts etc). Based on planned or estimated costs, orders will be sent for technical approval before being released for execution.

*4) Scheduling*

Scheduling is used after necessary planning has been conducted. Scheduling process involve activities to check availability of resources to perform the job. Subsequent to ensuring the materials availability, the planner will start to schedule or set the working date for the job. The order will be released once it is scheduled.

5) Work Execution

Print maintenance order, material issue slip and object list (if required). Monitor user status of order e.g. if there are operational, material, manpower constraint or if the work carried is only a temporary repair etc. or select and specify the relevant status on the maintenance order. Monitor estimated, planned and actual cost of order. Perform partial, full or collective time confirmation for the order.

*6) Reporting and Feedback*

Complete technical reporting in the system which includes maintenance report, specifications of damage and cause codes, confirmation on measurement/counter reading, if any, and specification of malfunction end date if the notification involves a breakdown. Set system status to TECO technically complete to indicate end of maintenance work.

TABLE II
RELATIONSHIP BETWEEN NOTIFICATION TYPES (NT) AND MAINTENANCE ORDER TYPES

| NT Type | Order Type | Description |
|---|---|---|
| RM | REM – Reactive Maintenance | Work performed as a response to failure to perform its intended function, breakdown or situation requiring maintenance attention. REM order type is defaulted when you create an order against a RM notification type. |
| PM | PPM - Planned Preventive Maintenance | Time or counter based maintenance to maintain equipment performance. PPM orders are normally generated from maintenance plans and are automatically released. |
| | PDM – Predictive Maintenance | Activities carried out to predict impending failure using modern technology and calculation technique which is non-intrusive in nature. Example; vibration reading, lube oil analysis, thermograph and bioscope activities, or ultrasound testing for wall thickness. This order type is normally created against a PM notification type. |
| | PRM – Proactive Rectification | Activities carried out to address observed deterioration of the equipment's performance. Maintenance carried out as a result of preventive and predictive work. PRM order type is defaulted when you create an order against a PM notification type. |
| | PSI – Plant Statutory Inspection | Used for plant turnaround and planned shutdown but not opportunity work. This includes DOSH inspection work, gas turbine and compressor scheduled overhaul, control valve servicing, transformer, UPS or other major electrical servicing. This order type is normally created against a PM notification type. |
| SM | SSM – Support Services Maintenance | Work meant for supporting functions but not directly related to core maintenance. SSM order type is defaulted when you create an order against a SM notification type. |
| PC | PCM – Plant Change Maintenance | Plant change request. PCM order type is defaulted when you create an order against a PC notification type. |

*C. Performance Management*

Performance Management is a data from all the maintenance work that was carried out. It will be extracted from the SAP system and stored in the SAP Business Warehouse (BW) and Carigali Maintenance Management Performance System (CMMPS) for analysis and reporting. Performance Management is aims to enable the users to generate accurate reports to analyze the efficiency and effectiveness of their maintenance work. It is also to provide Operations Unit with a feedback mechanism to track their progress towards best practice.

*1) SAP Business Warehouse (BW) reporting*

As an integrated system, SAP Business Warehouse (BW) is a reporting, and analysis tool and a part of a collection of solutions from SAP business suites. SAP BW gives management the advantage of a multi perspective view of their business which helps in making strategic business decisions. Under the hood, the BW engine is able to extract information from various sources making it a flexible data processing system capable of being integrated with SAP as well as non-SAP applications. The benefits of Business Warehouse are:-

(a) SAP BW extracts data from SAP R/3 and stores it in a separate server making data retrieval speed much faster.
(b) SAP R/3 system performance is not compromised by running of reports or data gathering.
(c) SAP BW is able to extract data from non SAP systems and integrate with SAP data to give more comprehensive, multi-dimensional information.

(d) BW organizes reports by customized roles e.g. Plant Manager, Maintenance Planner, Operations Engineers, etc for easy one step excess to reports of interest.
(e) Business explorer is a very powerful and yet user friendly data analysis tool. It gives you all the capabilities of Microsoft Excel and more.

There are five BW Reports which are Work Identification, Planning and Scheduling, Maintenance Execution, Feedback and Reporting, and Cost Management. TABLE 3 shows the explanation of BW Reports. BW reports can view from the BW Explorer. The user can select any types of reports to be viewed in Microsoft Excel or on the Web. Expert Users are suggested to use Excel as apart from the BEx Analyzer functions and can utilise all Excel functions. The report structure divided into three (3) items which are report title, filter cells, and result area.

TABLE III
EXAMPLE OF BW REPORTS

| Report | Report Provides |
|---|---|
| **Work Identification** | |
| Notification Ageing | All Notifications which are not closed and not pending for screening, excluding notifications marked for deletion and rejected. |
| **Planning & Scheduling** | |
| Created Order Statistics (Order Type & Priority) | Number of MOs created by Order Type and Priority for the reporting period |
| Created Order Statistics (Work Center & Priority) | Number of MOs created by Work Center and Priority for the reporting period |
| Completed Order Statistics By MHrs (Order Type & Priority) | Manhours of Orders with Actual End Date within the reporting period by Order Type and Priority |
| Completed Order Statistics By MHrs (Work Center & Priority) | Manhours of Orders with Actual End Date within the reporting period by Work Center and Priority |
| **Maintenance Execution** | |
| Overdue Maintenance Order Statistics (Work Center) | Number of uncompleted and Released MOs (no CNF status) that Basic end date has elapsed |
| Active Maintenance Order Statistics (Work Center) | Number of uncompleted and Released MOs (no CNF status) without work constraint |
| **Maintenance Execution** | |
| Active Maintenance Order Ageing (by Order Creation Date) | Number of uncompleted and Released MOs (no CNF status) without work constraint with 12 month Ageing by creation date |
| Inactive Maintenance Order Statistics (User Status) | Number of all uncompleted and Released MOs (no CNF status) with work constraint by User Status |
| **Cost Management** | |
| Actual Cost by Equipment | Actual Maintenance Cost by Equipment for current month and the previous 11 months |
| Actual Cost by Equipment Class | Actual Maintenance Cost by Equipment Class for current month and the previous 11 months |
| Actual Cost by Functional Location | Actual Maintenance Cost by Functional Location for current month and the previous 11 months |
| Actual Cost by Functional Location Class | Actual Maintenance Cost by Functional Location Class for current month and the previous 11 months |
| Actual Cost for Equipment (User Defined Period) | Actual Maintenance Cost for Equipment and Functional Location which allows users to define the 12-month ending period to be displayed in the report. |

*2) CMMPS*

Carigali Maintenance Management Performance System (CMMPS) is a front end application tool developed to generate the reports as specified by the Carigali Maintenance Management Guide (CMMG) in the form of 21 Key Performance Indicators (KPI's). In addition to that, the system generates for more Performance Indicators pertaining to the Average Processing Efficiency (APE) of work orders. The following is the items that used for KPI.

KPI 1 : Standard Non-Productive Manhours
KPI 2 : Total Real Available Manhours
KPI 3 : Manhours Utilisation
KPI 4 : Total Non-Productive Manhours
KPI 5 : Percentage of Proactive Work Created
KPI 6 : Equipment Availability, Reliability and Utilisation
KPI 7 : REM Completion
KPI 8 : Work Order Status Details
KPI 9 : Overdue Maintenance Order
KPI 10: Total Manhours % Distribution
KPI 11: Maintenance Overtime Hours
KPI 12: Production Loss Shutdown
KPI 13: Maintenance Mix Costs
KPI 14: Unit Maintenance Costs
KPI 15: Turbo Machinery Runhours per Start (RPS)
KPI 16: PPM Scheduled Compliance
KPI 17: Inspection Scheduled Compliance
KPI 18: Percentage of Completed Order by Type
KPI 19: Repetitive Work
KPI 20: Planning Effectiveness Percentage
KPI 21: Planned or Unplanned Orders Percentage

## V. DISCUSSION AND CONCLUSION

The findings show that asset management, work management and performance management are the core factors for PMMS. Asset management is a multi-users, multi-offices, web-based centralized database management system. The system aims to assists organization to better manage the allocation, distribution, and productive use of its assets. The system facilitates the management of assets with the objective of capturing information on assets and tracking of the assets through the entire assets life cycle of asset registration, assignment or allocation, transfer, stock checking, maintenance, and eventually disposal or reported lost. Asset management contains the plant asset structure and planned preventive maintenance plan. Plant asset structure represents the place at which a maintenance task is performed. It is a type of data object used in SAP to represent the functional part which an object can be installed, as opposed to the installed equipment, which represents the technical side. After that, planned preventive maintenance plan will be created to automatically generate maintenance orders when the maintenance task is performed.

Furthermore, work management facilitates the management of construction, maintenance, and operations work request by automating and streamlining the processes required to initiate, track, design, estimate, schedule, construct, and close work request. By tracking and analyzing information, and distributing it across the enterprise, these systems enable the PMO to increase the efficiency, accuracy and speed of the entire work cycle. In PMMS, work management consist work identification, pre-planning, planning, scheduling, work execution, and reporting and feedback. It is a work order creation and tracking system design for asset PMO, custodian, or contractors to manage work orders for their infrastructure.

Performance management is the systematic process of monitoring the results of activities and collecting and analyzing performance information to track progress toward planning results. Performance management uses performance information to inform and program decision-making and resource allocation. The main objective is to communicate results achieved, or not attained, to advance organizational learning. In PMMS, performance management consist sap business warehouse and carigali maintenance management performance system. It is consisting of the task of gauging, tracking, and sustaining PMO's employee progress through the analysis and reporting. The analysis and reporting will be extracted from SAP system and it is view from the BW Explorer.

On the basis of the simulation from the results, the SAP R/3 used to evaluate all approaches. SAP R/3 is arranged into distinct functional modules, covering the typical functions in PCSB. The most widely used modules at PCSB are Human Resources (HR), Procurement, Inventory and Plant Maintenance (PM). Each module handles specific business tasks on its own, but it linked to the others where applicable.

To sum up, PMMS can result in major benefits in terms of money and time. But, it requires a great deal of thinking and effort. Besides, PMMS has improved the monitoring system for maintenance management. In the other hand, PMMS provides awareness for the importance of the maintenance in PCSB which involving all parties. Therefore, in order to develop future research in this area, the following research questions should be evaluated:

- Are there any spaces to improve the current PMMS?
- How the PMMS can improve the listed KPIs progressively?
- What is happening to the PMMS if there has a lot of machines is broke down?
- What are the critical success factors that influenced the application of PMMS totally?
- What are the common problems faced by PCSB to sustain the application of PMMS?
- Are the PMMS can be applicable for other industrial background?

The authors of this paper intend to provide details of such research questions in the future publications. The authors believe that the above research solution may prove useful in helping to re-architecture the PMMS as effective approach towards the successful of plant maintenance management system.

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