Data Driven Maintenance Efficiency

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Abstract — *Significant opportunities for improvement were identified within the maintenance engineering department of a leading biopharmaceutical manufacturing firm. The primary focus is on addressing a known issue where preventive maintenance execution is unevenly distributed throughout the month. During the initial weeks, engineering technician teams tend to execute tasks at an arbitrary pace, only to hastily expedite their efforts towards the end of the month, leading to an accumulation of work. The project aimed to streamline and optimize preventive maintenance practices by enhancing reliability and balancing the workload among technicians. Historical preventive maintenance data was retrieved from the firm's computerized maintenance management system (Maximo 7). This data was then analyzed and pre-processed to uncover key correlations that could be leveraged to better distribute the workload across the month, thereby ensuring optimal processing of tasks. After identifying improvement opportunities, graphical aids were created to represent the analyzed data and presented to management, enabling the identification of teams that were underperforming compared to their peers. These visual tools were also used to continuously measure the outcomes of the implemented interventions. Although further improvement is still needed, positive progress was achieved, leading to an overall enhancement in preventive maintenance practices.*

Key Terms — *Computerized Maintenance Management System; PM Hours; Python for Data Analysis; Seaborn.*

INTRODUCTION

A recurring issue was identified within the maintenance engineering team of a prominent biopharmaceutical manufacturing firm. This firm has a comprehensive preventive maintenance program to ensure that all corporate equipment meets regulatory standards. Preventive maintenance is governed by U.S. Federal Code of Regulations (21 CFR 211.67 and 21 CFR 820.70). Additionally, the Food and Drug Administration (FDA) requires that all preventive maintenance execution records be retrievable for auditing purposes at any time, and all tasks must be completed as scheduled. Any deviations must be justified and corrected.

The main challenge facing the maintenance engineering team lies in the ineffective distribution of workload, particularly in months when the preventive maintenance demands are high. Preventive maintenance tasks are expected to be completed within the month they are scheduled. However, rather than spreading out the work consistently throughout the month, the team often rushes to complete most tasks just before the month's end. This practice introduces significant risks due to regulatory expectations for strict adherence to the schedule.

This project aims to normalize and optimize the distribution and execution of preventive maintenance work throughout the month. By ensuring a balanced workload, the team can enhance compliance, reduce last-minute efforts, and improve overall reliability and efficiency.

TRADITIONAL VERSUS QUANTITATIVE APPROACH

As previously stated, opportunities exist in the areas of preventive work distribution and the rate at which this work is completed. A primary issue appears to be the inefficient allocation of tasks, where work is performed as soon as an execution window becomes available. Additionally, there is often a misperception regarding the labor intensity of each preventive maintenance work order. This misunderstanding can lead to delays, as the most labor-intensive tasks, which are also the most time-consuming, should ideally be prioritized at the beginning of the month. Another challenge may arise from the methods employed by experienced managers, who often rely on traditional practices that have worked in the past rather than on quantifiable metrics. This approach can lead to inefficiencies, as these practices are not measurable and, therefore, difficult to improve upon.

It is crucial for professionals to remember that effective plant management must include a measurement component, ensuring that outcomes are both measurable and aligned with predefined plans. This approach not only optimizes outputs and facilitates continuous improvement but also supports the overall team. The stress derived from regulatory compliance is lessened, enhancing control. This improved management of preventive maintenance tasks not only ensures they are completed within the required timeframe with ease but also frees up time that could be used to further enhance the distribution of work or to explore new projects within the engineering maintenance department.

METHODOLOGY

To regulate and optimize the distribution and execution of preventive maintenance work, the following processes were implemented.

Historical Preventive Maintenance Data Retrieval

It is essential to access historical data on preventive maintenance completions, focusing particularly on the data from the current month. This approach facilitates the identification of personnel who consistently perform most of the work and assists in determining how the workload should be adjusted on a per-shift basis. The relevant data is stored in the Maximo 7 Computerized Maintenance Management System database, which operates on an Oracle platform. To retrieve this data, a connection was established using the PyODBC Python module, which utilizes the built-in Windows ODBC driver. This connection enables the extraction of data into a Python Pandas DataFrame, a tool specifically designed for data analysis.

Data Exploration and Trend Analysis

The process begins with exploring the data to understand its key attributes. This crucial initial phase includes cleaning the data by removing any null values or incorrect entries that do not match their designated attributes. The Pandas module, a Python tool specifically designed for data analysis, provides built-in functionalities that streamline this process. The complete history of preventive maintenance execution was initially retrieved from the database.

The historical data was then filtered to include only the preventive maintenance work orders completed in March 2024. As a final step in data cleaning, the data was organized by closure date. In addition to utilizing the Python programming language and the Pandas module, the Jupyter Notebook was employed as a vital tool. This tool functions as a text editor that allows Python code to be executed on a cell-by-cell basis, enabling the user to run only the specific code snippet being worked on without the need to execute the entire script.

Following the successful pre-processing of historical data, the open preventive work orders for the month were filtered out. For each work order, job plan hours were also obtained from the database, indicating the expected time for completion by the technical personnel. To determine which preventive maintenance work orders required prioritization, the work orders were grouped by job plan. Each group's job plan hours were multiplied by the number of open work orders for that plan, creating a unit called PM hours. By sorting the grouped work order DataFrame from highest to lowest PM hours, it became clear which work orders needed prioritization.

For the closed work orders of the month under evaluation, a similar methodology was applied.

Work orders were grouped by the technician's employee number, and the PM hours for each technician were assigned to the shift they performed duties in. By leveraging PM hours, it was possible to determine which preventive maintenance work orders needed to be executed first, their order of priority, and which shifts were performing most of the work.

Developing visual resources for decision making

A highly effective method for presenting information is through graphical representations of data. This approach not only familiarizes the audience with the data's structure but also enhances their understanding of the outcomes. Leveraging the Python programming language Seaborn, it is possible to display descriptive graphs. Table 1 displays the amount of PM hours per shift for the month of March 2024, while Figure 1 displays the same data in graphical format. They show the disparity of work distribution, where most of the workload is completed by shift B and D.

Table 1
Exact Amounts of Completed PM Hours Per Shift

SHIFT	PM Hours
A	13.0
B	76.0
C	5.0
D	87.0
Mfg	43.0

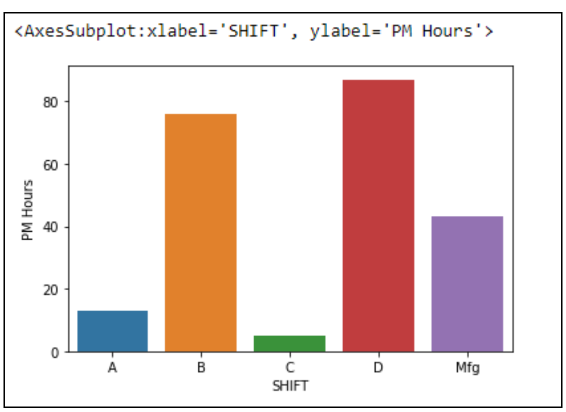

Figure 1
Preventive Maintenance Execution for the Month of March

Leveraging analysis to develop work distribution techniques

To optimize the dissemination of analytical findings, the Director of Engineering was briefed on the results, which were positively received. The Engineering Manager advised that both graphical and numerical data should be shared regularly via email with all departments to maintain transparency and visibility regarding which shifts are actively engaged in the work.

Additionally, to enhance the use of closed work informatic resources, the engineering team was provided with a table. This table groups open preventive maintenance tasks by job plan, alongside the designated time for each. The time allocated is then multiplied by the frequency of each job plan within the dataset, resulting in a column labeled 'PM Hours'. The table is organized in descending order based on PM Hours, recommending that job plans with the highest hours be prioritized for completion. Table 2 includes an example of that the Open Preventive Maintenance table looks like. This table will change from month to month on a recurrent basis.

Table 2
Open PM Work Per Job Plan

Pending Maintenance Technician PM duration for current Month

	Job Plan Description	Job Plan Number	Job Plan Count	Job Plan Duration	PM Hours
0	SEMI-ANNUAL MAINTENANCE / CERTIFICATION OF MAN...	134549	24	2.5	60.0
1	QUARTERLY MAINTENANCE OF MONOLITHIC SHT (10X16)	123268	45	0.5	22.5
2	ANNUAL MAINTENANCE /CERTIFICATION OF SYNTEGON ...	137061	11	2.0	22.0
3	ANNUAL MECH MAINTENANCE FOR HERMA LABELER AMG ...	136297	1	9.0	9.0
4	ANNUAL MECH MAINTENANCE OF CLOSURE LABELER, AC...	107197	1	8.5	8.5
5	MONTHLY MAINTENANCE OF VIAL INSPECTION GRIPPER...	113229	15	0.5	7.5
6	ANNUAL MECH MAINTENANCE OF MARCHESINI CARTONER...	127580	1	7.0	7.0
7	ANNUAL MAINTENANCE OF GROSS FILL VOLUME MANUAL...	110150	13	0.5	6.5

RESULTS

Pre-and post-methodology implementation comparison

Following regular feedback provided via email to the engineering maintenance shifts, a notable improvement was observed across most shifts. Shifts A, B, and D exhibited more consistent execution of work, with each shift maintaining a standard deviation of 3.58 PM Hours. Conversely, Shift C displayed suboptimal results, suggesting a need for management to investigate and implement necessary corrections to ensure uniform work distribution across all shifts. It is important to note that “Mfg” is not recognized as a separate shift but rather represents personnel borrowed from manufacturing to assist in completing preventive maintenance tasks.

Before the implementation of this system, preventive maintenance tasks typically consumed the entire month. However, following implementation, overall completion of preventive maintenance tasks was achieved with four days remaining in the month, illustrating a marked improvement in efficiency.

Conclusion

The implementation of a streamlined preventive maintenance management strategy at a prominent biopharmaceutical manufacturing firm has yielded substantial improvements in the distribution and execution of tasks. By leveraging historical data and sophisticated analytical tools, the project has successfully normalized the workload across all engineering maintenance shifts.

Significantly, Shifts A, B, and D demonstrated a consistent and uniform approach to task execution, maintaining a standard deviation of 3.58 PM Hours. This consistency highlights the effectiveness of the new system in promoting a balanced distribution of work. However, the performance of Shift C lagged, indicating areas for further improvement and managerial intervention to align it with the overall efficiency gains observed in other shifts.

The use of visual aids and continuous feedback mechanisms has played a critical role in identifying performance discrepancies and enabling timely corrective actions. These tools have not only facilitated better management decisions but have also ensured that all preventive maintenance activities are completed well within the regulatory compliance framework, with four days to spare at the month's end. Refer to Figure 2 for a visual representation of the pos-implementation visual results.

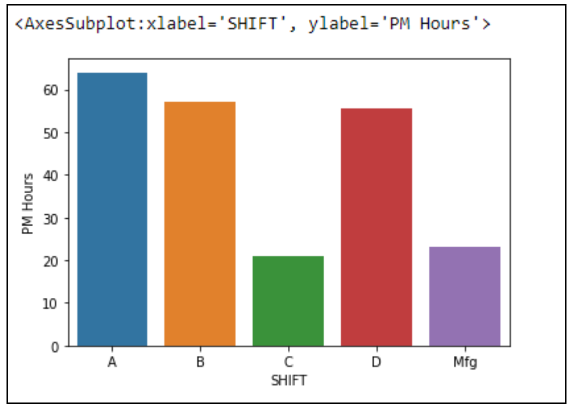

Figure 2
Post-Implementation Results for PM Hours Per Shift at End of April 2024

This project not only enhanced the efficiency and reliability of preventive maintenance operations but also fostered a culture of data-driven decision-making within the firm. Moving forward, the engineering maintenance team is well-positioned to continue refining these processes and exploring additional opportunities for improvement, ensuring both regulatory compliance and operational excellence.